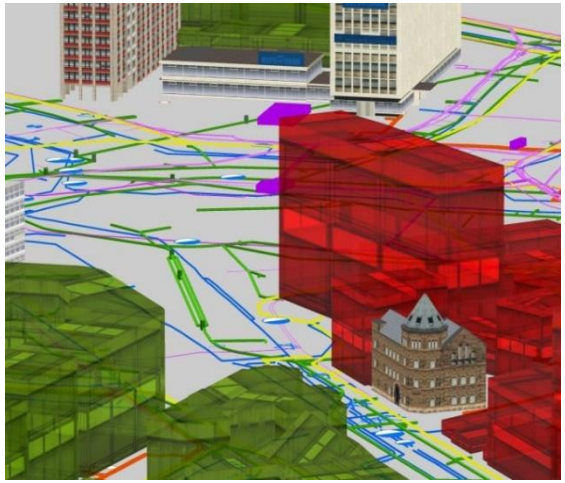
CityGML Utility Network ADE – Scope, Concepts, and Applications



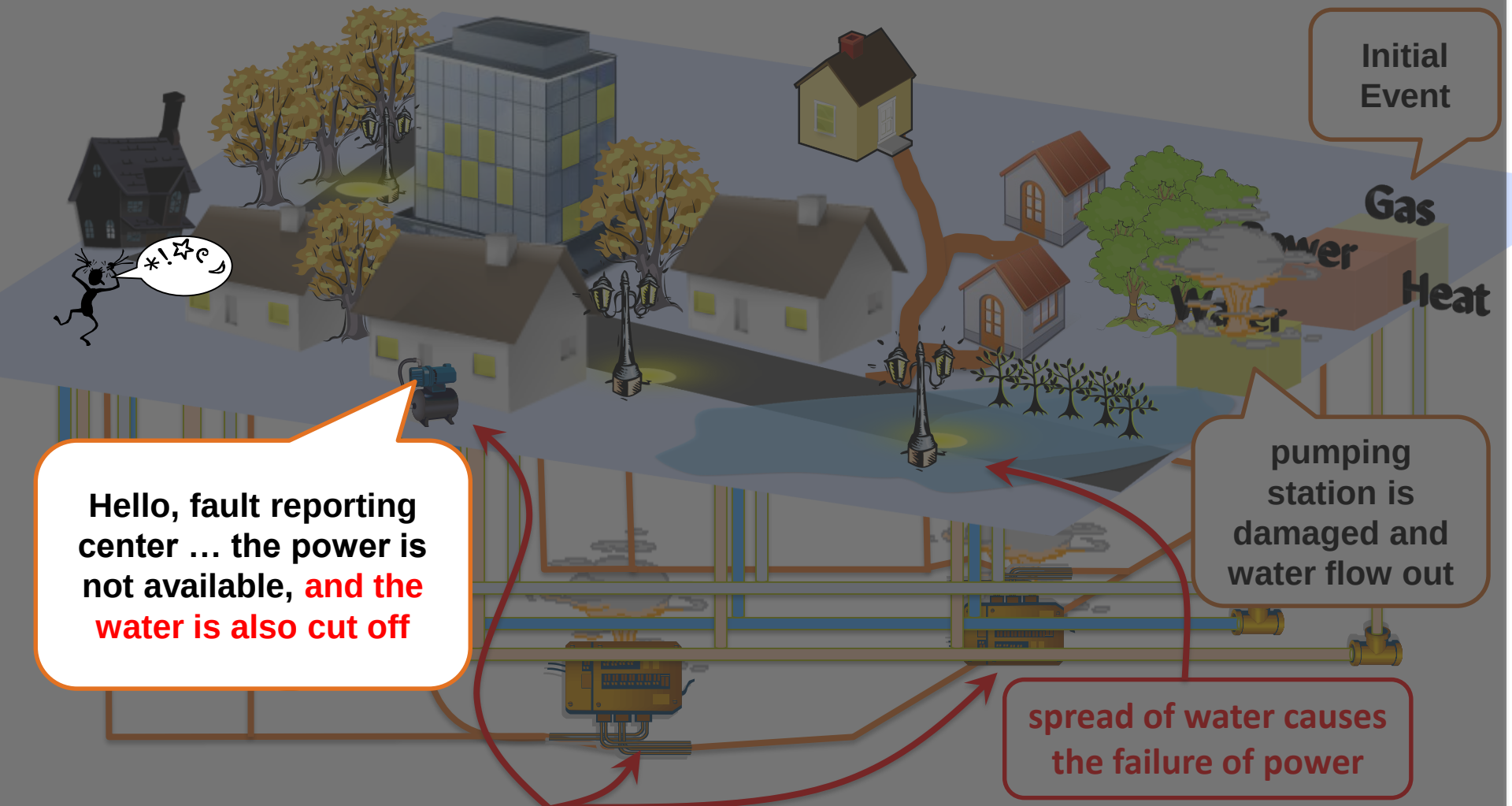
Tatjana Kutzner, Thomas H. Kolbe

Chair of Geoinformatics
Technical University of Munich

kutzner@tum.de, thomas.kolbe@tum.de

Underground Infrastructure Mapping and Modeling Workshop
New York City, April 24-25, 2017

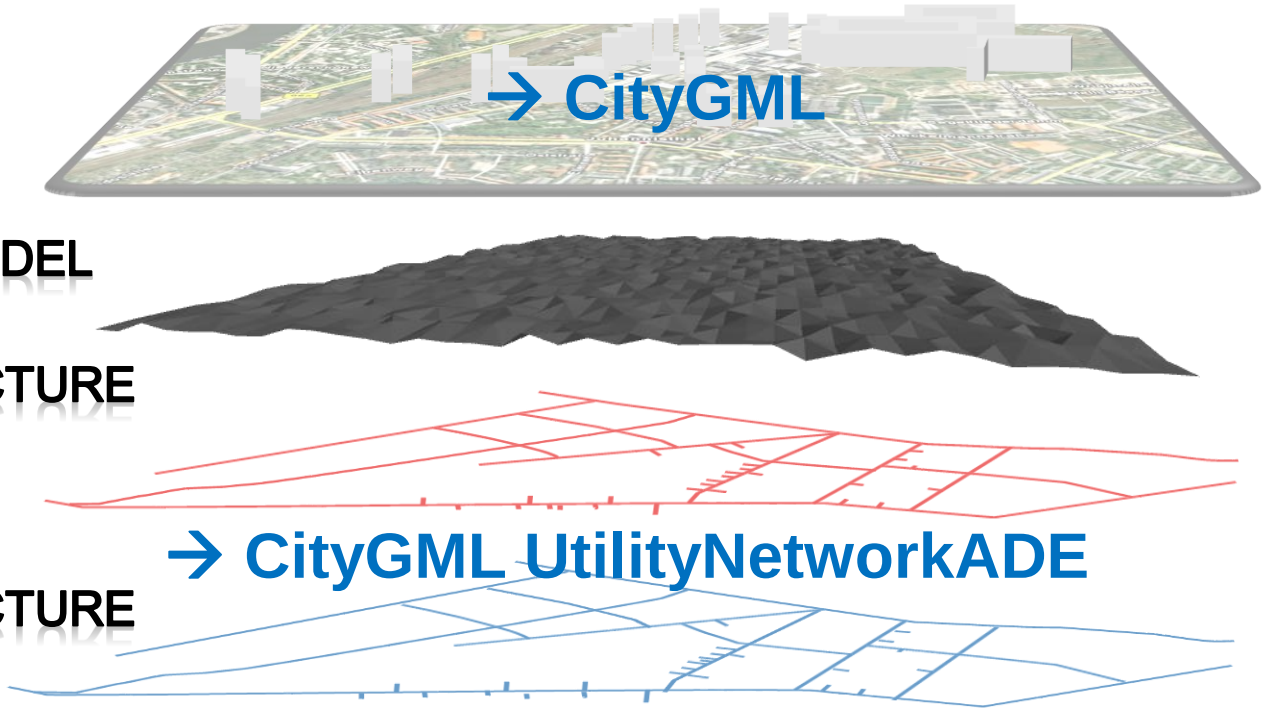
Motivation


Initial Event
Gas
Heat
Hello, fault reporting center … the power is not available, and the water is also cut off
pumping station is damaged and water flow out
spread of water causes the failure of power
due to the power failure, the pumps won‘t work

Integration of Utility Networks into the 3D City Model

- **Goal:** Development of a homogenized 3D network model for multi-utility failure simulation including the relevant thematic attributation (usage type, commodity, materials, operating parameters, no. of affected citizens etc.)

SEMANTIC
3D CITY MODEL
+
HIGH RESOLUTION
DIGITAL TERRAIN MODEL
+
UTILITY INFRASTRUCTURE
OF TYPE A
(E.G. ELECTRICITY)
+
UTILITY INFRASTRUCTURE
OF TYPE B
(E.G. WATER)



Projects using the Utility Network ADE

Disaster Management with SIMKAS 3D

- Simulation of intersectorial cascading effects caused by a failure of supply infrastructures using the 3D city model of Berlin (2009-2012)
- Focus on
  - simulating interdependent crisis situations
  - linking of situation information with the urban space
  - implementation of a common situation map which also allows for individual views and analyses by each provider
- An ArcGIS geodatabase was implemented based on the Utility Network ADE

Risk Analysis Supply Infrastructure

- Cooperation project with the company ESG (Germany) on behalf of the German Armed Forces (2015-2016)
- Study on the possibilities of utilizing supply infrastructures in training simulators
  - for crisis scenarios (e.g. evacuation)
  - for simulating the impact of a failure on the population
  - for simulating the impact on tactical operations

SIMKAS 3D

Das 3D-Stadtmodell von Berlin mit integrierten Infrastrukturen

Institut für Geodäsie und Geoinformationstechnik
Technische Universität Berlin

Hinweis: Die Präsentation spiegelt lediglich einen momentanen Bearbeitungsstand wieder, soll aber trotzdem den Kontext bzw. zukünftige Entwicklungen verdeutlichen!

2D/3D Analyses & Simulations

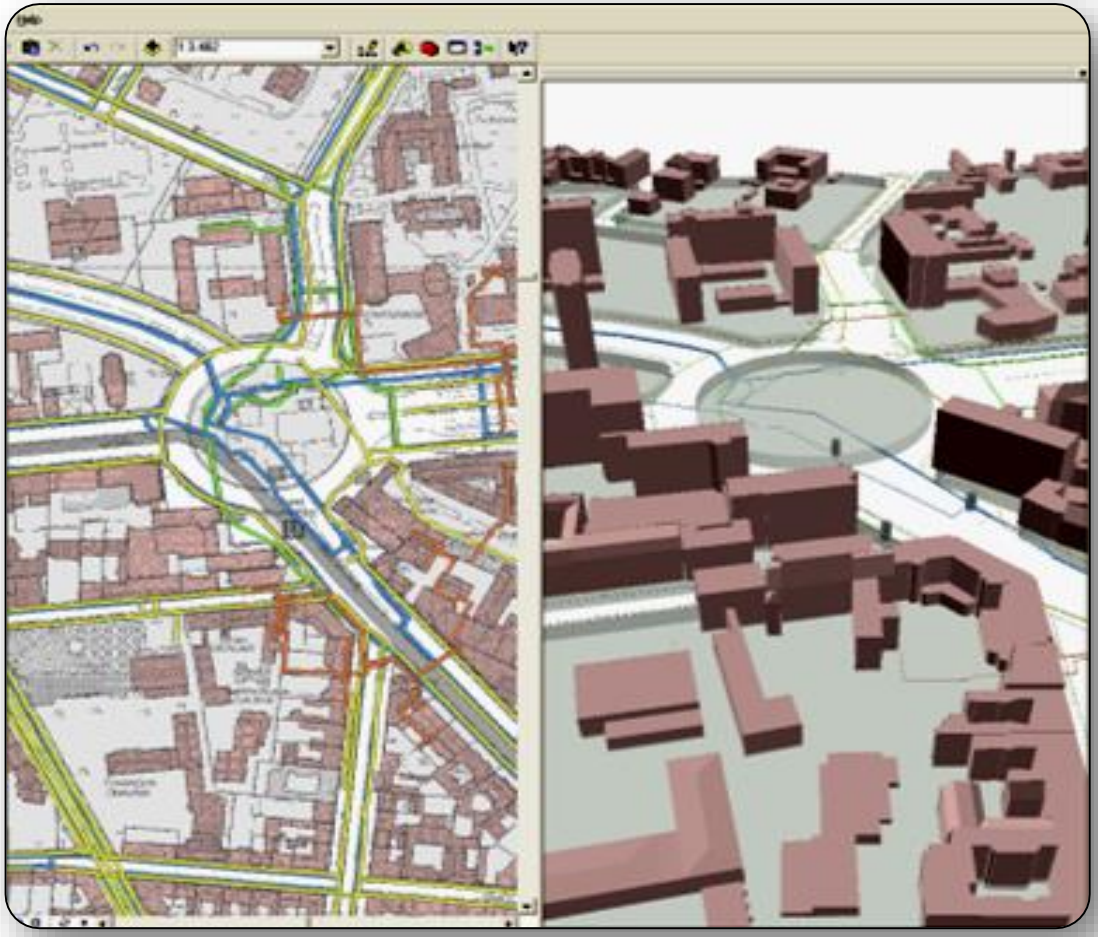
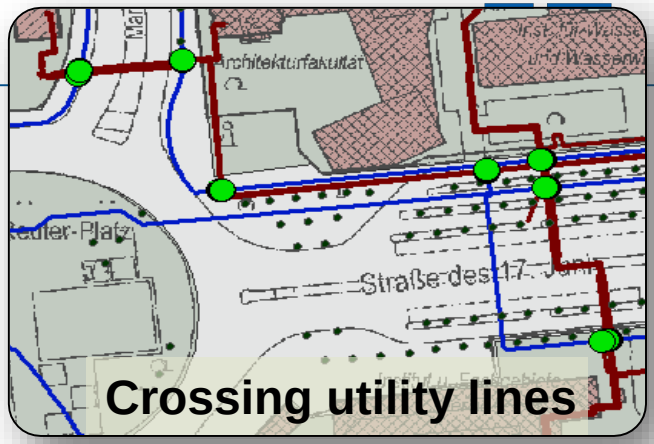
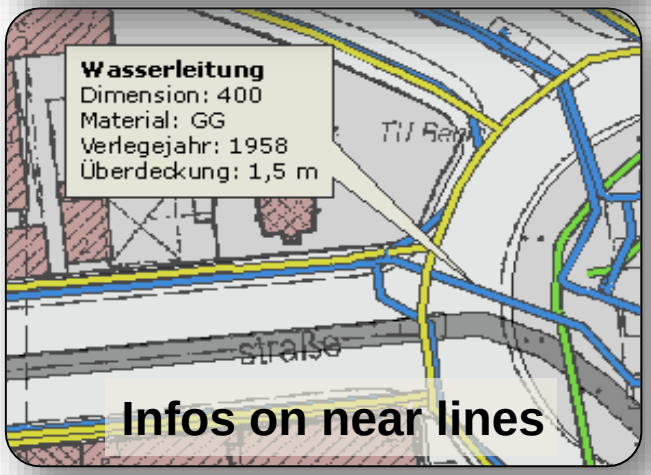
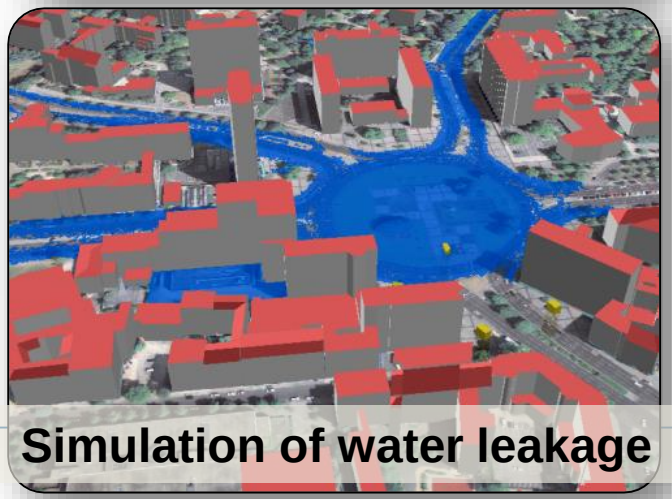


Image: DHI-WASY GmbH, SIMKAS 3D project partner

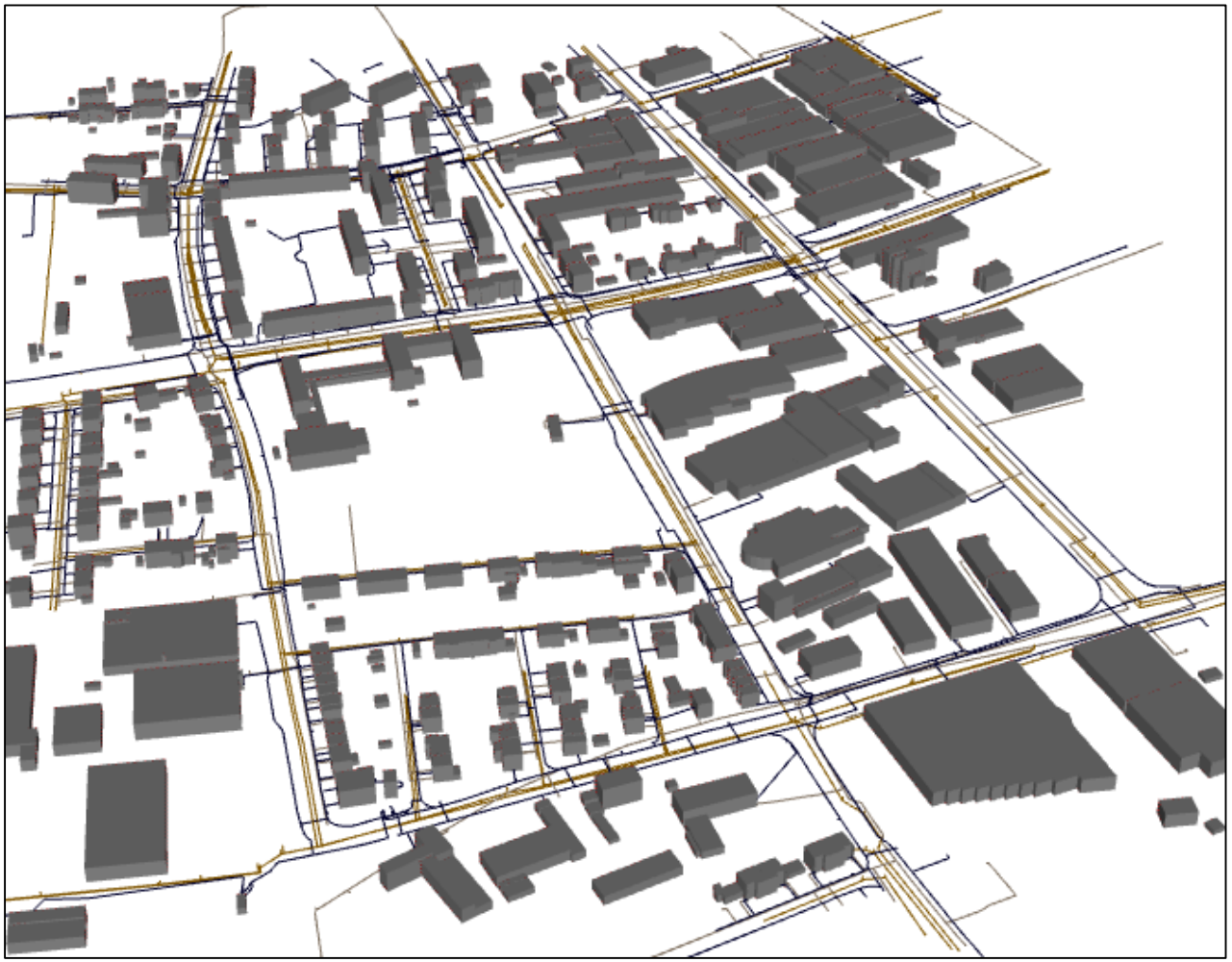






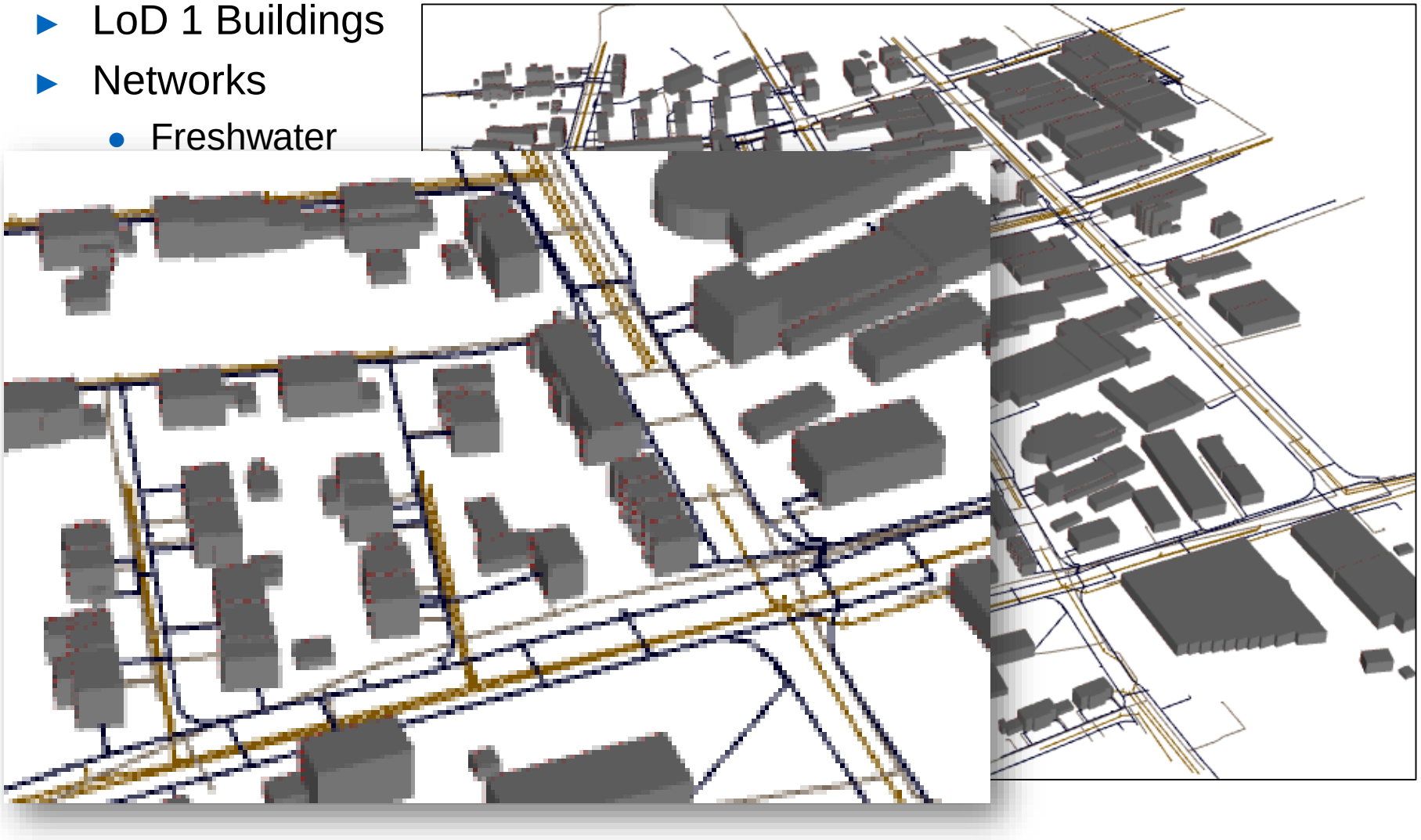
Use case – Simulation of cascading effects (I)

- LoD 1 Buildings
- Networks
  - Freshwater
  - Electricity
  - Wastewater



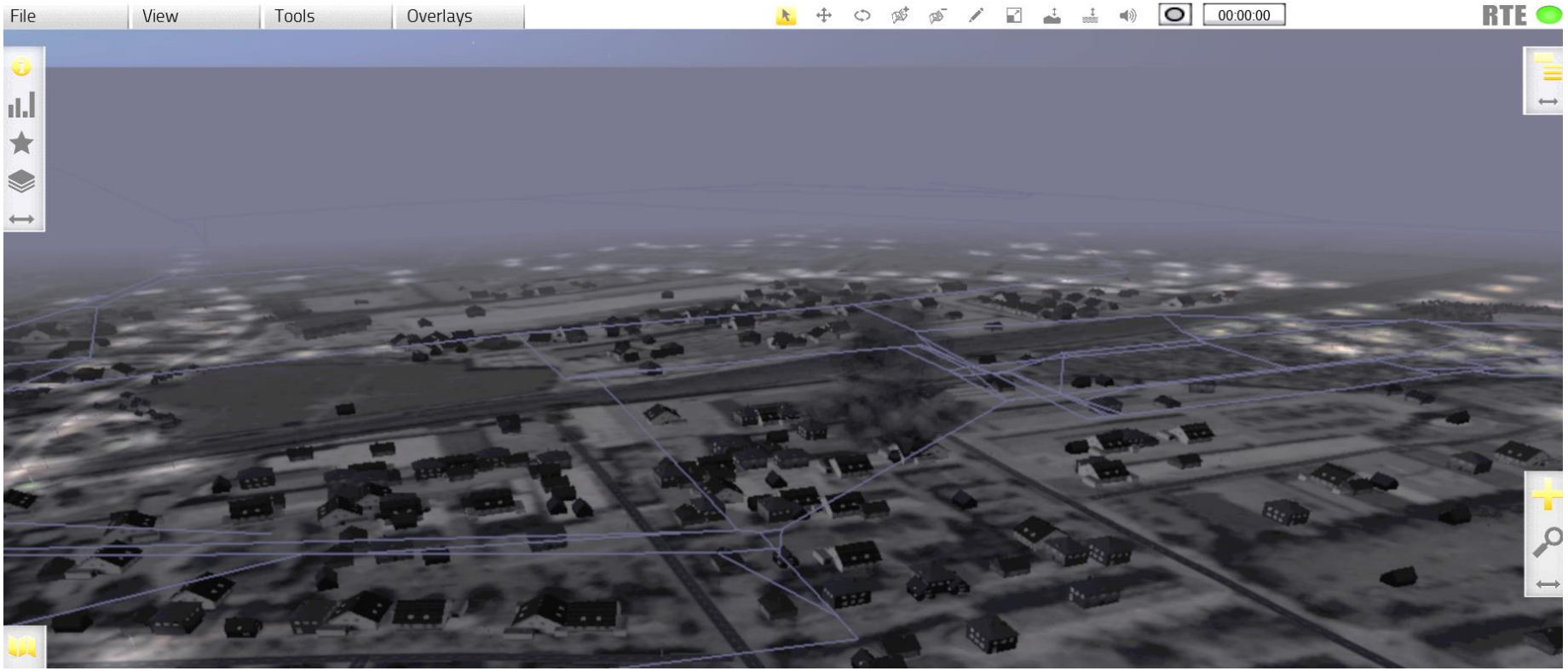
Use case – Simulation of cascading effects (I)

- LoD 1 Buildings
- Networks
  - Freshwater



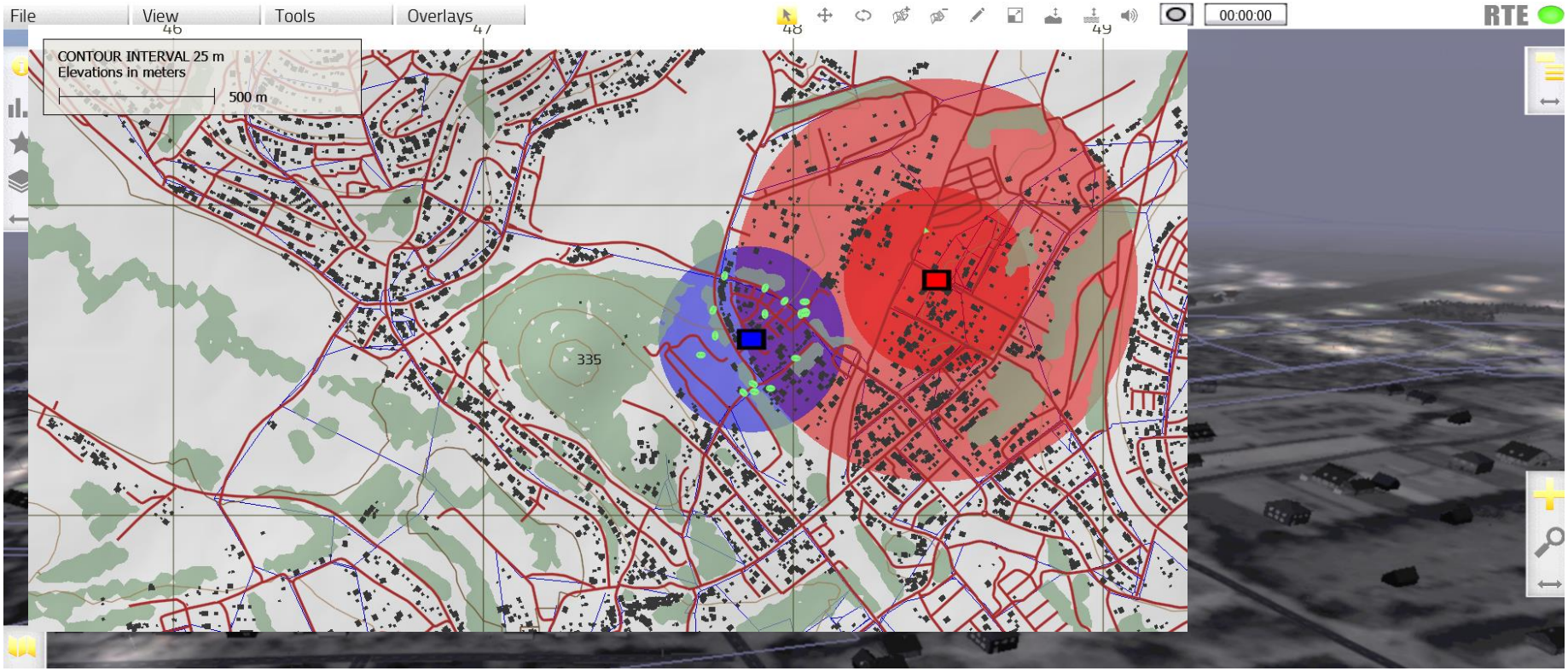
Use case – Simulation of cascading effects (II)

- Explosion in distribution station → Power failure in a district of the city
- Cascading effects caused by power failure → Failure of water works and of water supply → Water tanks provide water to population



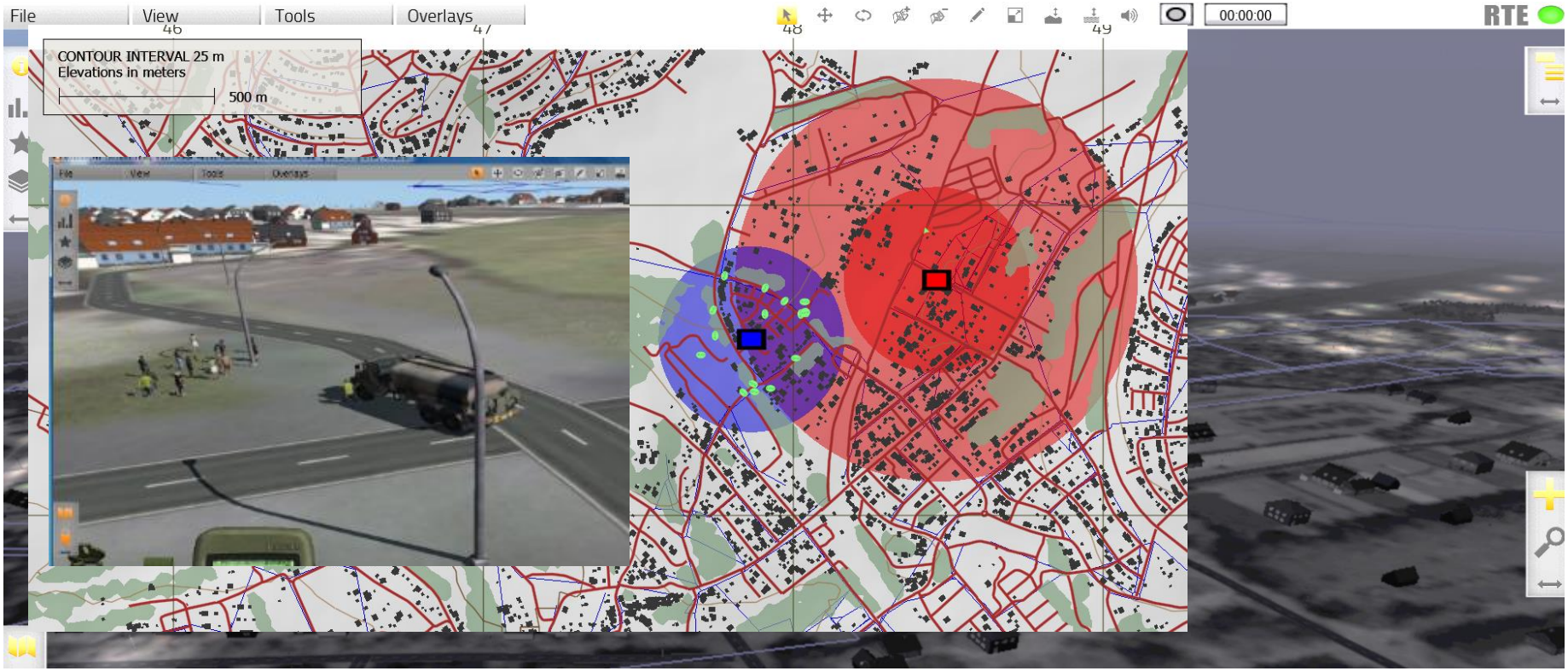
Use case – Simulation of cascading effects (II)

- Explosion in distribution station → Power failure in a district of the city
- Cascading effects caused by power failure → Failure of water works and of water supply → Water tanks provide water to population



Use case – Simulation of cascading effects (II)

- Explosion in distribution station → Power failure in a district of the city
- Cascading effects caused by power failure → Failure of water works and of water supply → Water tanks provide water to population



City Geography Markup Language (CityGML)

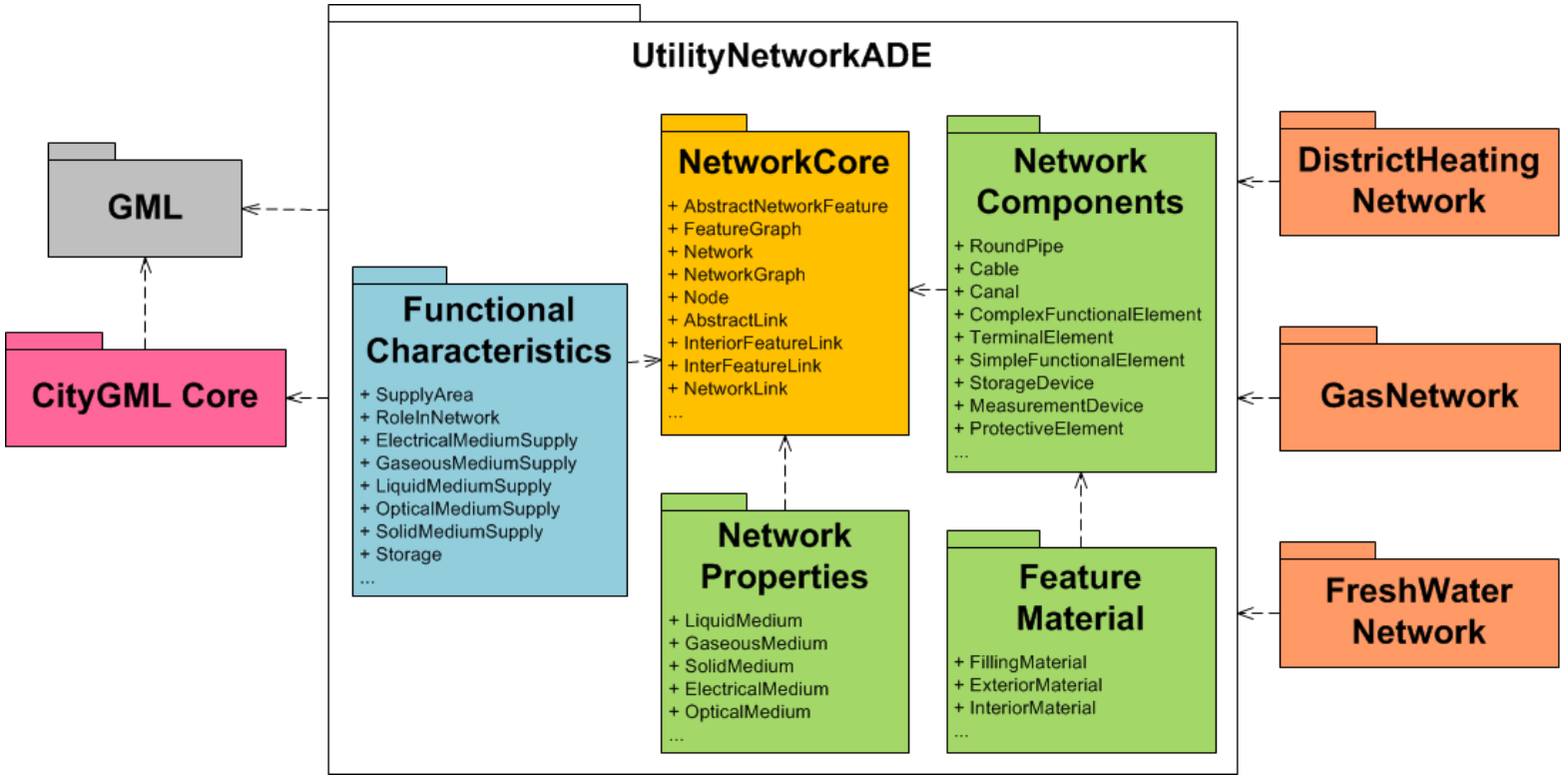
Application independent geospatial information model
for semantic 3D city and landscape models

- comprises **different thematic areas** (buildings, vegetation, water, terrain, traffic, tunnels, bridges etc.)

- International standard of the Open Geospatial Consortium
  - V1.0 adopted in 08/2008; **V2.0** adopted in 3/2012
  - V3.0 development started in 6/2014
- **Data model** (UML) + **Exchange format** (based on GML3)
- CityGML represents
  - 3D geometry, 3D topology, semantics, and appearance
  - in 5 discrete scales (Levels of Detail, LOD)

CityGML Utility Network ADE

- **ADE (Application Domain Extension)** = **CityGML's systematic extension mechanism** which allows extending every CityGML object type by additional attributes and introducing new object types
- The **CityGML Utility Network ADE** extends CityGML by the possibility to **represent supply and disposal networks in 3D city models**



CityGML Utility Network ADE – Packages (I)

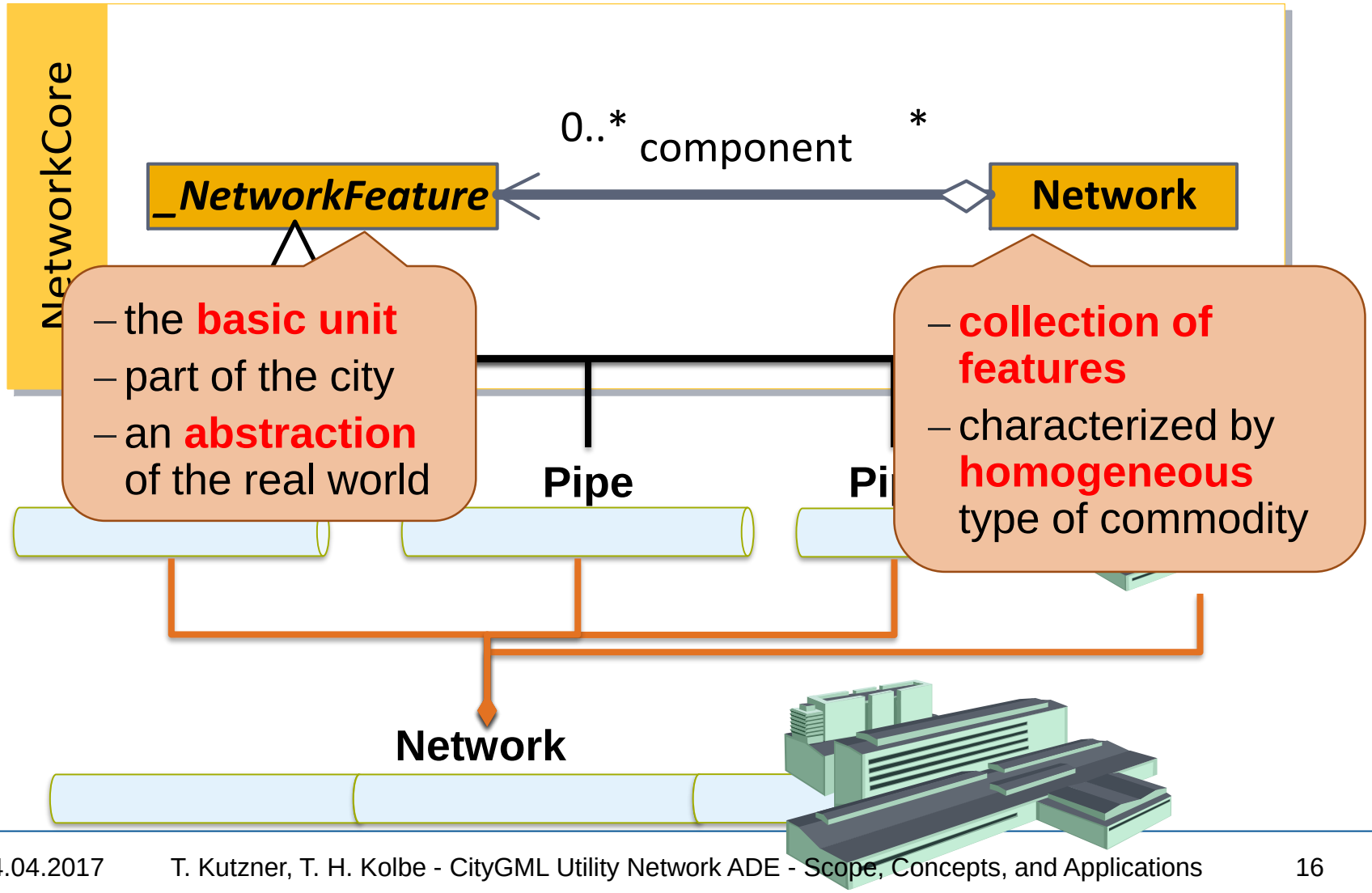
- **Network Core**
  - The most important package of the ADE
  - Defines the **topographic model** (feature and network) and the **topological / functional model** (feature graph and network graph)
- **Network Components**
  - Defines the individual components of utility networks including
    - **Distribution objects** (pipes, canals, cables etc.) for transport and distribution of a commodity
    - **Protection elements** (cable protection package, ductwork, etc.), relevant for network security, not for the network itself
    - **Functional objects** (manholes, station, etc.) for linkage, maintenance, and observation of a commodity / transport elements
- **Feature Material**
  - Defines the exterior, interior and filling **materials of network components**

CityGML Utility Network ADE – Packages (II)

- **Network Properties**
  - Defines the **commodities** (liquid, gaseous, solid, electrical, optical) **transported by networks and their characteristics** (e.g. temperature, electric conductivity, pressure, flammability)
- **Functional Characteristics**
  - Defines the following functional concepts
    - **Supply area** to relate all city objects located within an area to a certain supply station supplying that area
    - **Functional roles** to classify network and city objects into objects supplying and objects being supplied with commodities
    - **Suppliability/suppliedness** as additional information provided on the city objects themselves
- **District Heating / Gas / Freshwater Network / etc.**
  - Provide features required for specific network types
  - These packages are not yet defined

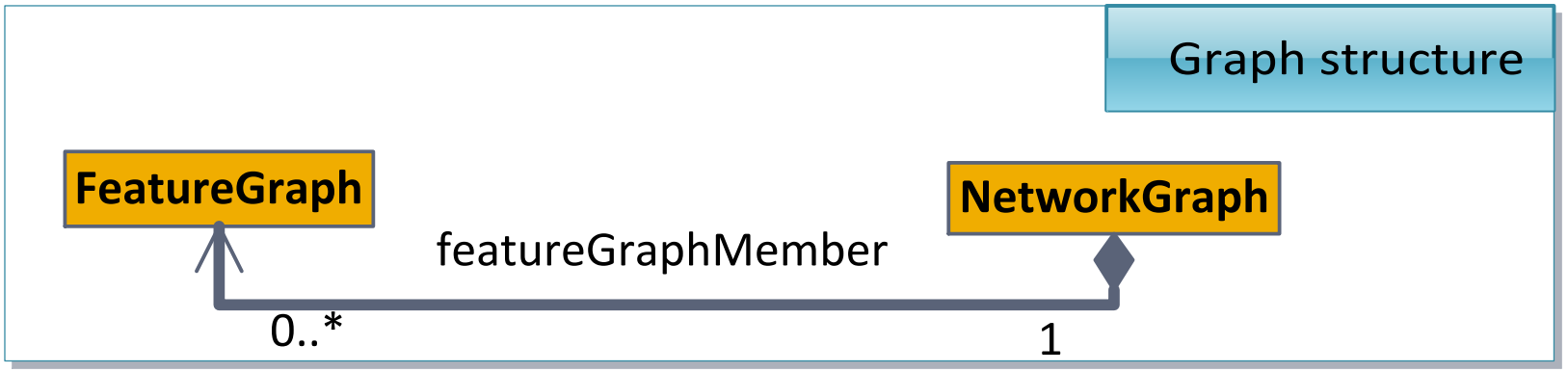
Understanding Utility Networks

All Networks are **aggregations of** atomic **entities** such as pipes, stations, cables etc.**!**



Representation of Network Entities

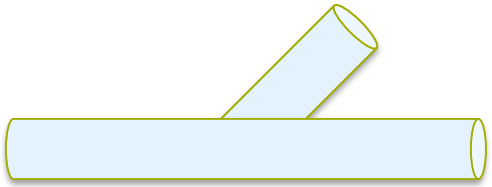
- parallel to its 3D topographic representation a network entity has functional and topological aspects
- Networks are typically represented as graph structures, and entities are separated either in line-like or point-like shapes (cf. INSPIRE, ESRI, etc.)
- **we understand a NetworkFeature as a sub graph of the whole network graph**

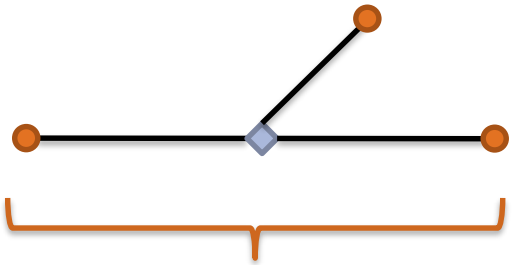


Graph Representations of Network Entities

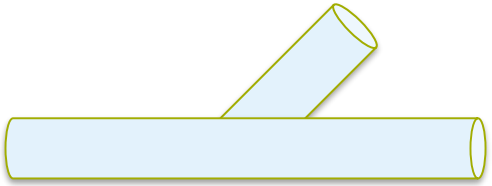
TOPOGRAPHIC MODEL

TOPOLOGICAL / FUNCTIONAL MODEL

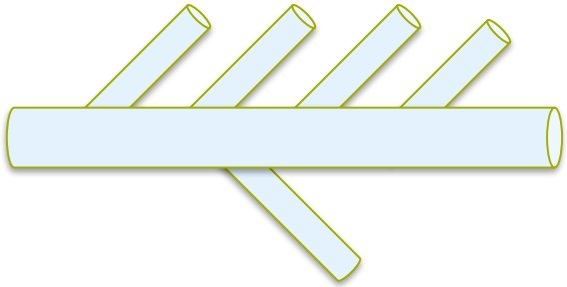


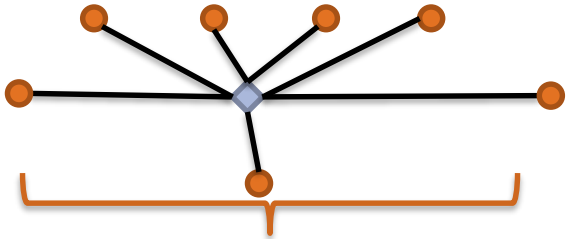


FeatureGraph



FeatureGraph





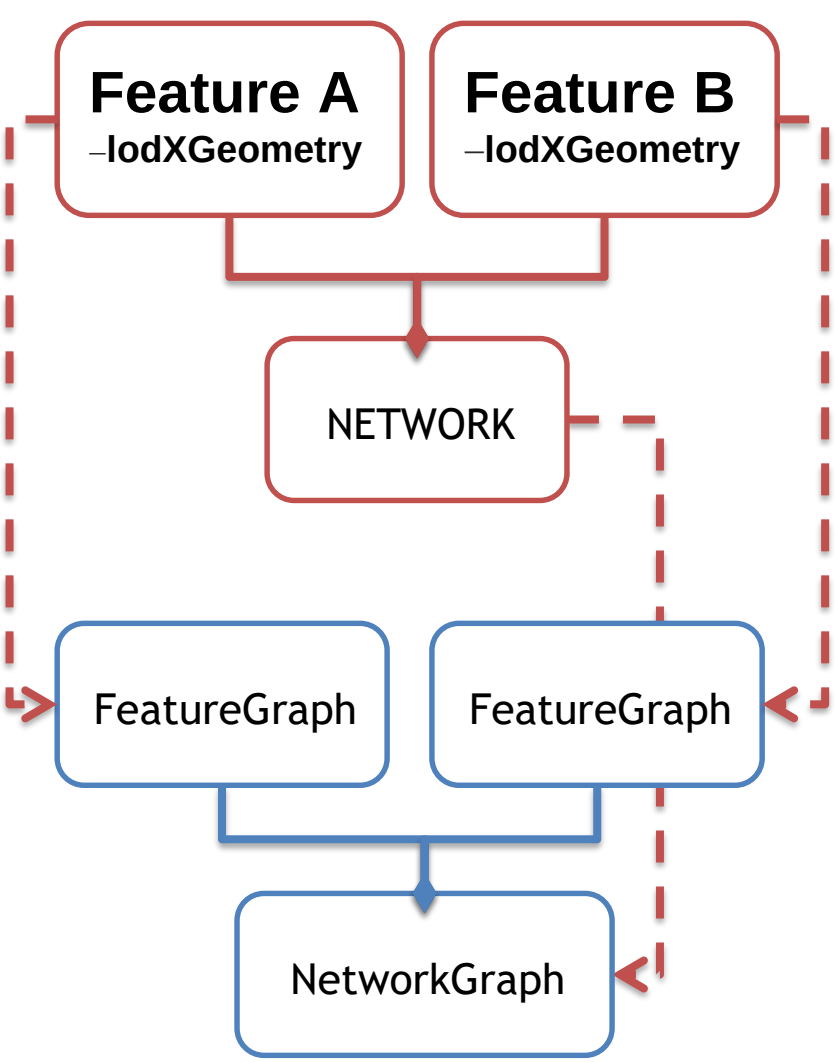
FeatureGraph

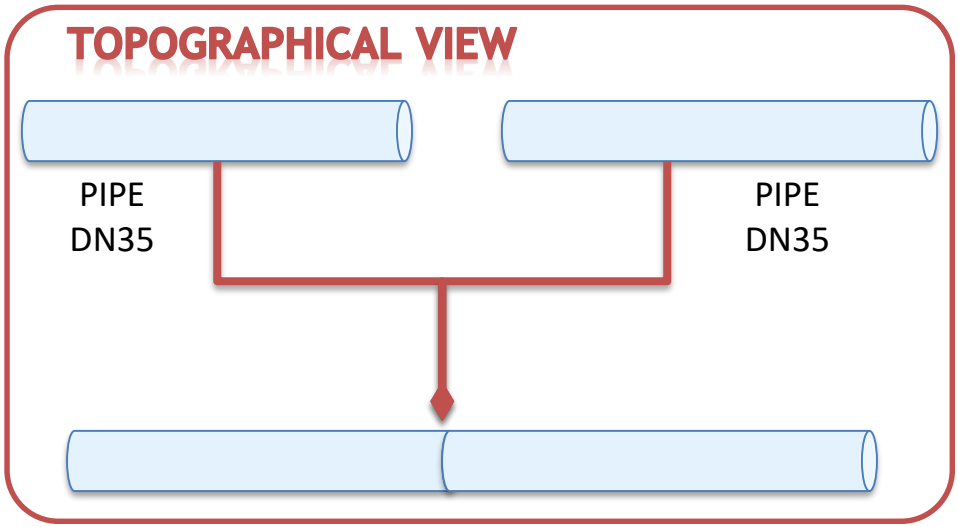
modeling of interior properties of the feature (interior link) using interior nodes allows for modeling pipe taping, valves, material change, etc

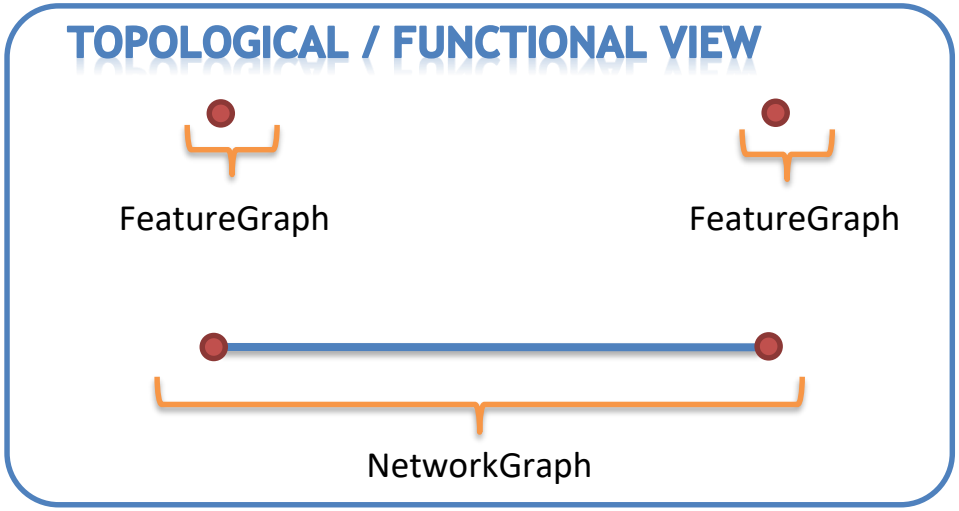
Legend

- Node (type: exterior)
- Node (type: interior)
- InteriorFeatureLink
- NetworkFeature

Joint Topographic and Functional Modelling



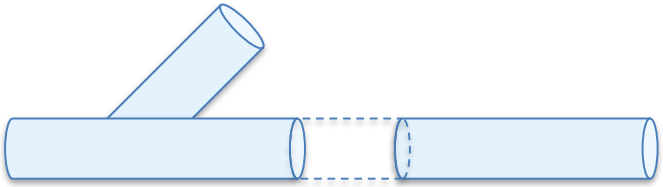


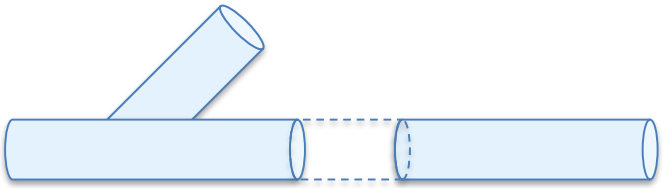


Source: SIMKAS 3D

Connecting Network Components

TOPOGRAPHICAL VIEW

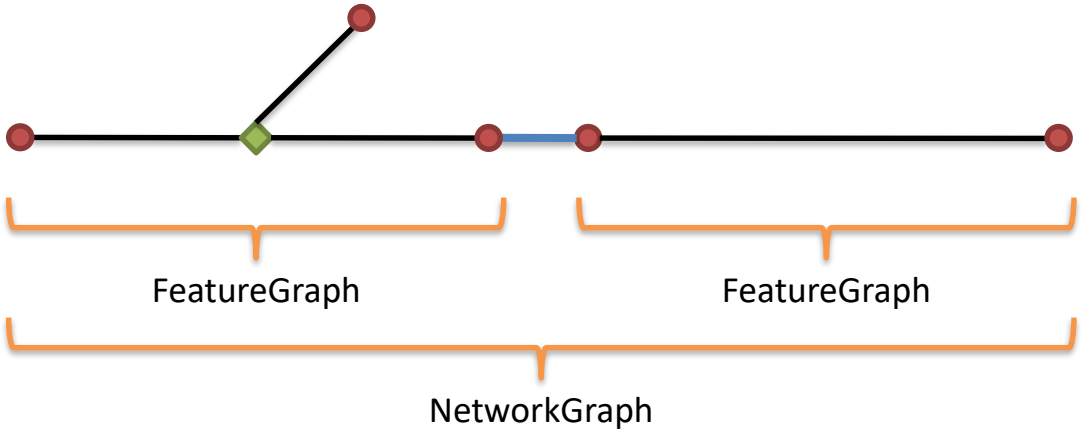


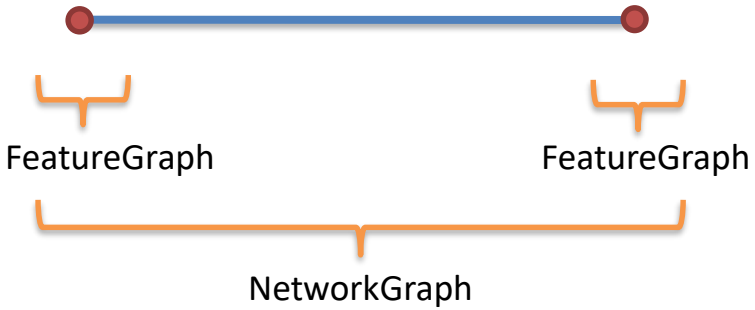


Legende

- Node (type: exterior)
- Node (type: interior)
- InteriorFeatureLink
- InterFeatureLink
- Network Component

TOPOLOGICAL / FUNCTIONAL VIEW

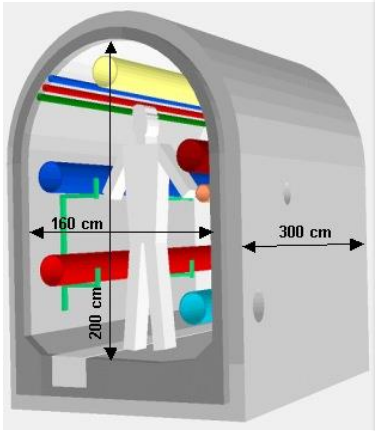




Source: SIMKAS 3D

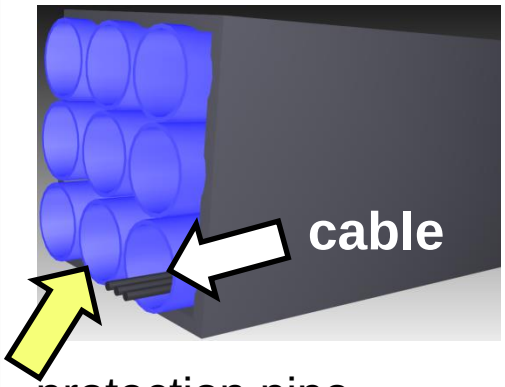
Network Hierarchies

multi-utility pipe



© Schaefer Naturstein

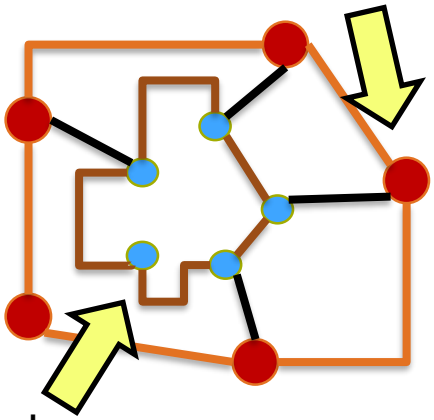
cable protection package



protection pipe

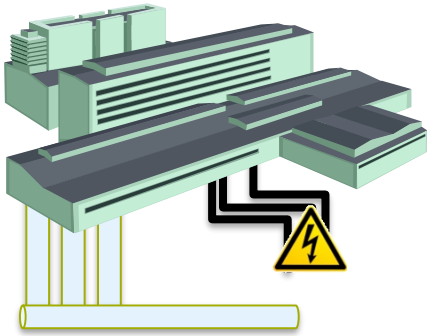
gas network

high pressure



low pressure

treatment plant

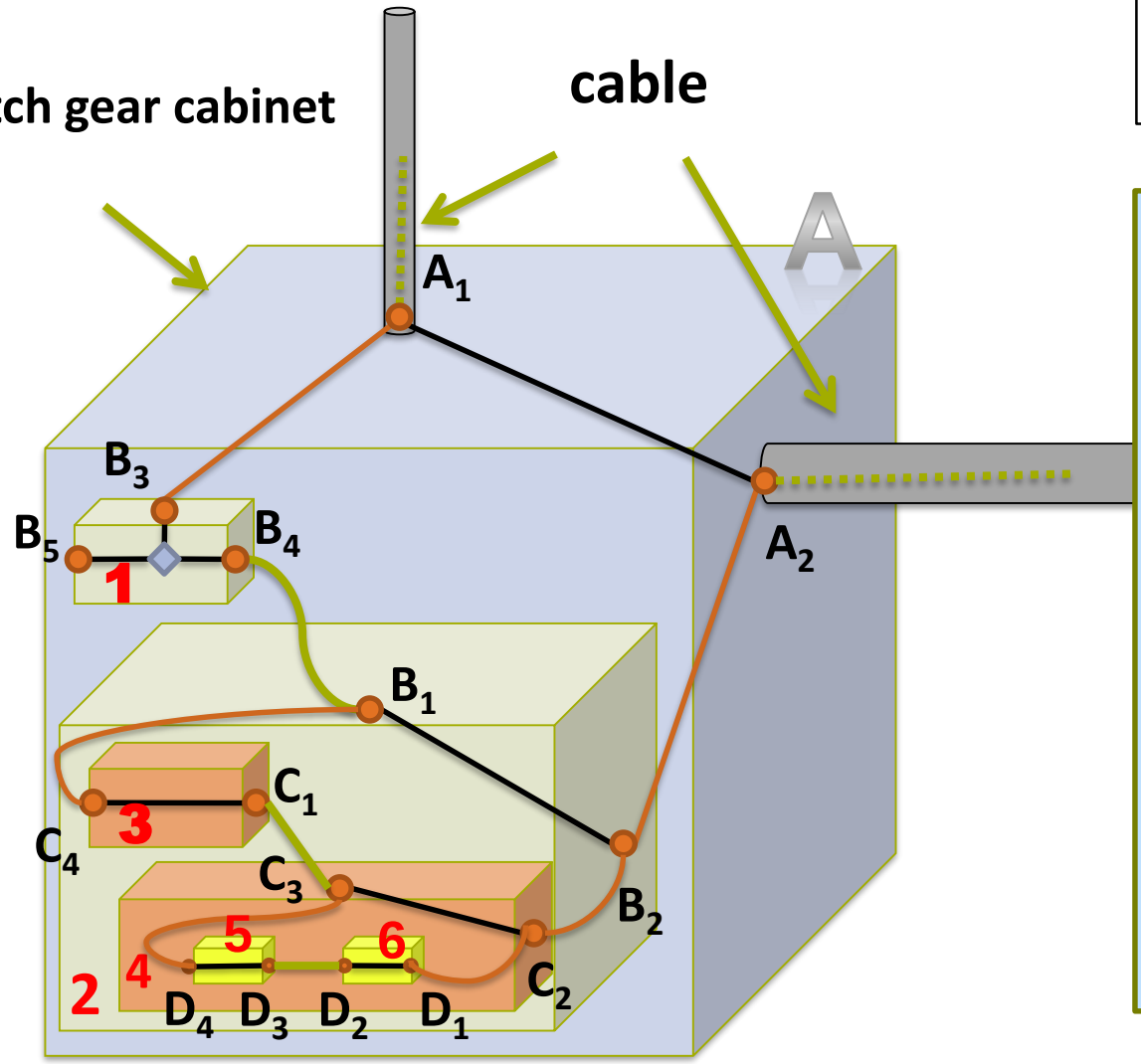


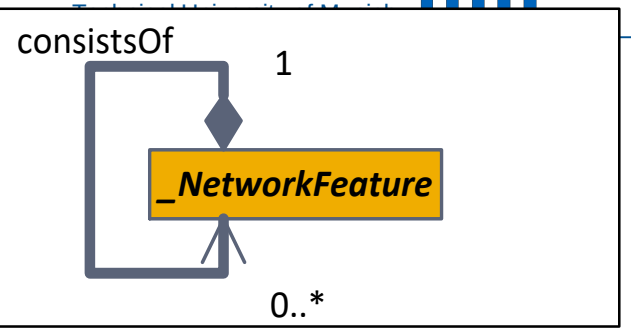
fresh water

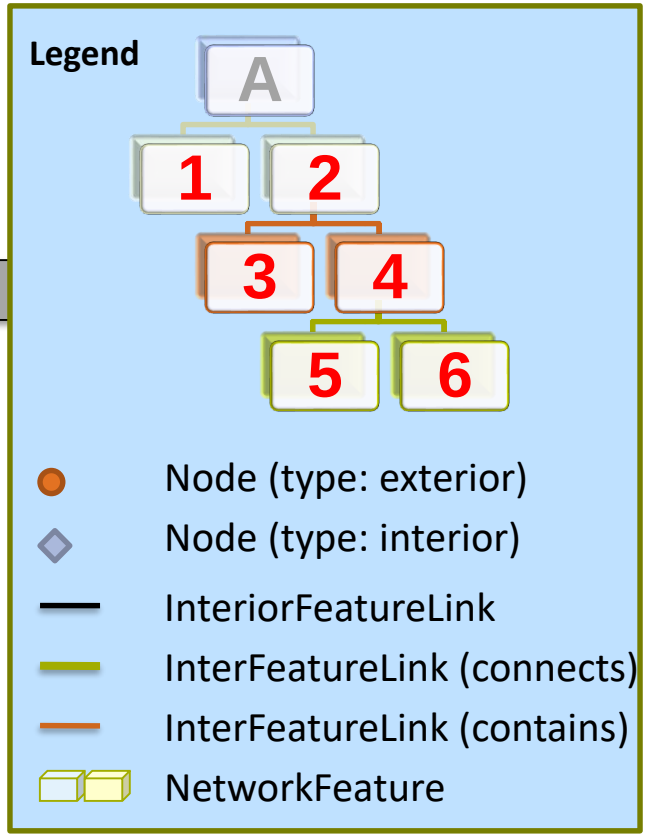
Feature Hierarchy | **Network Hierarchy** | **Multi-Utility Networks**

How can this be achieved by modeling NetworkFeatures / FeaturesGraphs / NetworkGraphs?

Hierarchies: Feature Hierarchy

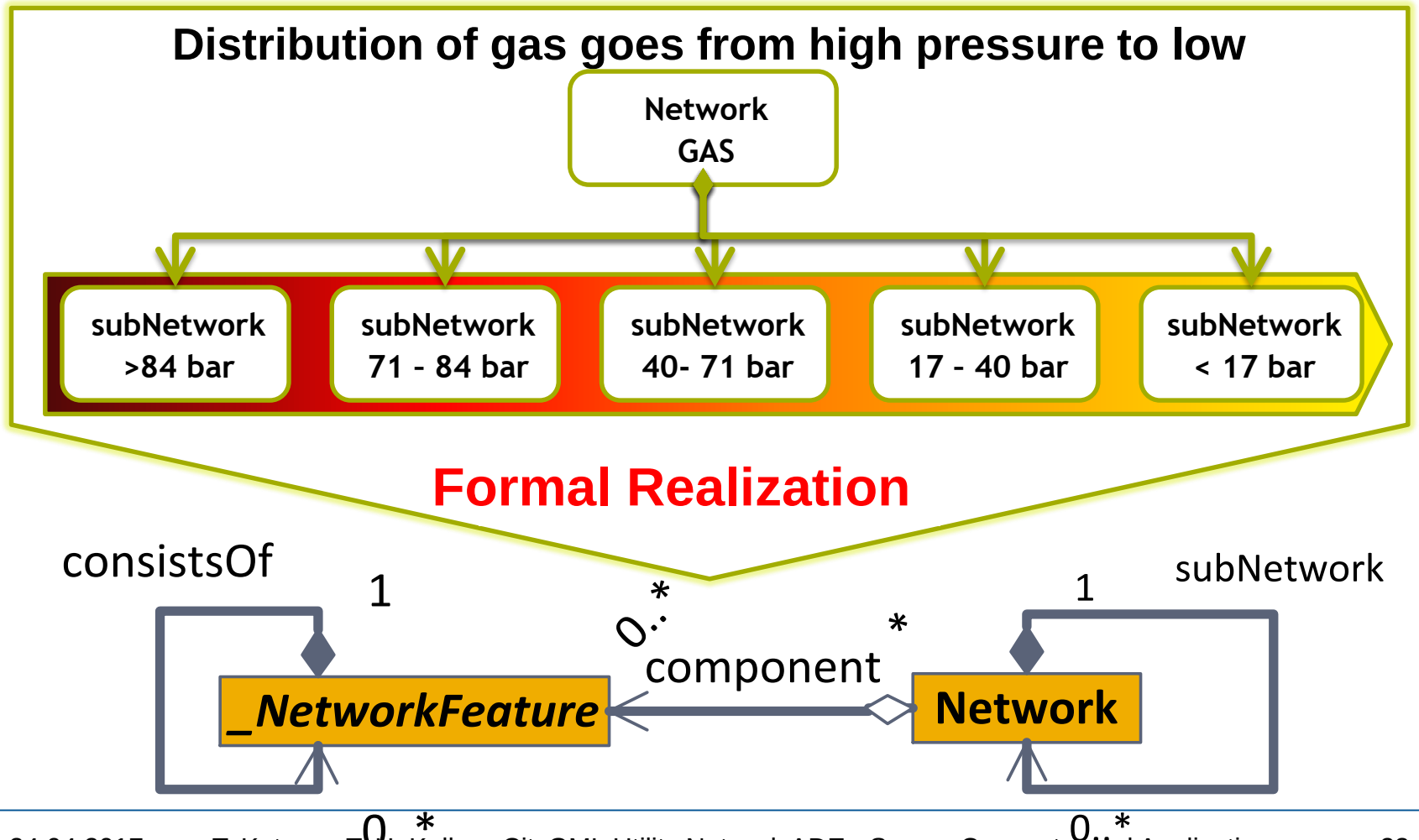






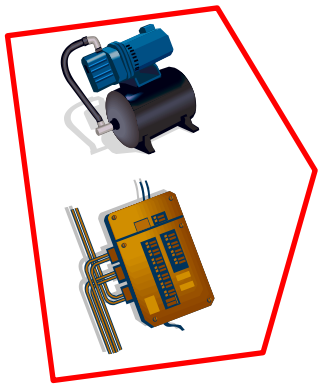
Hierarchies: Internal Network Hierarchies

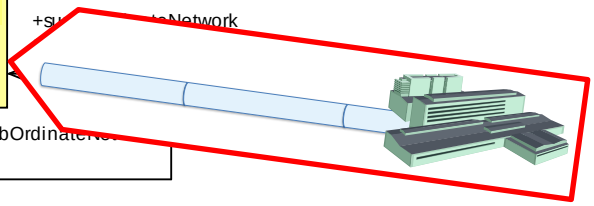
e.g. gas network is an aggregation of sub networks of same commodity, but different pressure systems and each sub network is an aggregation of Network entities

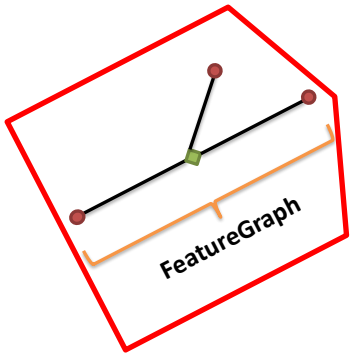


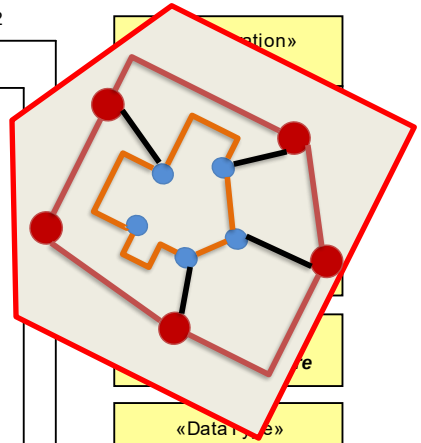
Complete Network

Core Model in UML









«FeatureType»
Core::AbstractCityObject

«FeatureType»
AbstractNetworkFeature

«Property»
+ function :FunctionValue [0..1]
+ usage :FunctionValue [0..*]
+ connectedCityObject :URI [0..1]
+ yearOfConstruction :Date [0..1]
+ status :StatusValue [0..1]
+ locationQuality :SpatialQualityValue [0..1]
+ elevationQuality :SpatialQualityValue [0..1]

+component 0..* 0..*

«FeatureType»
Network

«Property»
+ class :Code [0..1]
+ function :Code [0..*]
+ usage :Code [0..*]

+subNetwork 0..*

+consistsOf 0..*

+topoGraph 0..1

«FeatureType»
FeatureGraph

+featureGraphMember 0..*

«FeatureType»
NetworkGraph

+topoGraph 0..1

2

+nodeMember 1..*

«FeatureType»
Node
+ type :NodeValue
+ connectionSignature :AbstractSignature [0..1]
+ linkControl :AbstractLinkControl [0..1]

GM_Primitive
«type»
Geometric primitive::
GM_Point

+realization 0..1

+start 1 0..*

+end 1 0..*

GM_OrientableCurve
«type»
Geometric primitive::
GM_Curve

+realization 0..1

«FeatureType»
AbstractLink
+ direction :Sign [0..1]
+ linkControl :AbstractLinkControl [0..1]

«Data Type»
AbstractLinkControl

0..* +linkMember

0..* +linkMember

«FeatureType»
InteriorFeatureLink

«FeatureType»
InterFeatureLink
+ type :InterFeatureLinkValue

«FeatureType»
NetworkLink

Linking objects

Complete Network Core Model in UML

Topography

«FeatureType»
Core::AbstractCityObject

«FeatureType»
AbstractNetworkFeature

«Property»
+ function :FunctionValue [0..1]
+ usage :FunctionValue [0..*]
+ connectedCityObject :URI [0..1]
+ yearOfConstruction :Date [0..1]
+ status :StatusValue [0..1]
+ locationQuality :SpatialQualityValue [0..1]
+ elevationQuality :SpatialQualityValue [0..1]

+component
0..*
0..*

«FeatureType»
Network

«Property»
+ class :Code [0..1]
+ function :Code [0..*]
+ usage :Code [0..*]

+subNetwork 0..*
+superOrdinateNetwork
0..*
+subOrdinateNetwork
0..*

+consistsOf
0..*

Graph Representation

+topoGraph 0..1
+topoGraph 0..1
2

«FeatureType»
FeatureGraph

+featureGraphMember
0..*

«FeatureType»
NetworkGraph

+nodeMember
1..*

«FeatureType»
Node
+ type :NodeValue
+ connectionSignature :AbstractSignature [0..1]
+ linkControl :AbstractLinkControl [0..1]

GM_Primitive
«type»
Geometric primitive::
GM_Point

+realization
0..1

+start 1
+end 1
0..*
0..*

GM_OrientableCurve
«type»
Geometric primitive::
GM_Curve

+realization
0..1

«FeatureType»
AbstractLink
+ direction :Sign [0..1]
+ linkControl :AbstractLinkControl [0..1]

0..*
+linkMember

0..*
+linkMember

«FeatureType»
InteriorFeatureLink

«FeatureType»
InterFeatureLink
+ type :InterFeatureLinkValue

«FeatureType»
NetworkLink

0..*
+linkMember

«enumeration»
NodeValue
exterior
interior

«enumeration»
InterFeatureLinkValue
connects
contains

«DataType»
AbstractSignature

«DataType»
AbstractLinkControl

Existence of characteristics relevant to network modelling in various data models

	INSPIRE Utility Networks	IFC	ArcGIS Utility Networks	SEDRIS	Pipeline ML	CityGML Utility Network ADE
Representation of heterogeneous networks	+	•	•	+	•	++
Dual representation	+	++	+	++	–	++
Topographic/graphic aspects	++	++	++	++	++	++
3D geometries	–	++	–	+	–	+
Functional aspects	–	–	–	–	–	•
Hierarchical modelling						
• networks/ subnetworks	++	–	–	++	–	++
• components/ subcomponents	++	++	•	–	•	++
Interdependencies between						
• network features and city objects	–	•	–	•	–	++
• network features of different network types	–	++	–	–	–	++

– = no support, • = basic support, + = sophisticated support, ++ = comprehensive support

Source: Kutzer, T. & Kolbe, T. H., 2016: Extending Semantic 3D City Models by Supply and Disposal Networks for Analysing the Urban Supply Situation, http://www.dgpf.de/src/tagung/jt2016/proceedings/papers/36_DLT2016_Kutzner_Kolbe.pdf

Existence of characteristics relevant to network modelling in various data models

	INSPIRE Utility Networks	IFC	ArcGIS Utility Networks	SEDRIS	Pipeline ML	CityGML Utility Network ADE
Representation of heterogeneous networks	+	•	•	+	•	++
• network features and city objects	–	•	–	•	–	++
• network features of different network types	–	++	–	–	–	++

– = no support, • = basic support, + = sophisticated support, ++ = comprehensive support

- The CityGML Utility Network ADE meets best the requirements for modeling utility networks regarding the characteristics in question.
- The **aim of the CityGML Utility Network ADE**, however, is not to replace the other models or systems, but to **provide a common basis for the integration of the diverse models in order to facilitate joint analyses and visualization tasks**, e.g. by mapping data which is based on the IFC or ArcGIS model to the ADE.

Source: Kutzer, T. & Kolbe, T. H., 2016: Extending Semantic 3D City Models by Supply and Disposal Networks for Analysing the Urban Supply Situation, http://www.dgpf.de/src/tagung/jt2016/proceedings/papers/36_DLT2016_Kutzner_Kolbe.pdf

Next steps

- A **Joint SIG 3D and OGC Utility Network ADE working group** is further developing the ADE to make it usable for other use cases as well
  - Further information on the Utility Network ADE workshops including presentations and results is available at: http://en.wiki.utilitynetworks.sig3d.org/
  - Resources (UML model, XML schema, using the ADE with FME) are provided on this github repository: https://github.com/TatjanaKutzner/CityGML-UtilityNetwork-ADE
  - The next joint SIG 3D and OGC workshop will take place in Vienna on June 30, 2017: http://en.wiki.utilitynetworks.sig3d.org/index.php/Workshop_Vienna_2017
  - If you are interested in participating in the working group, please contact Tatjana Kutzner (kutzner@tum.de)

Next steps

- Several members of the working group are currently **generating publicly available test data** for the ADE. This includes data from
  - City of Rotterdam, Netherlands
  - City of Nanaimo, Canada
  - Test data provided by the company AED-SICAD
- As part of the development of CityGML 3.0, the final CityGML Utility Network ADE is to be integrated as individual module into CityGML.
- „Dynamizers“ will be another new concept introduced to CityGML 3.0. It will allow for connecting sensors and sensor data with city objects and utilities.

Possible use cases (I)

- **Storm drainage network**
  - Planning and managing of networks is important to reduce the overflow and to collect storm drainage network fees
  - Information on the total number of buildings sites, roofs and sewer system connected to the storm drainage network is required
- **Clean water act**
  - Inspection of waste water discharged by chemical labs / factories
  - Information on the network helps in finding the location of elements not working properly
- **Vulnerability assessment and disaster management emergency response**
  - Assessing the impact of a natural or man-made disaster on networks and analysing how their failure affects buildings and inhabitants

Possible use cases (II)

- **Urban facility management**
  - Coupling of supply/disposal networks with indoor installation
  - Management of planned/unplanned maintenance operations at the level of the individual consumer
  - Failure detection based on the suppliedness of individual consumers
  - Location of easy access points for maintenance
- **Smart energy planning, simulation and operation**
  - Analysing how a change in land use can affect energy consumption and production
  - Simulating and forecasting feed-in power and consumption over small periods which allows network operators to optimise operation in small-scale distribution networks

Linking utility networks with city models is not supported by other standards!

Possible use cases (III) – Multi-utility scenarios

- **Multi-utility planning, simulation and operation**
  - Planning of combined district heating and electrical power generation and distribution
  - Analysing how a change in consumption of one commodity (e.g. gas) impacts consumptions of other commodities (e.g. district heating)
- **Smart Cities**
  - Integrated urban planning, i.e. analysing the implact of planned urban transformations on multiple aspects (energy, traffic, environment)
- **Cascading effects in the failure of infrastructures**
  - Failure propagation of an electric grid on the water and gas supply

Existing utility modeling standards do not cover multi-utility scenarios!

Summary

- **Core model for the representation of arbitrary utility networks**
  - **3D topographic** modelling
  - **3D topological** and **functional** modelling
  - Support of **hierarchies**: complex objects, network hierarchies
  - Provides homogenized and integrated view on multi-utility networks
- **The core model is independent of a specific type of utility / commodity**
- **Utility-specific, concrete feature classes**
  - including characteristics, materials and functional aspects of the features
- The ADE allows for
  - **linking utility networks with 3D city models**
  - **modeling multi-utility scenarios**

  → this is not supported by other existing utility modeling standards

Further information on the Utility Network ADE

Publications:

- Becker, Thomas; Nagel, Claus; Kolbe, Thomas H. (2012) Semantic 3D modeling of multi-utility networks in cities for analysis and 3D visualization: http://mediatum.ub.tum.de/doc/1145724/287720.pdf
- Becker, Thomas; Nagel, Claus; Kolbe, Thomas H. (2011) Integrated 3D Modeling of Multi-utility Networks and Their Interdependencies for Critical Infrastructure Analysis: http://mediatum.ub.tum.de/doc/1145740/358854.pdf
- Kutzner, Tatjana; Kolbe, Thomas H. (2016) Extending Semantic 3D City Models by Supply and Disposal Networks for Analysing the Urban Supply Situation: https://mediatum.ub.tum.de/doc/1304227/1304227.pdf
- Hijazi, Ihab; Kutzner, Tatjana; Kolbe, Thomas H. (2017) Use Cases and their Requirements on the Semantic Modeling of 3D Supply and Disposal Networks: http://mediatum.ub.tum.de/doc/1352269/192884.pdf