MAGANET: map based AMI (Advanced Metering Infrastructure) network topology generator

[Poster abstract]

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ABSTRACT
The article describes MAGANET, a network topology generator based on the real map for sensor and advanced metering infrastructure (AMI) networks. The generator imports topologies of buildings from specific world areas, indicated by geographical coordinates. The described generator was used in a study on management protocols for large multihop AMI networks.

Categories and Subject Descriptors
C.2.1 [Computer-Communication Networks]: Topology analysis and generation −*Wireless communication*

General Terms
Algorithms, Verification.

Keywords
Advanced metering infrastructure, AMI, network topology generator

1. INTRODUCTION
The AMI (Advanced Metering Infrastructure) networks are designed to handle communications between smart meters, exchanging information regarding operation of devices measuring consumption of electricity, water, gas, heat etc. The AMI networks are gathering data from the fixed nodes, which transmit the measurements to one or multiple gateways. In the majority of AMI solutions the communication takes place in a wireless way.

The AMI networks typically cover large areas and may consist of up to millions of devices. The discrete event simulations are widely used for the performance evaluation and testing of novel networking protocols and algorithms for such networks. The simulation models require a correct representation of the network topology, defining the location of the simulated nodes and the links between the network nodes. Unlike in the other types of sensor networks, the topology of AMI networks is closely related to the arrangement of buildings, their area, function, relative positions and other urban planning features. Although multiple tools for the generation of the random network topologies have been proposed (e.g. BRITE [2]) there are no tools providing correct representation of the wireless AMI networks properties.

Preliminary studies have shown that the characteristics of network topology has a significant impact on the operation of the protocol and its effectiveness. The clustering of nodes in specific areas of the network is of particular importance. Thus simplified assumptions on deployment of network nodes, taken for simulation studies can lead to erroneous conclusions as to the effectiveness of developed solutions and protocols. Existing statistical studies for the Smart Grid [1], based on the parameters of the real network indicate some properties of the network, e.g. "small world" properties of such networks. The results, however, do not correspond to the specifics of the AMI network, mainly because the described referenced networks were sparsely connected and the average node degree was low.

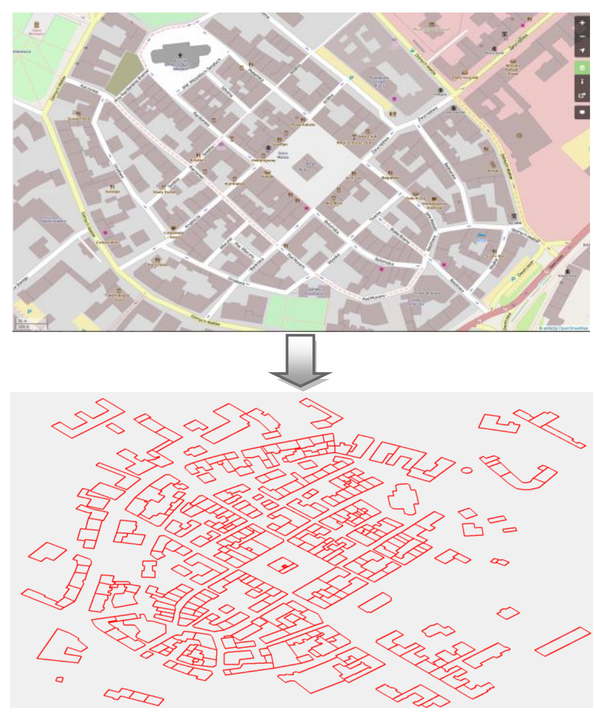

Fig.1. The map of an example city (Gliwice, Poland, urban mixed density of building) in OpenStreetMaps and the obtained buildings topology.

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2. RELATED WORK

There are a few network topology generators available that allow to represent wireless networks. BRITE [2] is a very flexible generator, allowing to create hierarchical and flat topologies with predefined parameters. GT-ITM [3] allows to reproduce hierarchical structure of the internet, but does not represent the properties of wireless mesh networks. Most of the generators are designed to build general topologies for the Internet, which present significant differences to sensor or AMI networks. Tools dedicated to sensor networks, such as Topo_gen [4], GenSeN [9] or Atarraya [5], allow the configuration of several important parameters, but do not take into account urban planning parameters, which we planned to analyze. The necessity to take into account the urban planning features and dependencies is indicated also in available studies, e.g. [6].

3. TOPOLOGY GENERATOR

We propose to use network topology based on real buildings arrangement for typical areas (industrial buildings, high-density housing typical for downtown, low-density suburb housing, dispersed development in rural areas). We have developed a novel generator: MAGANET, which generates a network topology based on the maps of specific areas and allowing for parameterization of specific features of the topology (in particular, the formation of clusters of neighboring nodes).

The MAGANET (Map-based Generator of AMI Network Topology) software imports topologies of buildings from area of the world indicated by geographical coordinates. Next it randomly deploys the network nodes (smart meters) inside the buildings. The meters are uniformly distributed within the buildings, which is sufficient for planned applications, but the random distribution used may be easily modified in the future. The map data are fetched from OpenStreetMap, which do not have licensing restrictions and rely on the data produced by the community of users [7]. Thanks to this it allows to define a topology representing different characteristics of building localization, e.g. urban areas by selecting city center or rural areas. Depending of the number of the buildings and size of the selected area, the generator will place single or multiple nodes within a single building. Sample map imported to the MAGANET and the outline of the buildings is presented in fig. 1.

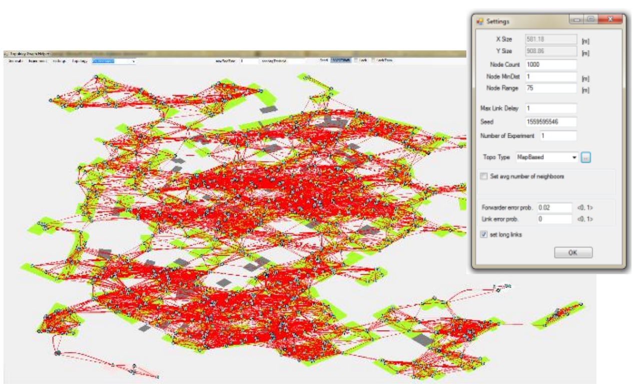

Fig.2. The graph of example AMI network topology generated according to a set of specific parameters.

The MAGANET creates a graph of Layer II connections between the nodes. Fig. 2 present sample generated topology. Currently the tool assumes a planar (2D) topology based on simple model of radio propagation – “disk model” where only parameter is the maximum range allowing for communication [8]. The model can be however easily extended to support more complex signal propagation models, e. g. taking into account already available or additional information (building walls, height of buildings, terrain etc.)

MAGANET allows the definition of the map fragment that should be used for the topology generation. The generation parameters also include the number of nodes placed on the map and the range of a node. Alternatively the average number of neighbors per node can be select, by which the range is calculated. Created connectivity graph may be disconnected, so optionally “long links” may be introduced, which are longer than node radio range (such situation is shown in fig. 3). These links correspond to radiolines or cable connections used for assuring connectivity in the whole network.

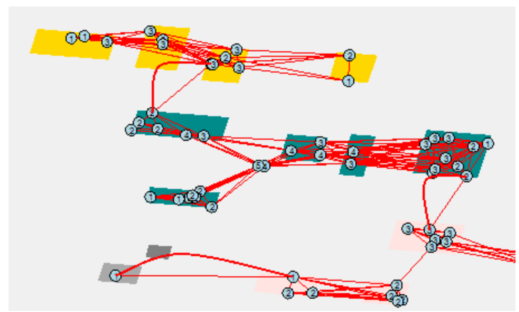

Fig. 3. The enlarged part of the topology. Different colors denote buildings in separate areas, connected via a long-links (indicated by the arcs)

The topology created by the generator (neighborhood graph) can be exported as neighbor lists in text file or XML and used as input for simulation studies with popular simulation software (e.g. ns-3, OMNeT++).

The MAGANET generator also allows analysis of generated topology, calculating chosen topology parameters: avg. number of neighbors, clustering coefficient, avg. path length, path length distribution, neighbors’ distribution, and shared neighbors’ distribution. Analysis of a sample generated topology is shown in fig. 4. For comparative evaluations the generator allows also to create fully random topology, when the nodes are randomly deployed on the 2D area.

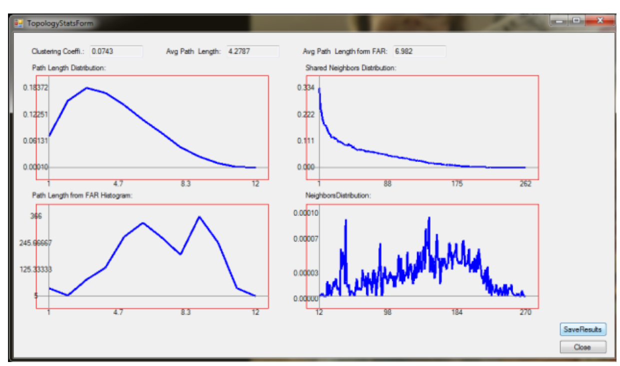

Fig. 4. The example calculations of topology parameters.

4. SUMMARY

The described MAGANET topology generator is a useful tool for the simulation study on protocols for large multihop AMI networks. It can be used to generate input files for commonly used simulation environments, and provides topologies representing different properties representing urban or rural areas.

5. ACKNOWLEDGMENTS

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