Lower the impact of aggravating factors in crisis situations thanks to adaptive foresight and decision-support tools

D5.1: [Engineering grid models and deterministic grid interfaces]

[Models of grids that are quantitatively modelled]

For the attention of the Research Executive Agency

FHG	
Author	Katja Faist, Uli Siebold
Due date	
Issue date	31/05/2015

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 606742

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 606742

Document information

Document title	D5.1: [Engineering grid models and deterministic grid interfaces]
Document file name	
Revision number	
Issued by	
Issue date	31/05/2015
Status	

Nature of the deliverable

R	Report	X
P	Prototype	
D	Demonstrator	
O	Other	

Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Document Approval

Name	Role in the project

Document Review

Date	Version	Reviewers

Acknowledgement

This report forms part of the deliverables from a project called "Snowball" which has received funding from the European Union's Seventh Framework Programme FP7/2007-2013 under grant agreement n° 606742. The Community is not responsible for any use that might be made of the content of this publication.

Snowball aims at lowering the impact of aggravating factors in crisis situations thanks to adaptive foresight and decision-support tools.

The project runs from March 2014 to February 2017, it involves 11 partners and is coordinated by Gedicom.

More information on the project will soon be found at http://www.snowball-project.eu.

Abstract

For developing agent models, damage models and damage propagation in supply grids, the grids itself have to be modelled and implemented into the simulation tool. This part of the simulation tool will be the foundation for a later development and implementation of the mentioned methods. For providing an efficient implementation, the general structure of the modelled supply grids (power grid, water grid, mobile phone grid) has to be studied and commonalities have to be identified, the selection of a suitable grid modelling method is necessary and the structure of the modelled grids has to be brought to the simulation tool.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 606742

Executive summary

In this document the base for the simulation tool (grid models) is described. Before implementing the agent models for human behavior or the damage models, a useful model for the different grid types (water, power, mobile phone grid) has to be developed. In this document the general structure of the grids is studied, grid modelling methods are identified, grid models are constructed and are finally brought to the simulation tool.

The first step for the definition of the models is the study of characteristics of the grids, which are described within this report. In the given document, it is ascertained, that the modelled grids have much similarities. Every grid contains for example elements (nodes) with a geo position and a mean time to repair in case of a damage, like transformer stations or power poles in the power grid. Besides that, a flow between the nodes in every grid type, like electricity in the power grid, water in the water grid or information/data in the mobile phone grid is identified. These properties influence the mode and are included into the model. The interfaces between the grids are identified for including them in the model for the involving of the cascading effects later in the project.

The second step for the grid model is the selection of a suitable grid modelling method which includes the mentioned properties of the grids. A suitable grid modelling is selected in this report with preceding studies of methods in computer science. The selected method is a graph with a flow network, where the elements are mapped to nodes and the connections between the elements are edges with an added flow of electricity/water/data.

The design of the simulation tool is evolved for different uses: preparation for crisis situations, planning purpose and real time analysis. On the base of the general grid structure, the grid model and the design, the first part of the simulation tool is developed, which is able to import grid files, connect the grid types and construct a grid model on the base of the imported data.

Based on this approach, it will be possible to add agent models for human behavior and damage models at a later point of the project.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 606742

Table of content

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 606742

List of Figures and Tables

ABBREVIATIONS

A list of abbreviations is strongly recommended.

DEFINITIONS

Adjacency list

Possibility for storing neighbors of a vertex in a graph, where the neighbors are stored in a list.

Degree of Vertices

Number of neighbors, where a neighbor is connected to an outgoing edge.

Directed Graph

In a directed graph, all edges have a direction. An edge from a node A to a node B means, that there is a relation from A to B, but not vice versa.

General Structure of a Grid

The general grid structure describes how a grid looks like in the most cases. It does not describe a particular grid of a specific city, but it describes how a grid looks like in the most cities.

Planar Graph

A graph is planar if can be drawn with two dimensions (plain) without any intersecting edges.

Undirected Edge

In an undirected graph, the edges have no direction. An edge from a node A to a node B means, that there is a relation from A to B and from B to A.

Unit Test

This is a test method ensuring the functionality of source code by testing small units of it.

Weakly connected

For evaluating if a graph is weakly connected, all edges in the directed graph are replaced with undirected edges. If a way from each vertex to every other vertex in the graph among the undirected edges exists, the graph is weakly connected.

INTRODUCTION

The simulation tool will model and simulate damage propagation including cascading effects on different supply grids, where human behavior will be taken into account with the aid of agent models. For developing agent models, damage models and damage propagation in supply grids, the grids itself have to be modelled and implemented into the simulation tool. This part of the simulation tool is described in this report and will be the base for a later development and implementation of the mentioned methods.

The modelling of the grids can be divided into three parts: the study of the general grid structure, the model of the grids and the import into the simulation tool. The study of the general structure of the modelled supply grids (power grid, water grid, mobile phone grid) is done in section 1. Furthermore, the grid interfaces are identified and an abstract view on the modelled grids and their interfaces is given.

Based on the general grid structure, a suitable grid modelling method for the properties of the modelled grids is selected by a preparatory study of different grid modelling methods of computer science. Afterwards, a description of the grid model including the different grid types is given. The results are summarized in section 2.

Based on the selection of the modelling method the report will further lay out how the structure of the modelled grids is brought to the simulation tool and how the simulation tool is designed. The design includes different purposes of the simulation tool, which are explained in section 3.1. The current development state of the simulation tool is described in the section 3.2 and 3.3.

1 STRUCTURE OF THE MODELLED GRIDS

In D3.1 different supply grids were selected for modelling. For building up a realistic model of these grid types, their structure has to be studied. In this section the structure of the power grid, water grid and the mobile phone grid is presented.

1.1 Power Grid

The power grid contains the following elements (Schwab, 2012):

- Power plant
- Transformer stations
- Distributors
- Power lines
- Power pole

The power grid consist of different levels: low voltage, medium voltage and high voltage. Cities and towns are connected to the low voltage grid, which is connected through a transformer station to the medium voltage grid. Figure 1 shows this architecture. The high voltage and the maximum voltage network are mainly used for the transportation of electricity. Hence, they contain mainly power plants. Figure 2 shows the architecture of the high voltage and the maximum voltage part of the power grid.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 606742

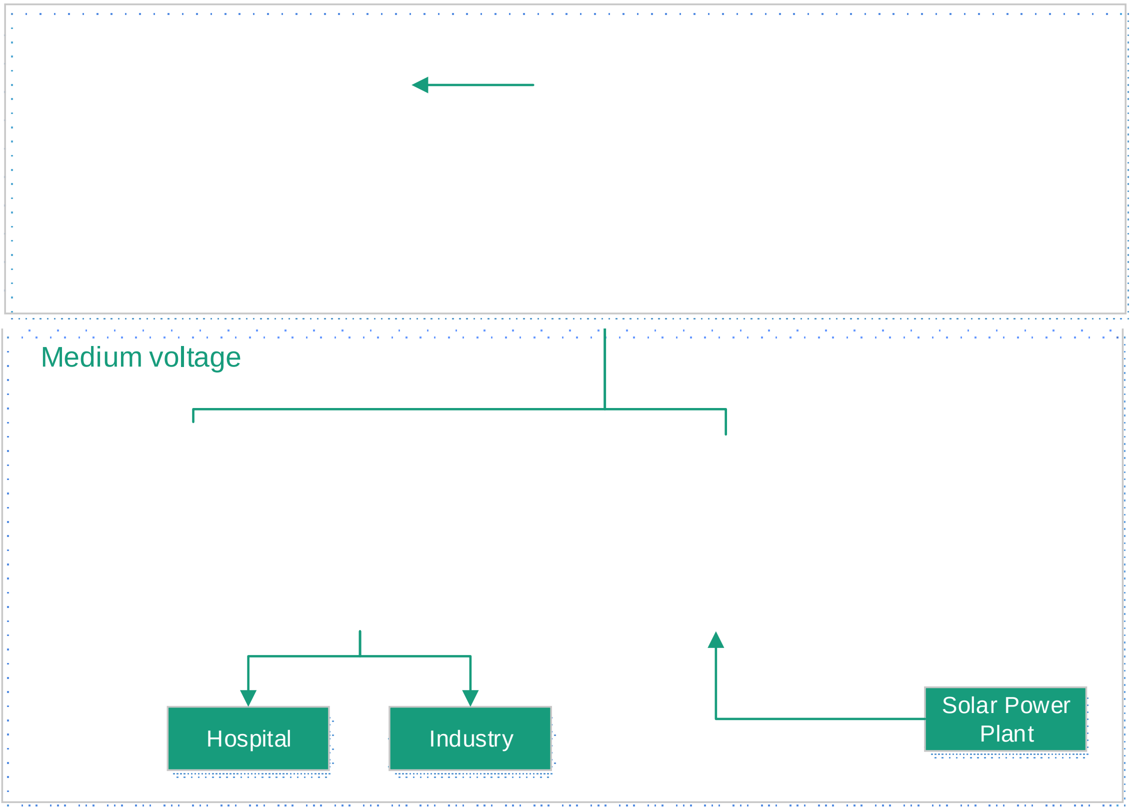

Figure 1: Architecture of the low voltage and medium voltage power grid.

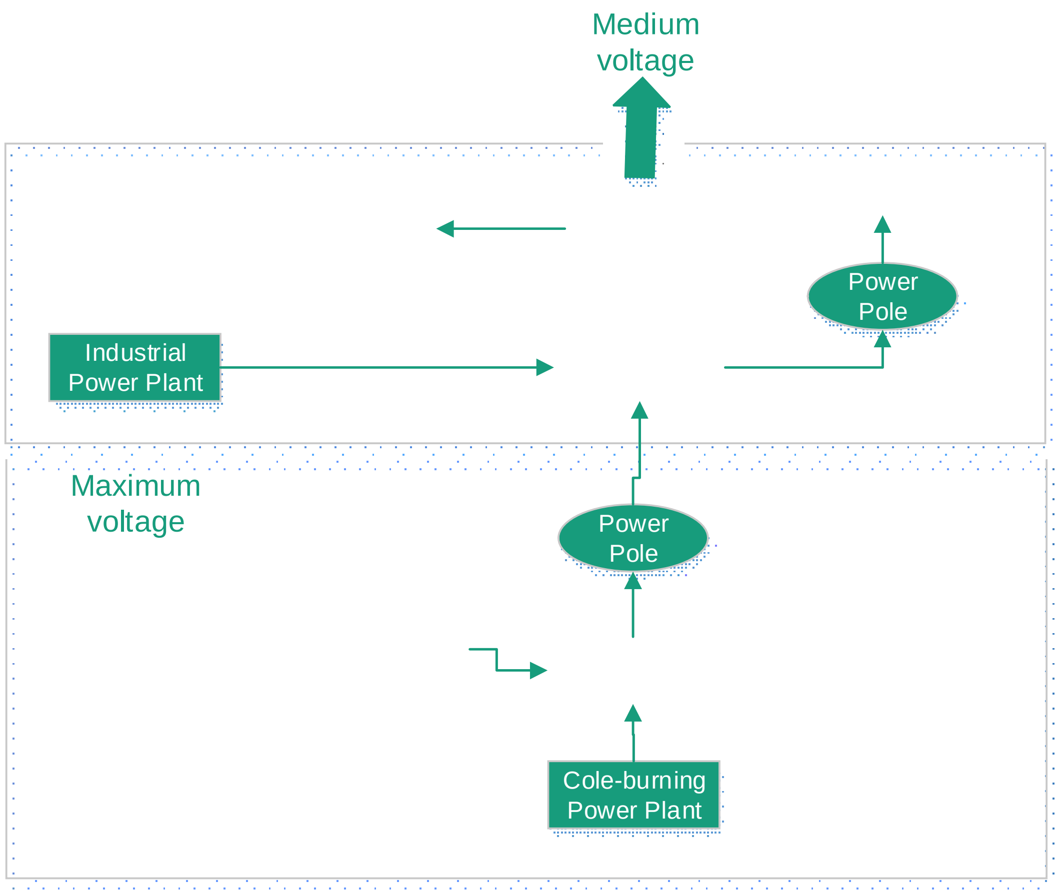

Figure 2: Architecture of the high voltage and maximum voltage power grid.

1.2 Water Grid

The water grid contains the following elements (Sattler, 1999):

- Pump stations
- Booster station
- Water pipes
- High level tank

The water grid is organized in two different topologies: a ramification network (often in rural area) or a mesh network. Figure 3 shows the typical architecture of a water distribution grid, where water supply could be a booster station or a high level tank with a pump station. Each water grid can be supplied by one or more booster stations or high level tanks.

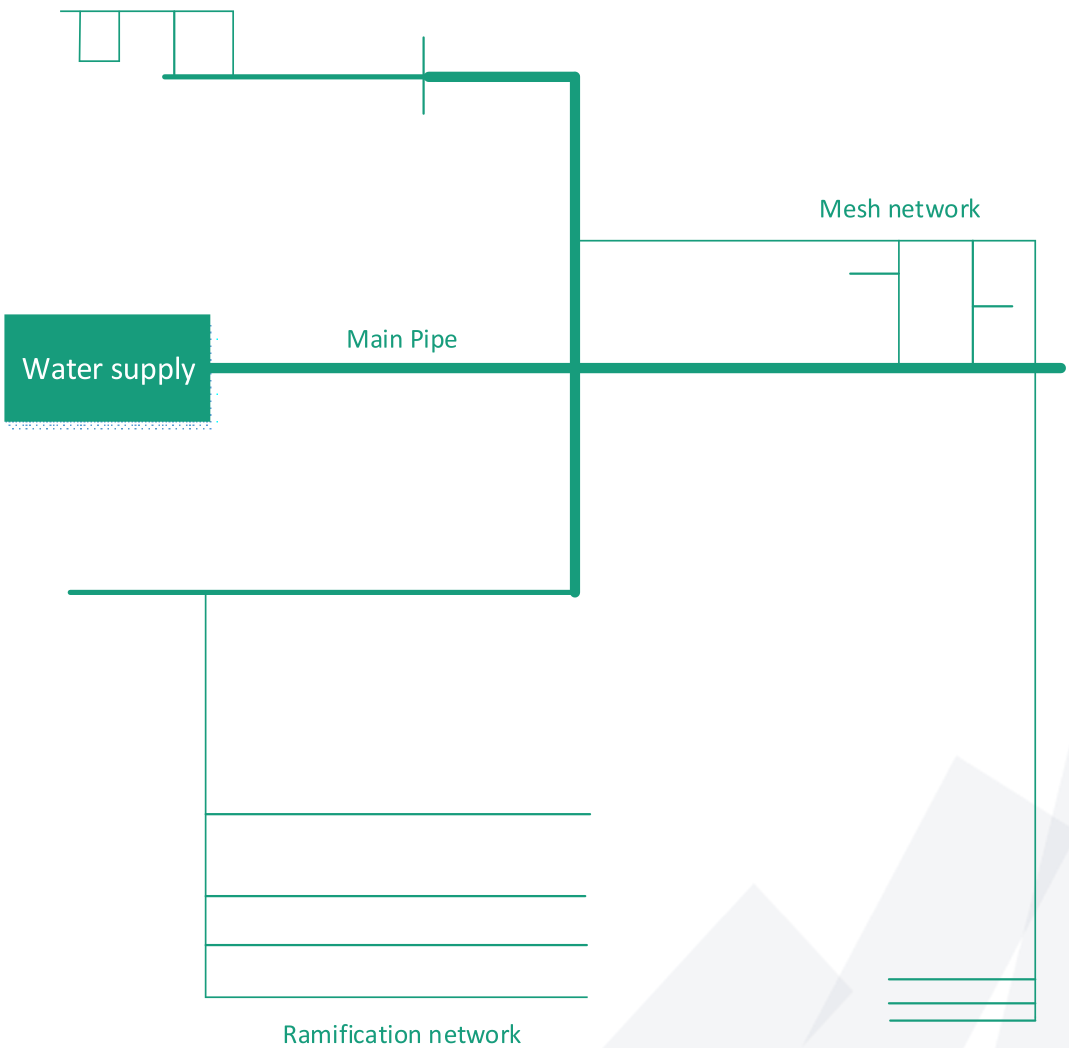

Figure 3: Architecture of the water grid with water pipes, where the stroke width indicates the maximal amount of water flow. Nodes (consumers) are not shown in this representation.

1.3 Mobile Phone Network

The mobile phone grid consists of a GSM/GPRS network and an UMTS network. The UMTS network is integrated in the GSM network.

Figure 4 shows the structure of the GSM/GPRS/UMTS network. As shown in Figure 4 the components are (Sauter, 2010)

- Mobile Station: Also called Mobile phone. This component is connected to one Base Transceiver Station.
- Base Transceiver Station: Air interface to Mobile Stations. Each Base Transceiver Station is able to manage up to 30 phone calls in parallel. Not each Base Transceiver Station is connected to a

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 606742

Base Station Controller, there is the possibility to forward the traffic to another Base Transceiver Station and afterwards to a Base Station Controller.

- Base Station Controller: Manages the signal of several Base Transceiver Stations. Normally, one Base Station controller is connected to 10 up to 100 Base Transceiver Stations.
- SGSN: This component is for forwarding the package oriented traffic. One SGSN manages the package oriented traffic of several Base Station Controllers.
- GGSN: Forwarding the package oriented traffic to the internet.
- Mobile Switching Center: Manages the connections and the user data. Each Mobile Switching Center manages the traffic of several Base Station Controllers.
- G Mobile Switching center: Managing of calls to the PSTN
- Home Location Register: In this component all user data is stored. When a user connects to the mobile phone network, his data is sent from the Base Transceiver Station through the Base Station Controller and the Mobile Switching Center to the Home Location Register. At this point there is a lookup of the user rights. This data is sent back to the Mobile Switching Center, in which a visitor file is stored in the Visitor Location Register. Because of the importance of the Home Location Register, it is often redundant in a mobile phone network.
- Operation Administration Maintenance: Component for finding failures in the network and for maintenance.
- eNode-B: Component of the UMTS network, works like the Base Transceiver Station in the GSM network.
- Radio Network Controller: Component of the UMTS network, works like the Base Station Controller in the GSM network.

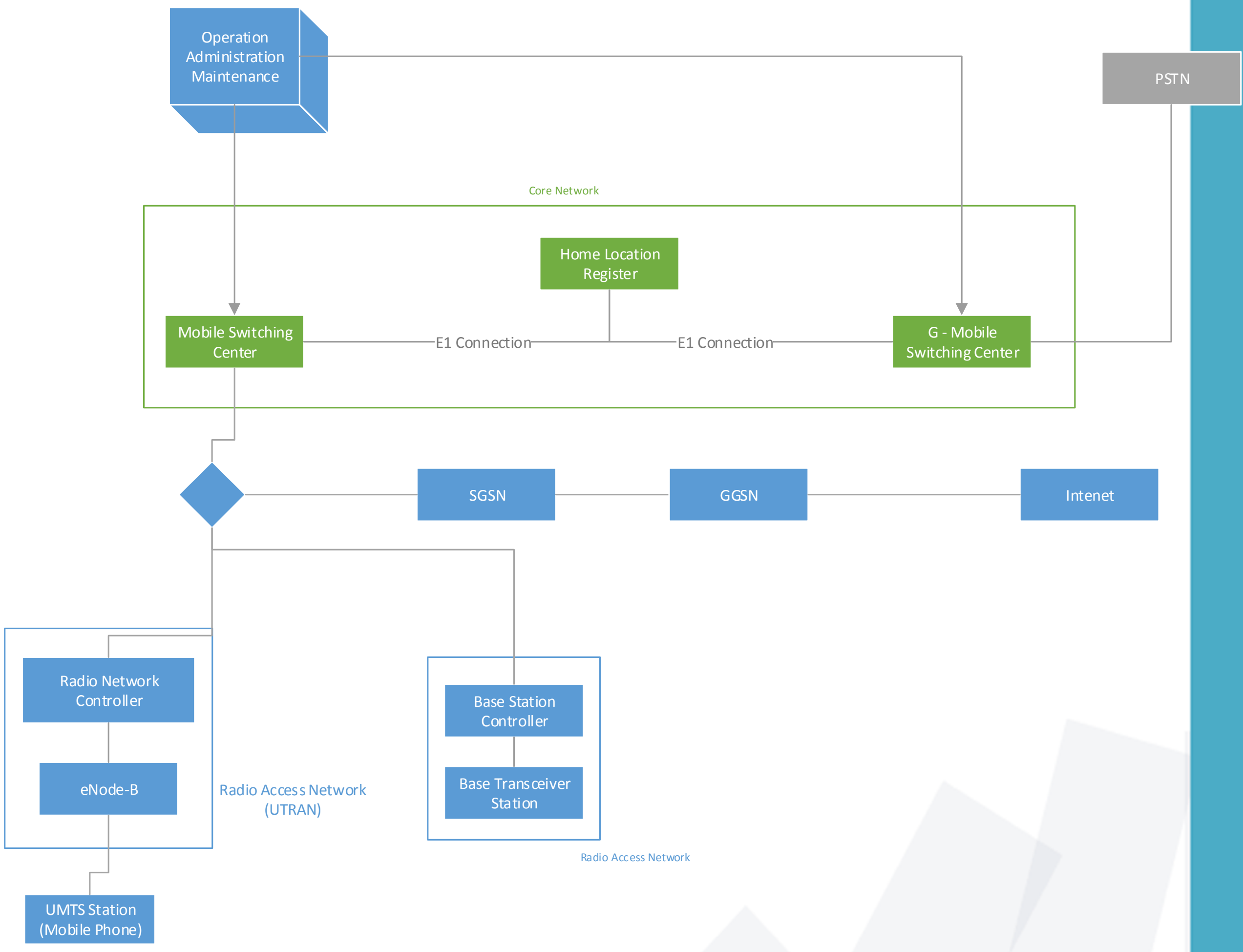

Figure 4: Architecture of mobile phone grid (GSM, GPRS and UMTS).

1.3.1 Cells in the mobile phone grid

The mobile phone network is organized as cell network with cell size from 2 meter up to 20 kilometer, depending on participant number. In theory, the maximal distance of a Mobile Phone to a Base Transceiver Station would be around 35 km (Sauter, 2010). Figure 5 shows how the cell network is organized. The cells are managed by the Base Transceiver Stations, where each one can manage up to three cells with an angle of 360°, 180° or 120°.

In the GSM part of the mobile phone network, the size of the cells is fixed. In UMTS, there is a cell breathing, which means the size can change dynamically. With an increasing number of users, the interferences are also increasing in the UMTS network, because of the used code multiplex method. This leads to a higher transmittion power. When a user U_1 is close to the cell edge and sends already with the highest possible power and another user approaches the UMTS cell, the interference increases and all users have to send with more power. User U_1 has to send also with more power for keeping the signal and balancing the interference. This is not possible since user U_1 sends already with the highest possible

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 606742

power, such that he will lose the signal. Due to technical issues, the cell size decreases if there are too many users and it increases if the number of users is decreasing. (Sauter, 2010)

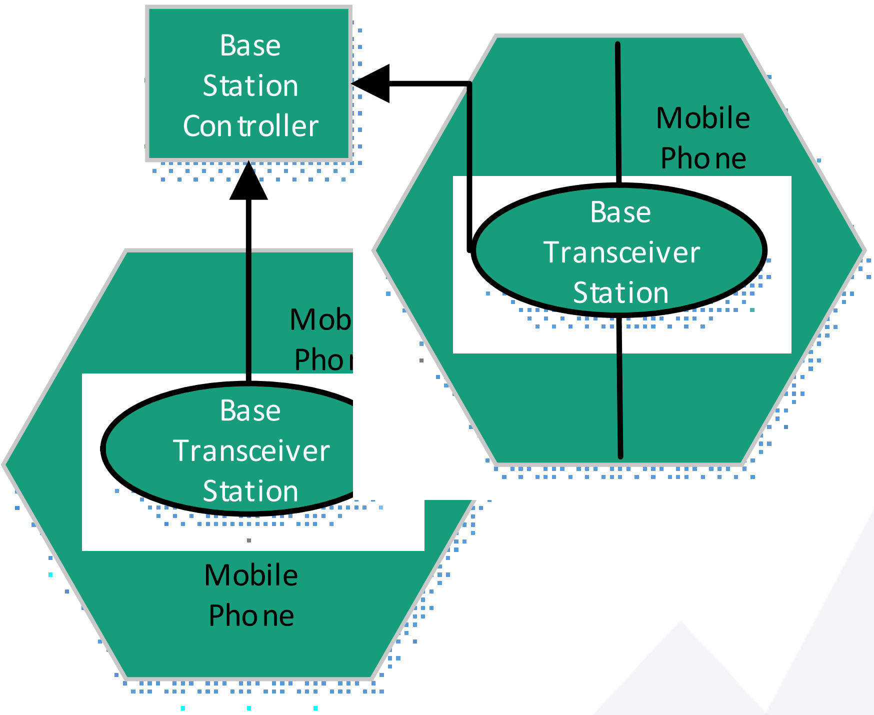

Figure 5: Scheme of cells in mobile phone networks, where one Base Transceiver Station (upper right) manages two cells with 180°.

The view on the different grids is abstract. In reality, there are some more components, integrated in other ones, like for example the Visitor Location Register in the Mobile Switching Center in the mobile phone network. For the model in Snowball, the geo location of the components is needed for the damage model. Hence, if the Mobile Switching Center is damaged, there is also a damage in the Visitor Location Register. Because of this point, the Visitor Location Register is modelled within the Mobile Switching Center.