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Data Models for Moving Objects in Road Networks - Implementation and Experiences

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1. Motivation

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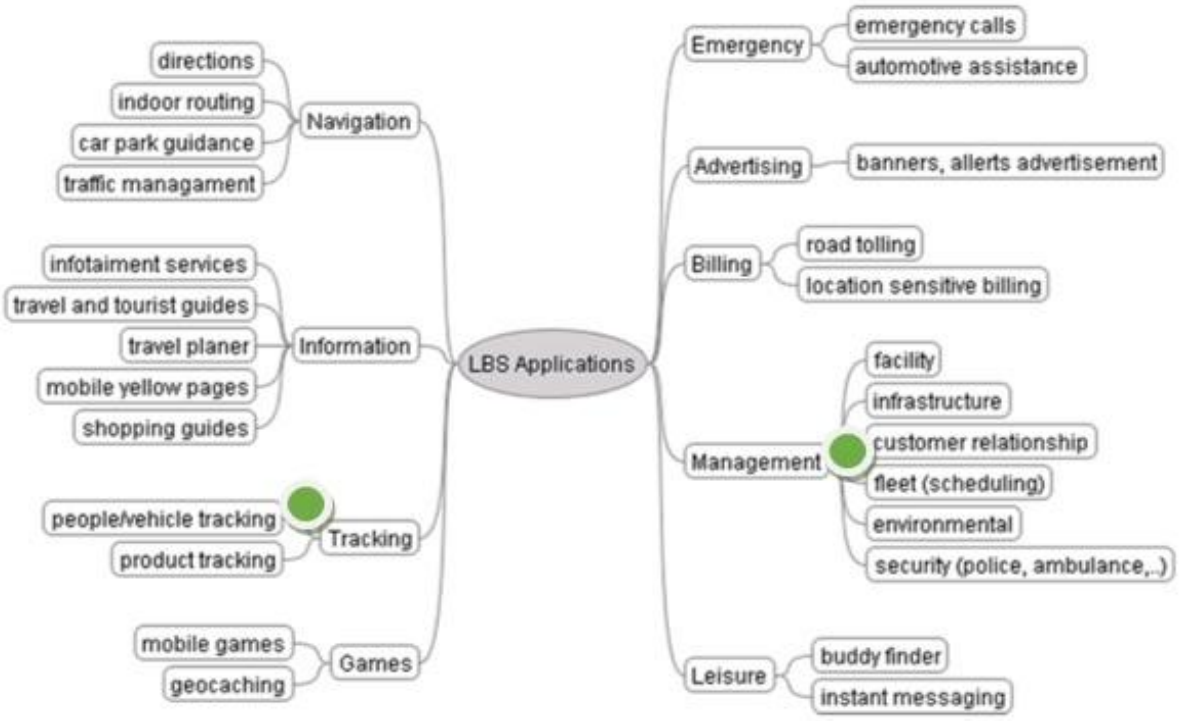
- Subject of Interest: Fleet management (FM) / Automatic vehicle location (AVL)

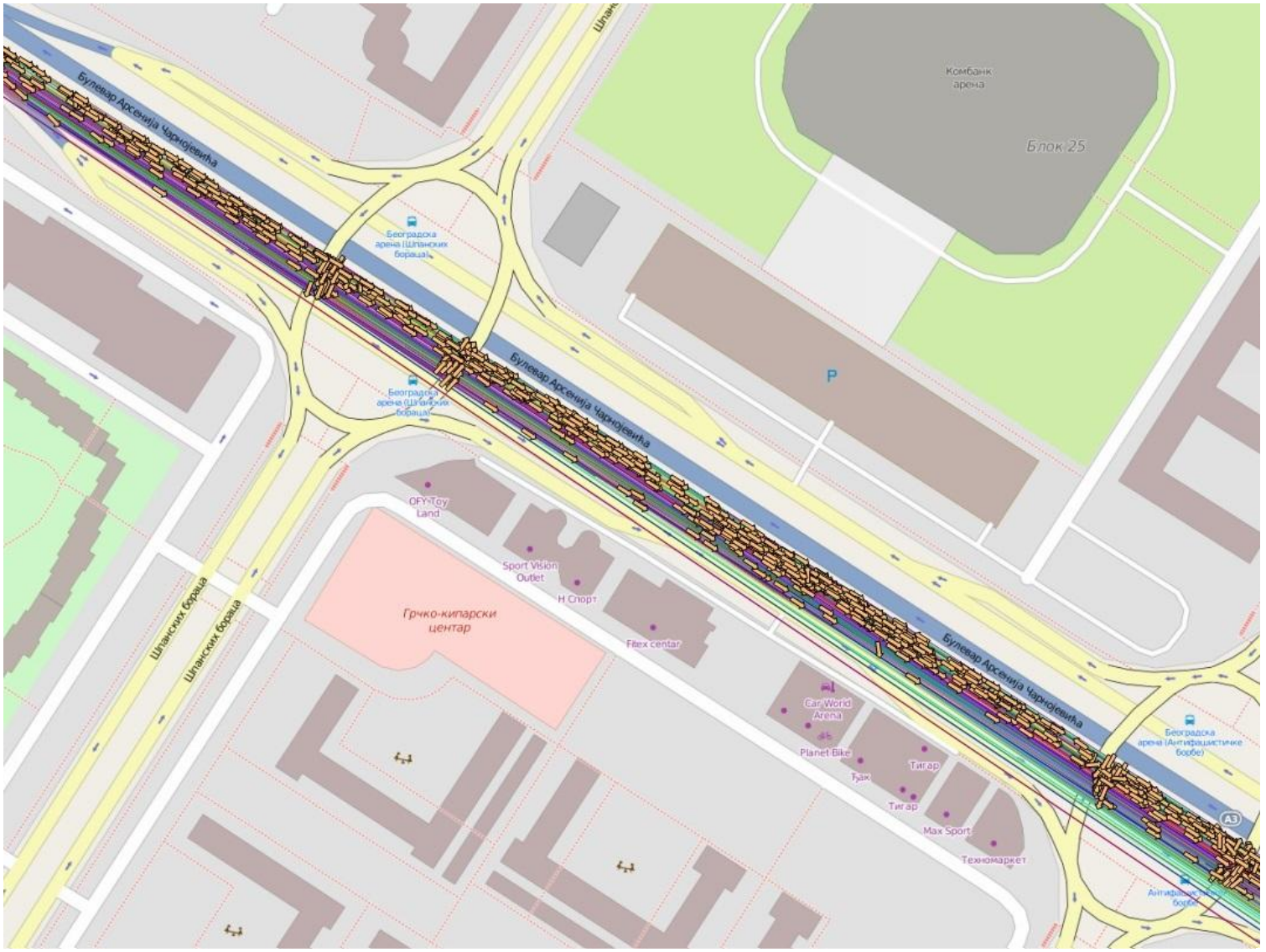


LBS application categories / Foundations of LBS (Steiniger et al. 2006)

1. Motivation

- FM/AVL is based on data model for moving objects (MO)
  - We already have good MO data models - research started more than two decades ago
- Should FM/AVL and its MO data model be based on road network (RN)?
  - We think that it **should be** (memory savings, performances, routing, etc.)
  - However, this is usually **not the case** in practical applications!
    - Reasons
      - Lack of high quality RN data
      - Existing commercial systems more focused on vehicle tracking and telemetric data
    - Is this a major problem?
      - NO - FM/AVL useful for many practical application scenarios can be developed and implemented using
        - standard RDBMS tables (even without spatial extensions)
        - standard SQL language
        - services available from industry content providers
- Now we have RN datasets available - the situation should/could be improved
  - OpenStreetMap (OSM)

1. Motivation



Mobile objects move freely in space

1. Motivation

Mobile objects move on road network

1. Motivation

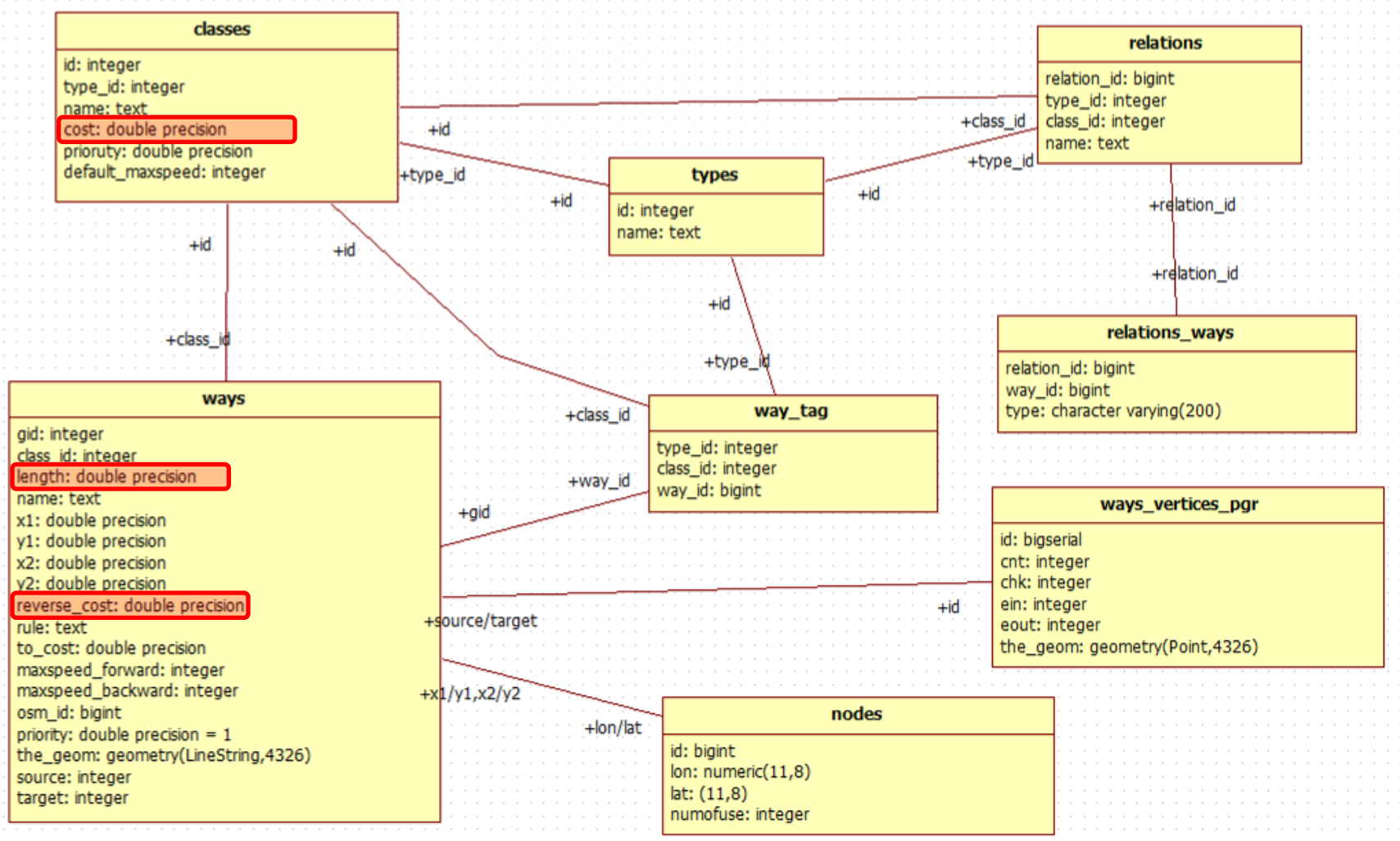
- Research goal:
  - Explore possibilities for the transition from FM/AVL system that is not based on RN to a system that is based on RN data (more specifically - OSM RN data)
- Research activities:
  - Assessment of **OSM RN data**
    - Which models are suitable for FM/AVL systems
    - Assessment of OSM RN data quality
  - **Redesign of existing FM/AVL system** to facilitate usage of OSM RN data
    - Concept (data modelling, data processing, data update)
    - Implementation (integration of FM/AVL system and OSM RN data production system)
    - Testing and evaluation of the proposed solution
    - Evaluation of FM/AVL routing services
      - Online services (Google/OSM)
      - Local data processing (OSM data)

2. OSM Road Network Data

2. OSM Road Network Data – Data Models

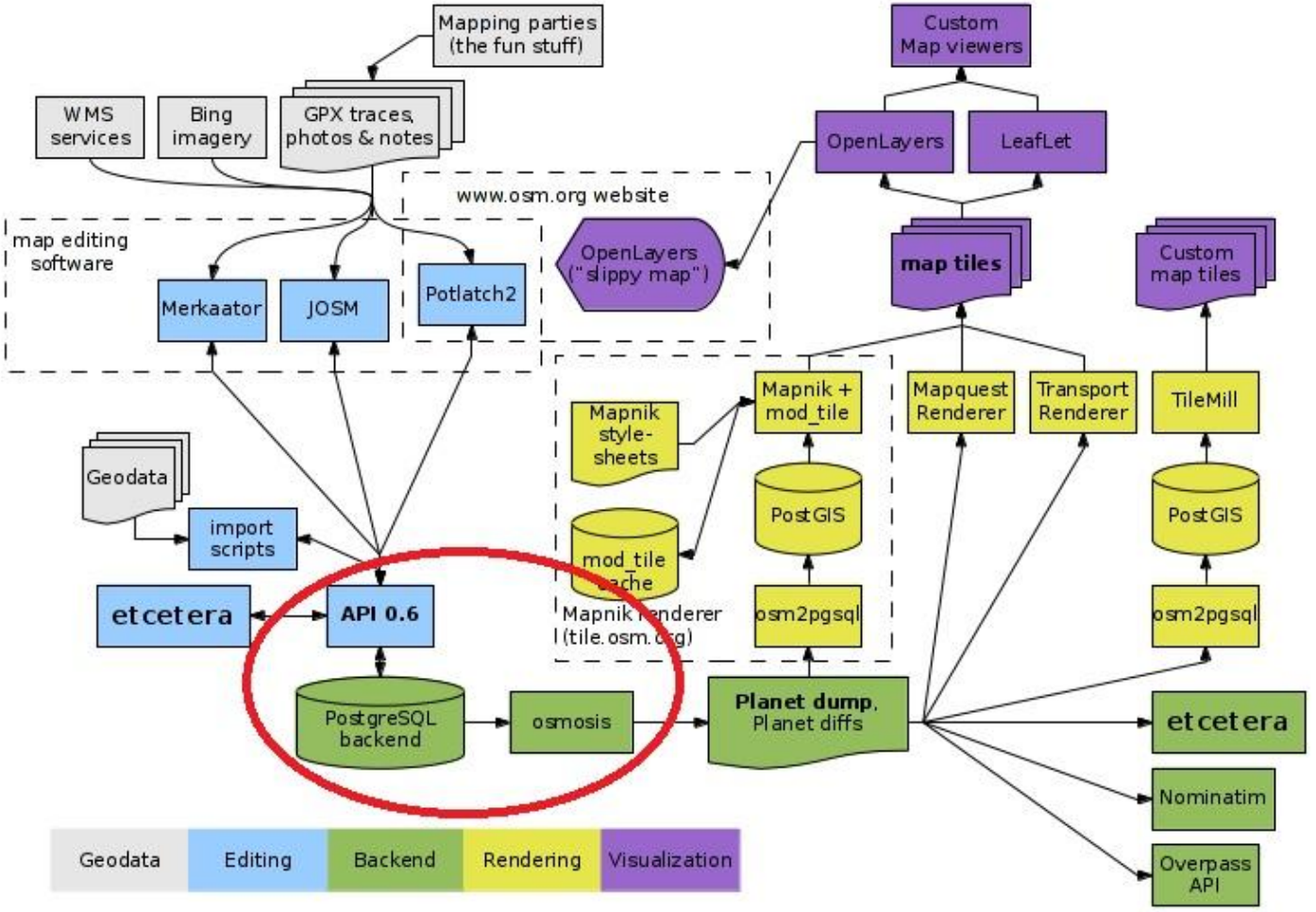
- The easiest way of using OSM RN data for moving object modelling and routing is to import the data into PostgreSQL/PostGIS database
- Models for moving objects have to
  - support **object identification**
  - facilitate **data versioning**
  - support to **routing**
- Applications that are most frequently used are the following:
  - *osm2pgrouting, osm2po, osm2pgsql, osmosis*
- Models can be classified into following groups (depending on what kind of data models these applications build):
  - Models appropriate for **routing** (*osm2pgrouting* and *osm2po*)
  - Models appropriate for OSM **map display** (*osm2pgsql*)
  - Models appropriate for OSM **data update** (*osmosis*)

2. OSM Road Network Data – Data Models



Model appropriate **for routing** - pgRouting data model (*osm2pgrouting*)

2. OSM Road Network Data – Data Models



Osmosis model appropriate for **data update** - systems for data production and data utilization

2. OSM Road Network Data – Data Quality

Aspect	Modelling	Routing
Lineage	1 - Less important aspect.	1 - Less important aspect.
Positional accuracy	5 - Very important aspect.	3 - Medium important aspect. It is good if positional accuracy is high, but topological consistency is more important than positional accuracy.
Attribute accuracy	3 - Important aspect. It is good if attributes are accurate, but it is not vital for the proposed model.	4 - Very important aspect, especially for the routing which takes into consideration various types restrictions.
Logical consistency	3 - Important aspect. It is good if attributes are logically consistent, but it is not vital for the proposed model.	5 - Very important aspect.
Completeness	5 - Very important aspect.	5 - Very important aspect.
Semantic accuracy	3 - Important aspect. It is good if semantic accuracy is high, but it is not vital for the proposed model.	4 - Very important aspect, especially for the routing which takes into consideration various types restrictions.
Usage, purpose and constraints	3 - Important aspect.	4 - Very important aspect, especially for the routing which takes into consideration various types restrictions.
Temporal quality	5 - Very important aspect.	5 - Very important aspect.

Data quality elements and their relevance for modelling of moving objects and for routing applications

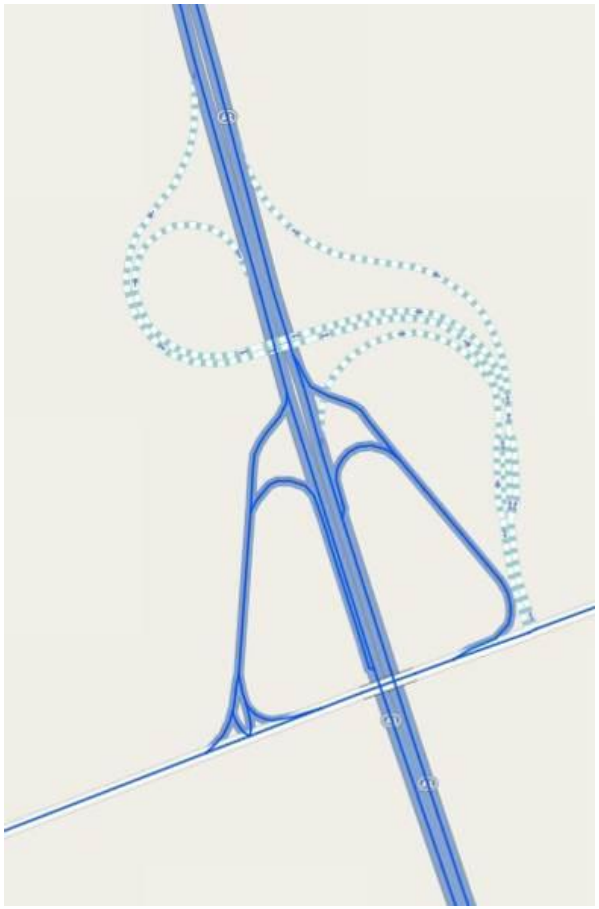
2. OSM Road Network Data – Data Quality

- Studies revealed the following (Haklay, 2010; Girres and Touya, 2010; Neis et al. 2012, Corcoran et al. ,2013) :
  - There is a huge quantity of OSM data on a global level
  - Quality of OSM data is highly heterogeneous
  - For many application scenarios OSM data have immense value and they are highly useful
  - For moving objects application scenarios (especially if they are based on road network) demands are quite high
  - OSM data quality (for modelling moving objects movement and for routing) is varying to a great extent for different regions in the world and in many regions the data are almost useless

2. OSM Road Network Data – Data Quality

Google

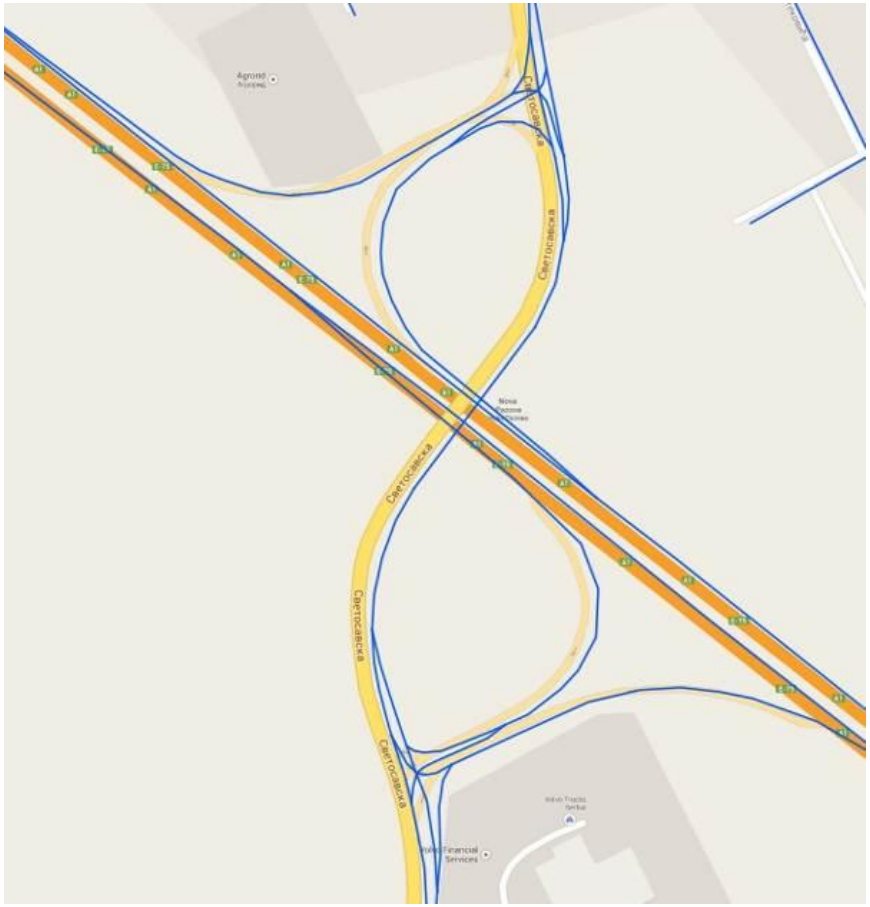
Bing



OSM

Up-to-dateness - Highway example

2. OSM Road Network Data – Data Quality



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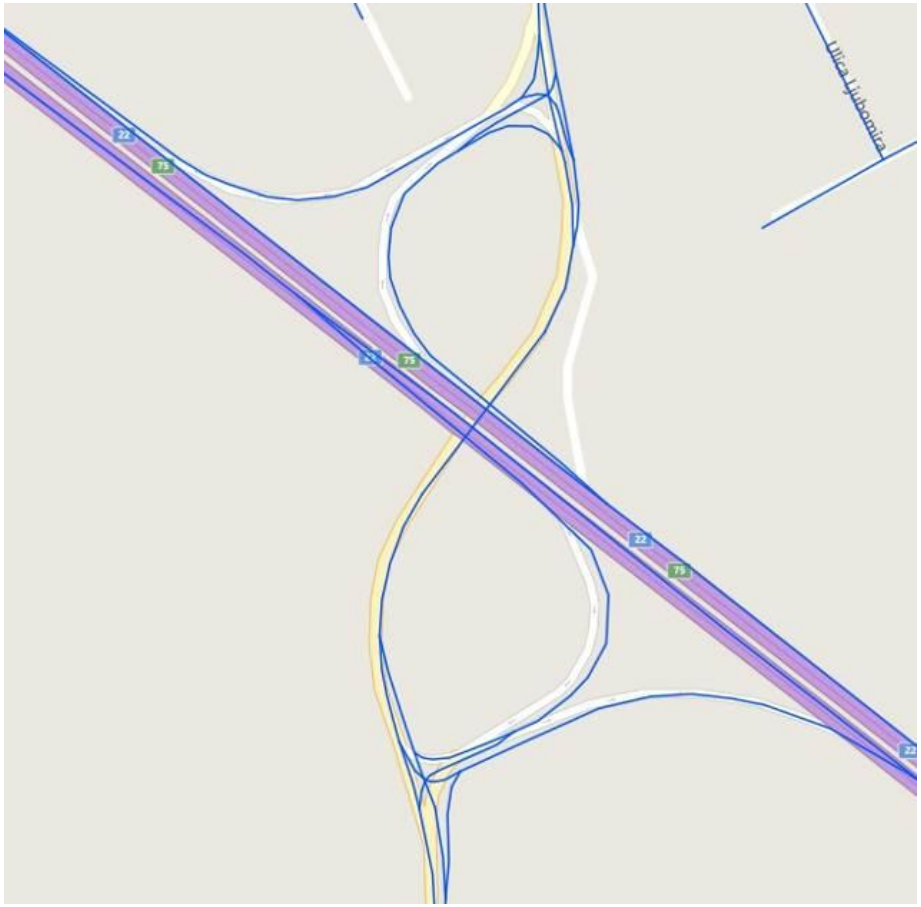

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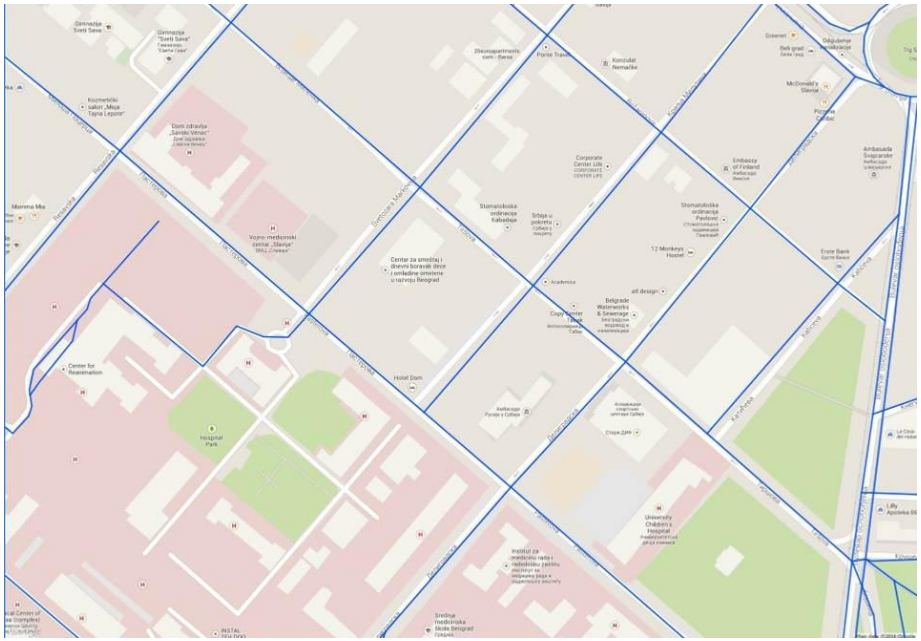
Positional accuracy - Highway example

2. OSM Road Network Data – Data Quality



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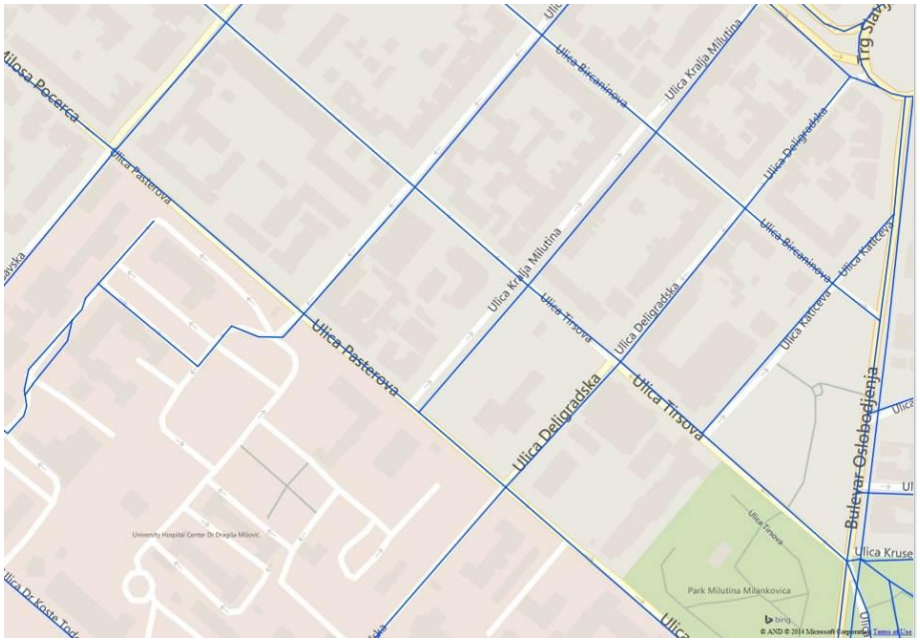

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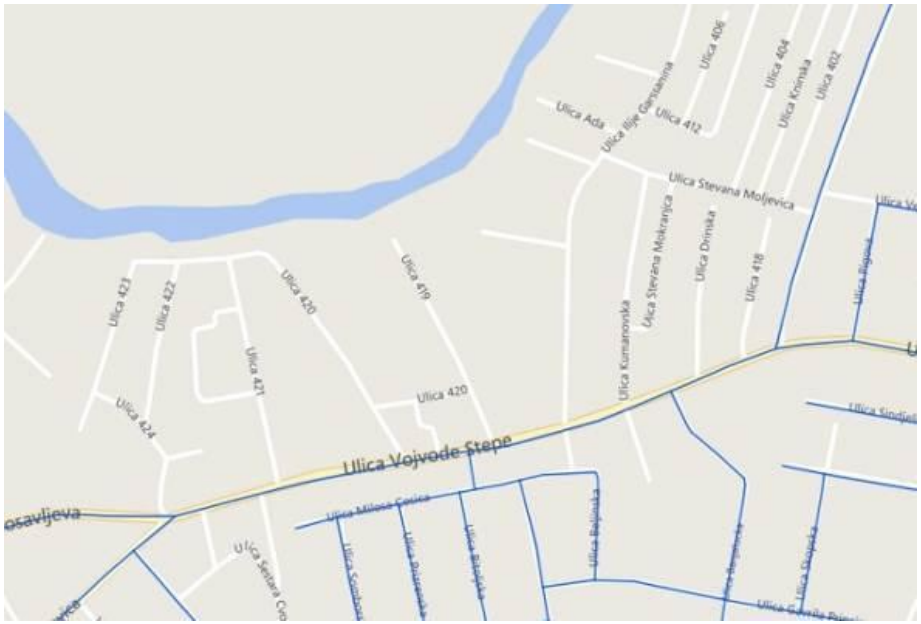
Completeness – Example for large city (Belgrade)

2. OSM Road Network Data – Data Quality

Google



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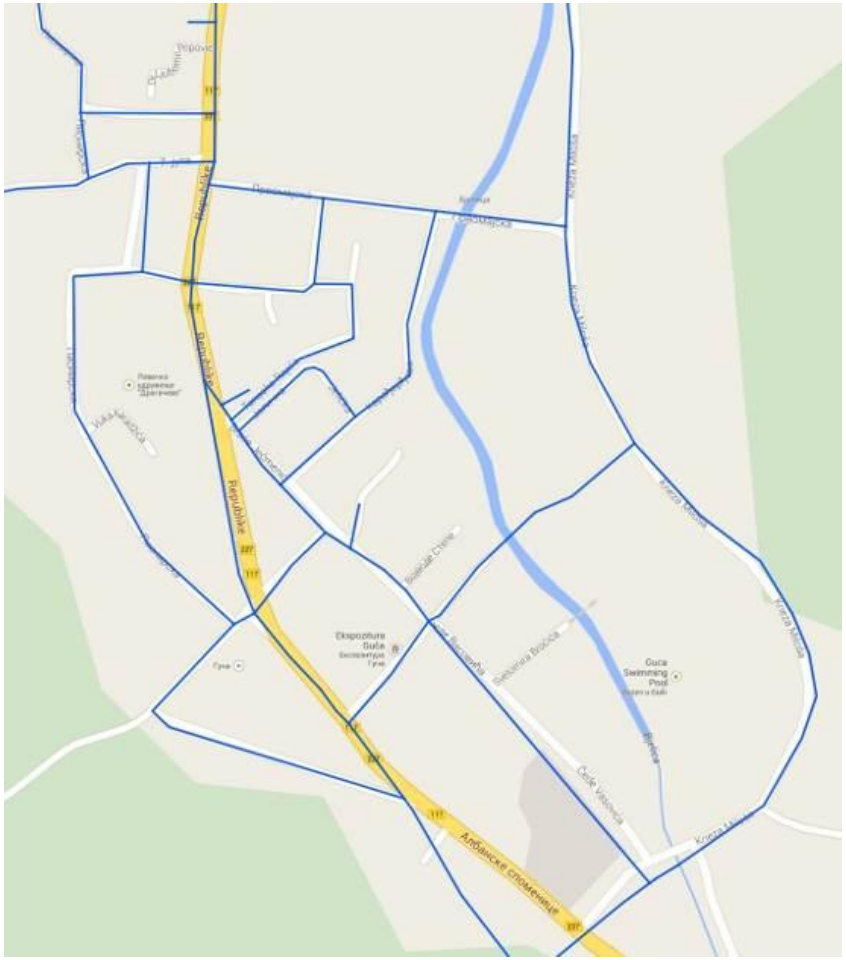
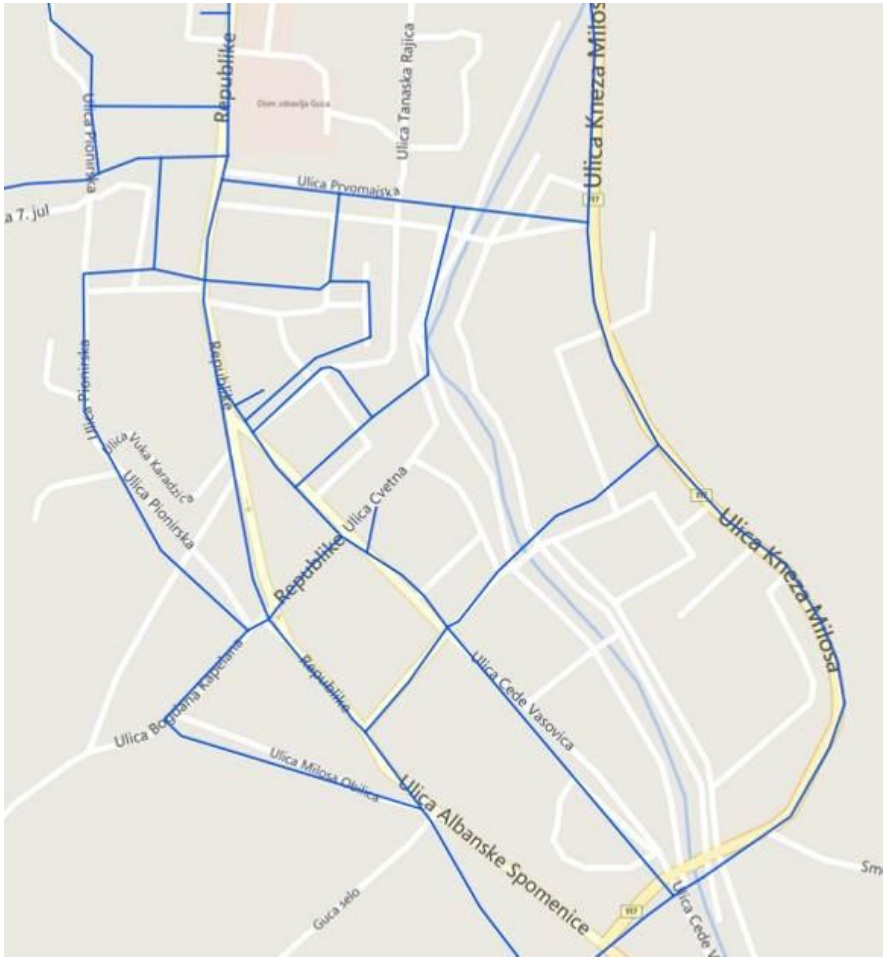
Completeness – Example for middle-size city (Cacak)

2. OSM Road Network Data – Data Quality



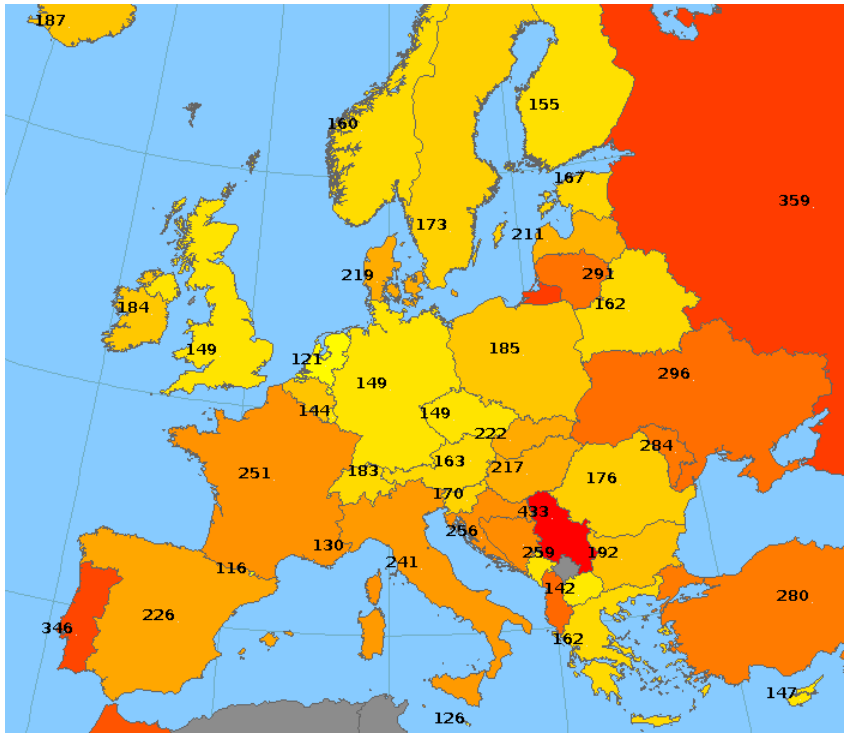
Google



Bing

Completeness – Example for small settlements

2. OSM Road Network Data – Data Quality



Changes for the road network for the period 2009-2012 (OpenStreetMap Forum)

	Serbia	Hamburg	Luxemburg	Slovenia
current_nodes	4255	531.6	413	3333
current_relations	0.4	2.6	0.4	2.6
current_ways	331.8	114.8	66.6	204.2

Average number of elements added to OSM data every day for different territories

3. FM/AVL Based on OSM RN Data

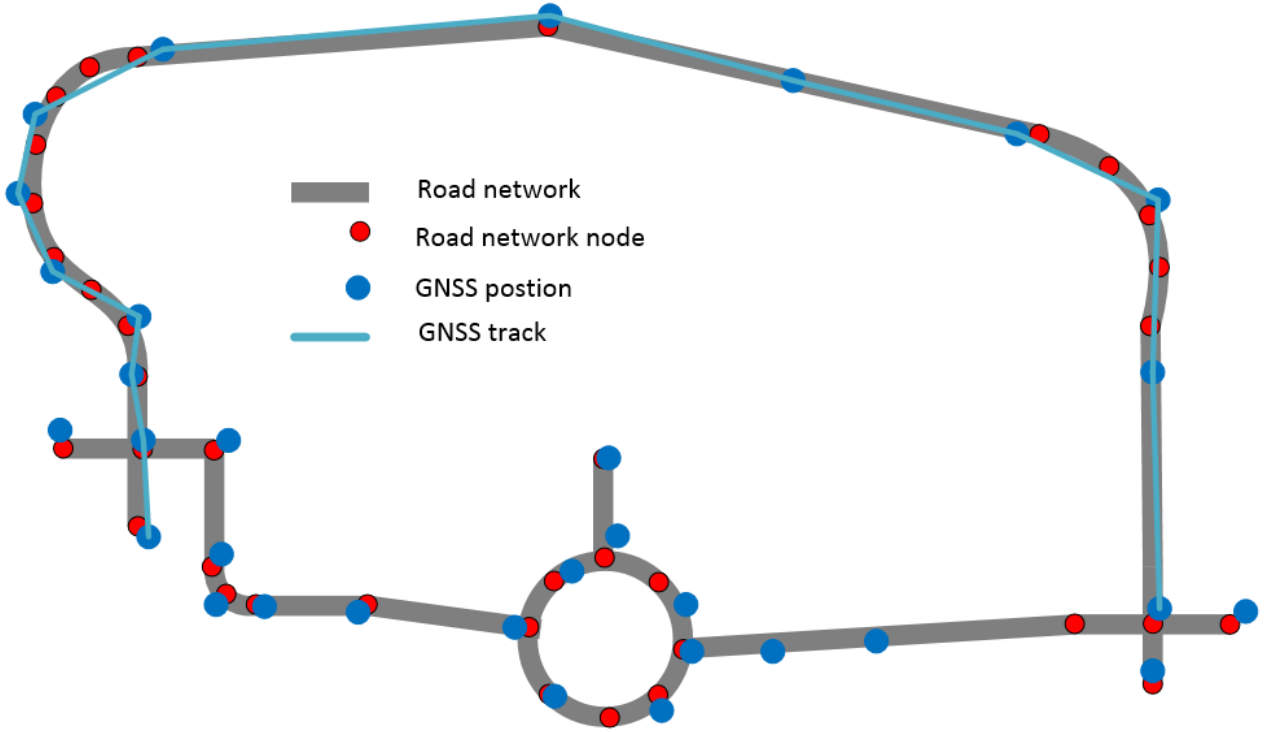
3. FM/AVL Based on OSM RN Data – Concept

Model	Advantage	Disadvantage
Raw data	The ***simplest*** model. The ***easiest*** for the implementation. The smallest amount of information is stored. ***Fast queries*** providing data/results that can have official status.	Either ***more spatial information is stored*** due to expected geometry queries than needed ***or spatial queries are too costly*** (in terms of time) because some additional on-the-fly calculations have to be made. Limitations and much ***lower performances for spatial queries based on road network and routing*** (it this functionality is provided by using external services).
Moving objects move freely in space ***MOFS***	***Simpler*** model. ***Easier*** for the implementation. ***Fast queries*** providing data/results that can have official status.	Much ***more spatial information is stored***. Limitations and much ***lower performances for spatial queries based on road network and routing***.
Moving objects move on road network (RN) ***MORN***	Enables ***fast spatial queries***. Enables fast and powerful queries based on road network data model. ***Enables routing***.	The ***most complicated data model***. The most complicated for the implementation. ***Requires*** availability of additional resources – ***road network data***. Much ***lower performances for spatial queries*** related to the original data providing ***results that are officially valid***.

Models for moving objects

3. FM/AVL Based on OSM RN Data – Concept

- Starting assumptions: matching between moving object path and road network segments



Registration of vehicle positions in respect to the road network in a typical FM AVL scenario

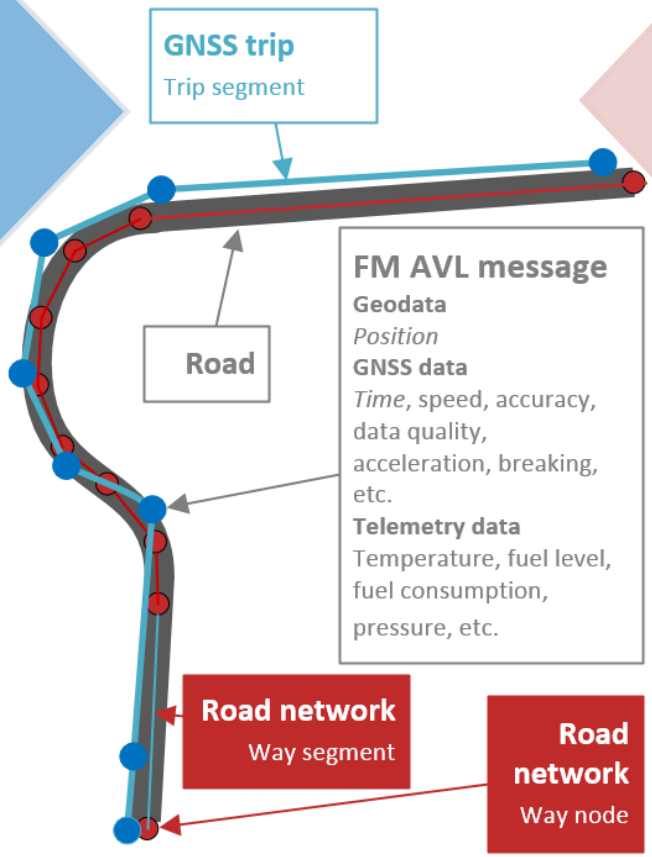
Region	Hamburg	Luxemburg	Slovenia	Serbia
Average road network segments [m]	58	120	172	257

3. FM/AVL Based on OSM RN Data – Concept

❖ Starting assumptions: matching between moving object path and road network segments

FM AVL devices programmed to collect data according to the following principles

- Travel distance: 200 - 500m
- Travel time : 30 sec
- Direction angle: 20-30 degrees



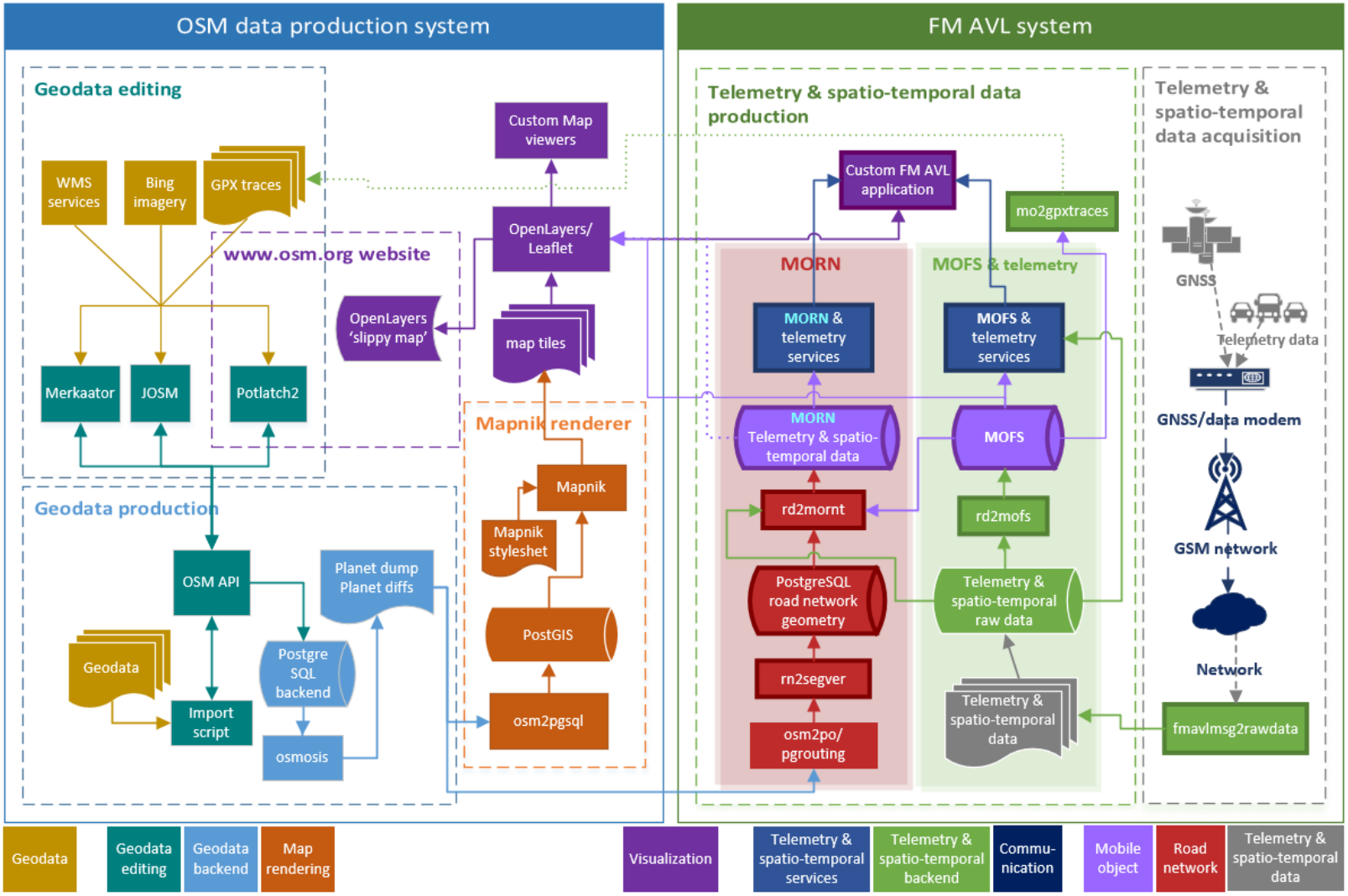
- Road segment : ~180 m
- Travel time : 15 sec
- Direction angle: ~20 degrees

Road network

Conclusion:

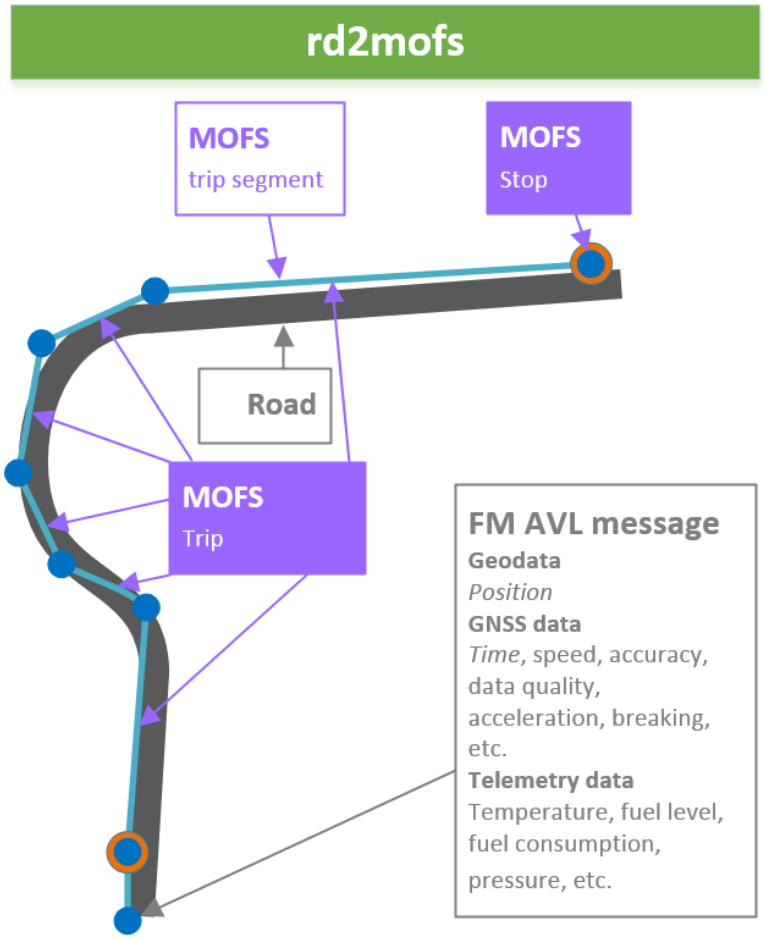
road network path and the vehicle movement path **closely match each other**

3. FM/AVL Based on OSM RN Data – Concept



FM AVL system architecture and its relationship with the system for the production of OSM data and maps

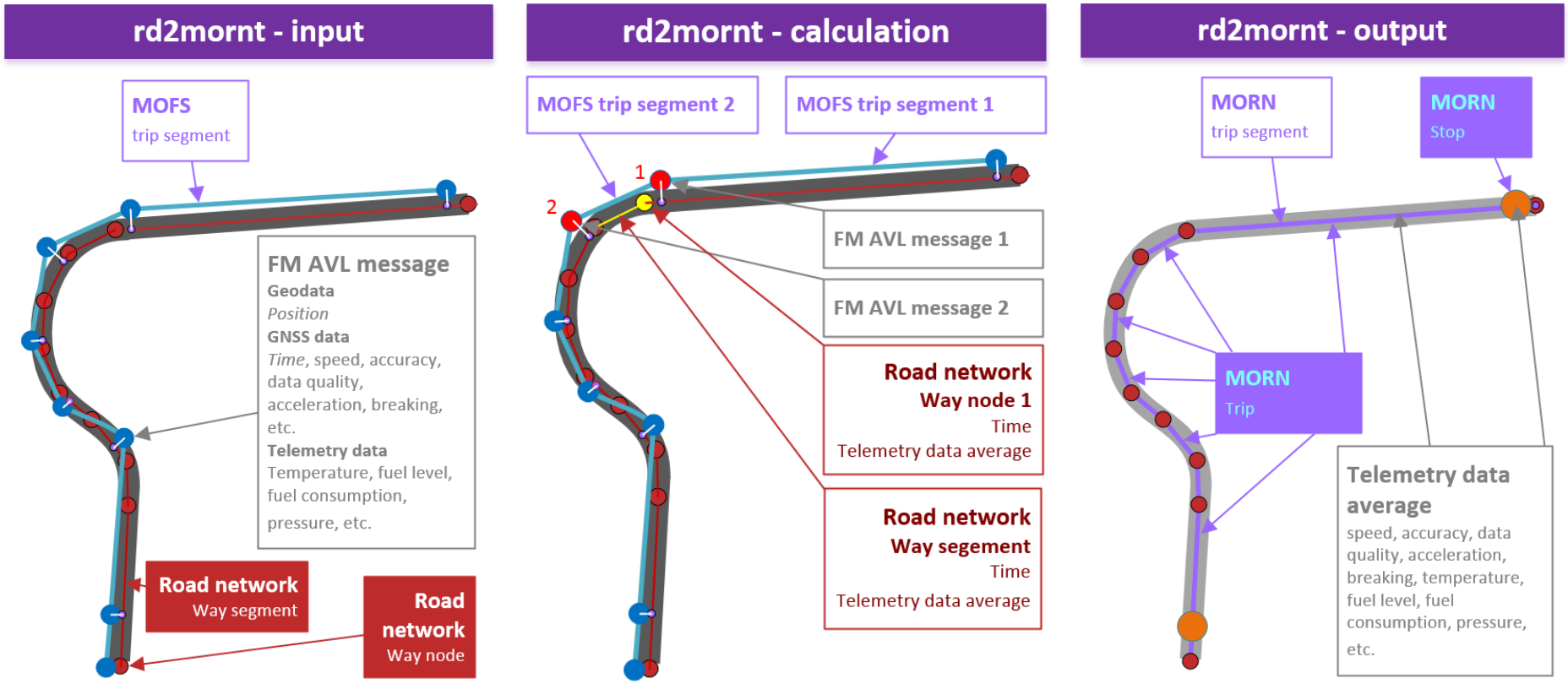
3. FM/AVL Based on OSM RN Data – Concept



Process ***rd2mofs***

raw data → **moving objects' geometries** (objects move freely in space - MOFS)

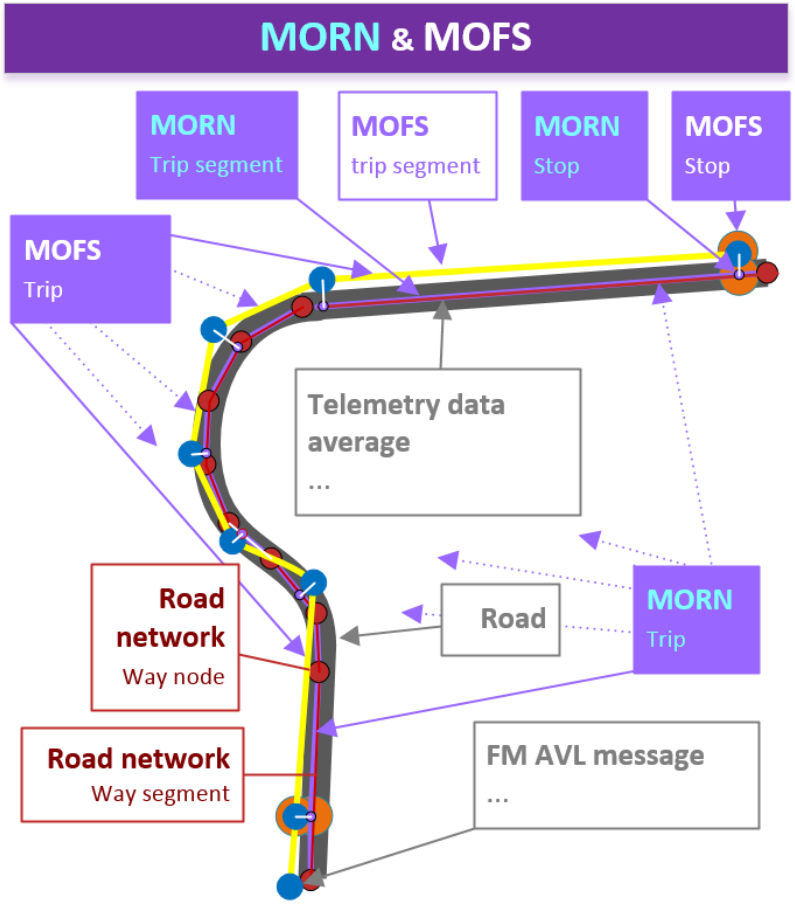
3. FM/AVL Based on OSM RN Data – Concept



Process ***rd2mornt***

raw data & MOFS → moving objects' road network data (objects movement constrained by network - MORN)

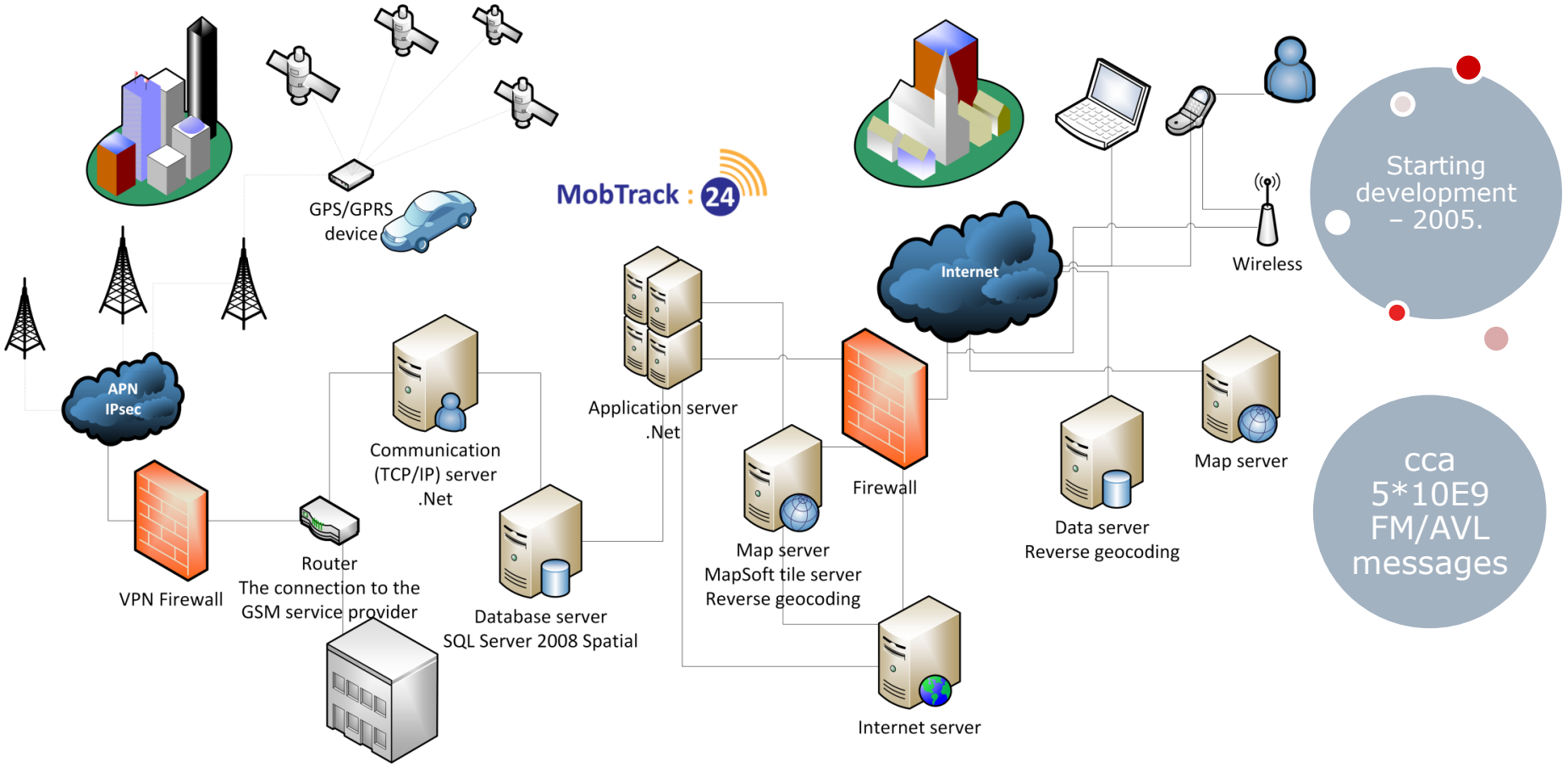
3. FM/AVL Based on OSM RN Data – Concept



Basic elements of the moving objects models MORN and MOFS

3. FM/AVL Based on OSM RN Data – Implementation

- MobTrack:24 FM/AVL system

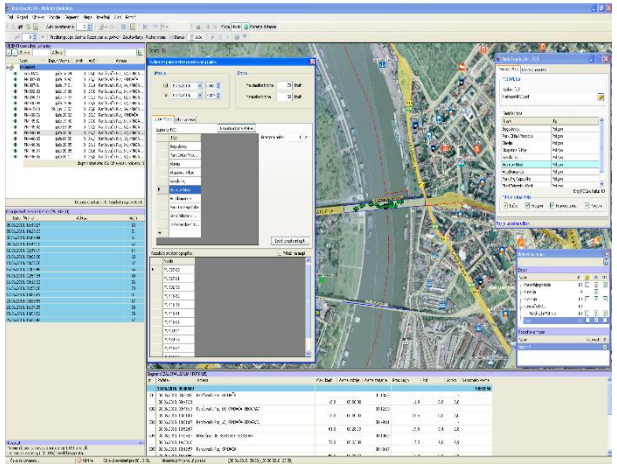


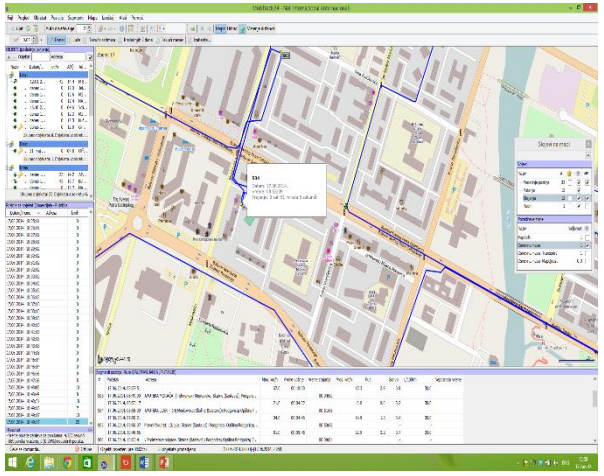
MobTrack:24 system architecture

3. FM/AVL Based on OSM RN Data – Implementation

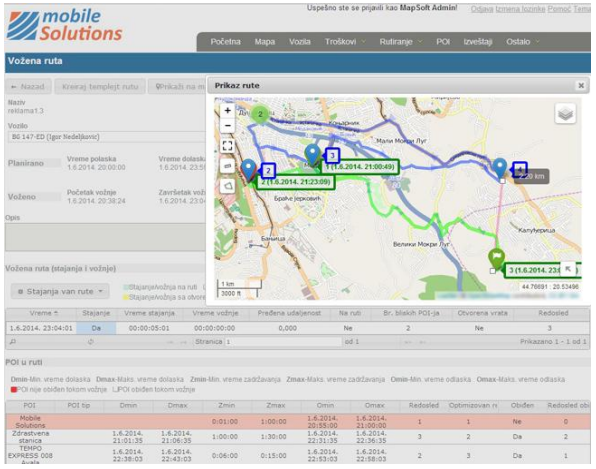
- MobTrack:24 FM/AVL system

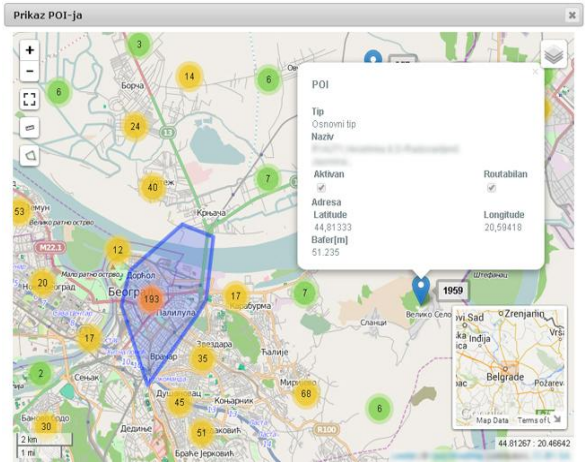
Desktop



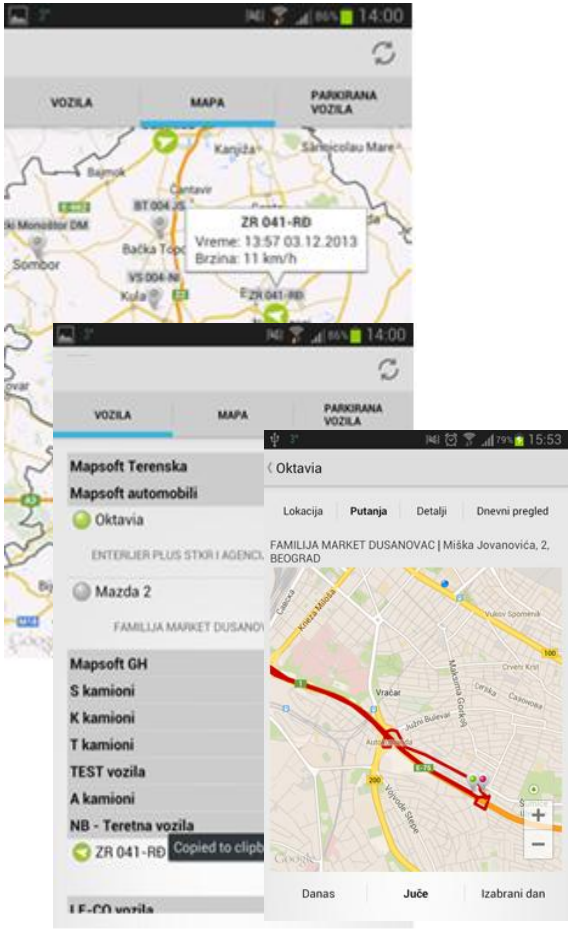


Web

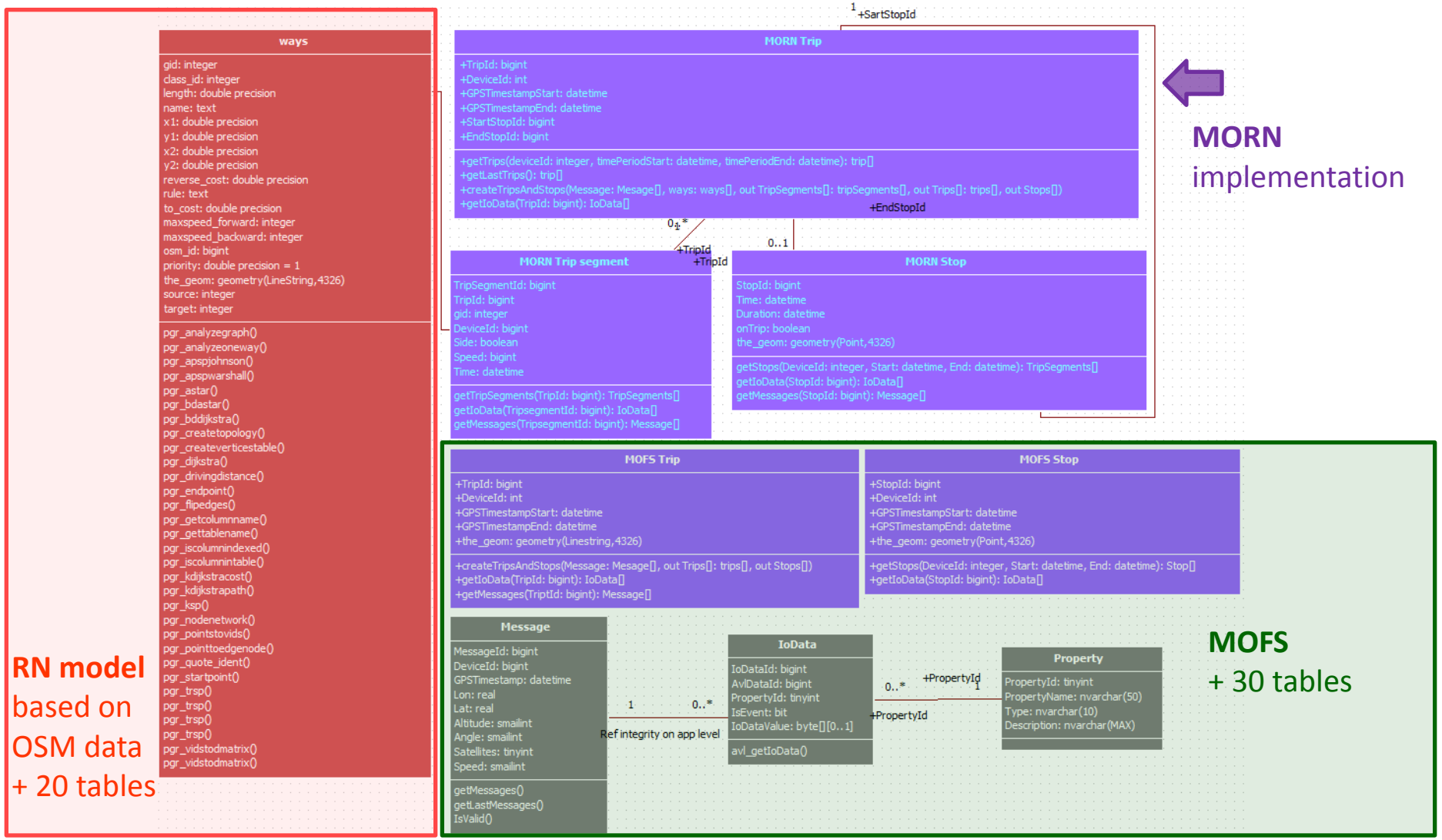




Mobile

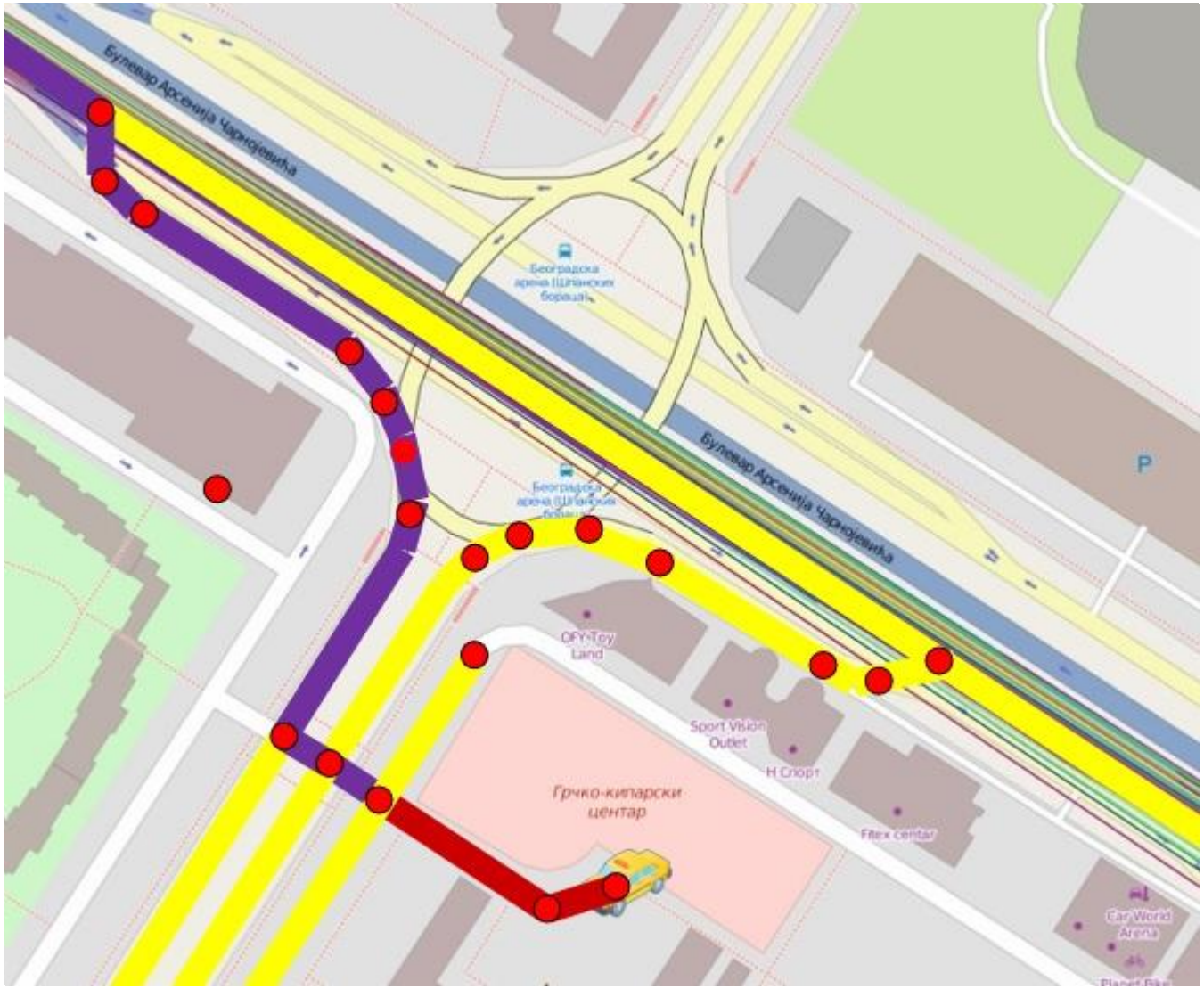


3. FM/AVL Based on OSM RN Data – Implementation



The MORN model obtained by extending existing MOFS model by using concepts proposed in this paper

3. FM/AVL Based on OSM RN Data – Implementation



Vehicle is located in a region without high quality road network - existing MOFS model has to be used

4. Conclusions

4. Conclusions

- For efficient use of OSM RN data to MORN data models open-source libraries (*osmosis, pgRouting* can be used, but **additional procedures have to be developed**
- **FM/AVL moving objects path** geometries roughly **correspond to road network geometry** - **OSM ways/segments can be used as spatial reference for modelling** and storing data generating by FM/AVL devices – proposed model is based on this assumption
- Implementation of the proposed model is done within a commercial FM/AVL system
  - Existing MOFS model **can be extended and modified** according to proposed principles to implement the proposed MORN model – god way of migration for existing FM/AVL systems
  - First experiences indicates that **system which is based on MORN**, due to the **insufficient quality of the data**, in FM/AVL scenario **cannot be used as the proper solution** for the model of moving objects movement, **at least for the time being** so **back-up option has to be provided** (when vehicle is located in a region without high quality road network - existing MOFS model has to be used).
  - **Data (GPS track)** from MOFS collected within FM/AVL **can be used for update of OSM data**
- There is a trend in OSM data quality improvement - moving objects movement **models based on OSM road network are likely to be used in near future**.

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