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RoutesMobilityModel: Easy Realistic Mobility Simulation using External Information Services

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Outline

- Mobility models for ns-3
  - ns3::RandomWaypointMobilityModel
  - SUMO
- Using external information services
  - Google Maps API
- ns3::RoutesMobilityModel
  - Features
  - Results
  - Internals
  - Limitations
- Future (current) work

Mobility Models for ns-3

- Simulation of mobile communication makes use of mobility models
- ns-3 possesses several synthetic mobility models implemented, such as:
  - Random Waypoint Mobility Model
  - Random Walk 2D
  - Gauss-Markov Mobility Model
- Another approach is coupling ns-3 with a traffic simulator, such as
  - Simulation of Urban MObility (SUMO)
  - Multi-agent Microscopic Traffic Simulator (MMTS)

ns3::RandomWaypointMobilityModel

- This module picks for each node a destination and velocity at random. When the node reaches the destination, it pauses for a specified amount of time and restarts the process.

- Easy to configure:
  - Only parameters: area where to place the nodes, speed range, pause time

- Disadvantages
  - Not much realism (constant speed, random positions, random destinations, does not consider the underlying road network)

SUMO

- SUMO is a microscopic vehicular traffic simulator
- Provides lots of interesting features
  - Can model vehicles, pedestrians and public transport
  - Can import maps, or generate custom road networks
  - Can model car following models and inner junction traffic
  - Gas emissions, traffic light frequency, etc
- Disadvantages
  - Steep learning curve
  - Can potentially take long time to configure since many details can/have to be specified
  - The user documentation consists mainly on its wiki
  - The SUMO architecture consists on a number of small programs that comprise the SUMO suite
    - Need to know, and possibly configure and run each tool to maximize realism

Using an external Information Service

- Synthetic mobility models in ns-3 are relatively simple and straightforward to use
  - However, they suffer from a low degree of realism.
- Full-fledged traffic simulators such as SUMO are more realistic
  - Time-consuming configuration
  - Easy to misconfigure / need expertise in vehicular traffic simulation
- We propose to distill data from travel planning services into mobility directives
  - We built a prototype that makes use of Google Maps API

Why Google Maps API?

- The Google Maps Web Services are one of the main core products of Google and provide geographic data for applications
  - Good support to developers
  - Feature rich

- We propose to use two APIs in particular:
  - Directions API
    - This API retrieves direction information between two locations
  - Places API
    - This API retrieves real world places (restaurants, hospitals, etc) around a given real world location

ns3::RoutesMobilityModel

- What it is
  - An interface to request directions between two (or more) points from external services, and parse them into a ns-3 mobility
  - A trade off between complex traffic simulations and easy (unrealistic) synthetic mobility trace generators
- What it isn't
  - A full-fledged traffic simulator for ns-3

- Currently, implemented for Google Maps only
- Can function online (contacting external service) or offline (importing travel plans from filesystem)
- Allows to select transportation method (driving, walking, cycling and public transportation)
- Allows to specify a departure time
  - Especially important when modeling public transportation

Visual comparison

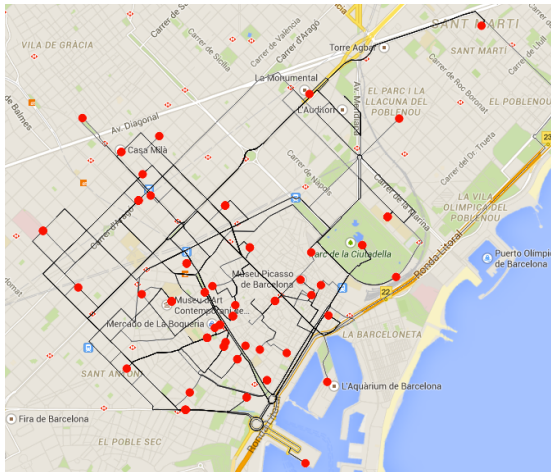


Figure 1 – RoutesMobilityModel

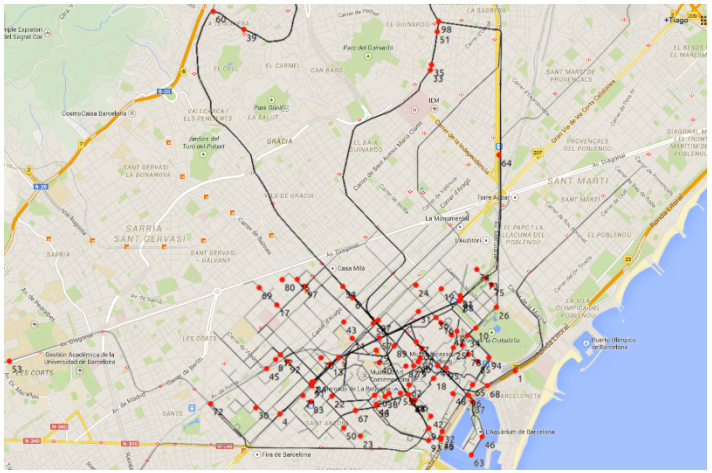


Figure 2 – SUMO

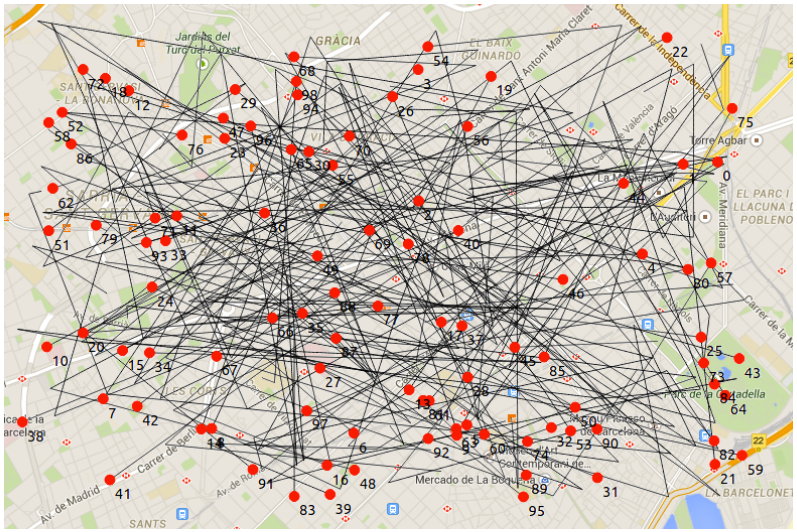


Figure 3 – RandomWaypointMobilityModel

Configuration complexity comparison

```
MobilityHelper mobility;
//Assign initial random positions
ObjectFactory pos;
int64_t streamIndex = 0;
pos.SetTypeId ("ns3::RandomBoxPositionAllocator");
pos.Set ("X", StringValue ("ns3::UniformRandomVariable[Min=0.0|Max=4600.0]"));
pos.Set ("Y", StringValue ("ns3::UniformRandomVariable[Min=0.0|Max=3000.0]"));
pos.Set ("Z", StringValue ("ns3::UniformRandomVariable[Min=1.0|Max=2.0]"));

Ptr<PositionAllocator> pAlloc = pos.Create ()->GetObject<PositionAllocator> ();
streamIndex += pAlloc->AssignStreams (streamIndex);
//Configure the speed and the pause time
std::stringstream ssSpeed;
ssSpeed << "ns3::UniformRandomVariable[Min=0.0|Max=" << 11.2 << "]";
std::stringstream ssPause;
ssPause << "ns3::ConstantRandomVariable[Constant=" << 5 << "]";
mobility.SetMobilityModel ("ns3::RandomWaypointMobilityModel",
                           "Speed", StringValue (ssSpeed.str ()),
                           "Pause", StringValue (ssPause.str ()),
                           "PositionAllocator", PointerValue (pAlloc));
mobility.SetPositionAllocator (pAlloc);
//Install the mobility to the nodes
mobility.Install (nodes);
streamIndex += mobility.AssignStreams (nodes, streamIndex);
```

Figure 4 – ns3::RandomWaypointMobilityModel configuration

```
MobilityHelper mobility;

mobility.SetMobilityModel ("ns3::WaypointMobilityModel");

mobility.Install(nodes);

RoutesMobilityHelper routes (41.306717, 2.119782,0);

routes.ChooseRoute(nodes,41.385329, 2.179434,2000);
```

Figure 5 – ns3::RoutesMobilityModel configuration

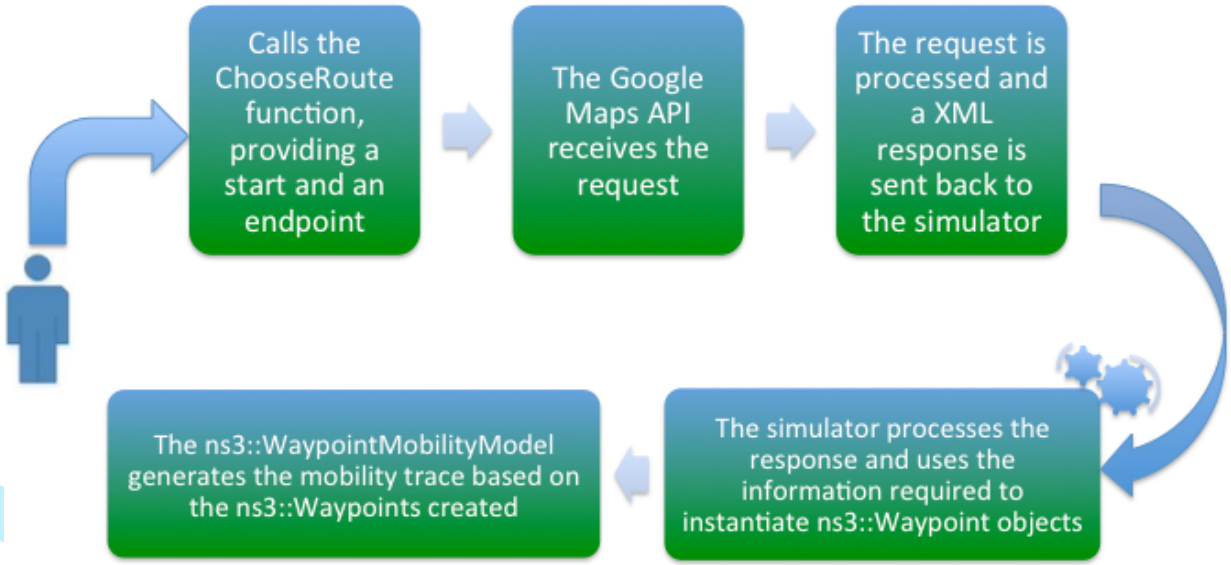
```
Export OSM map
netconvert --osm-files Downtown\ Barcelona.osm -o dwntwnBarcelona-net.xml
polyconvert --net-file dwntwnBarcelona-net.xml --osm-files Downtown\ Barcelona.osm --type-file typemap.xml -o DowntownBarcelona-poly.xml
python /usr/share/sumo/tools/trip/randomTrips.py -n dwntwnBarcelona-net.xml -r barcelona-rand.xml -e 50 –l
sumo -c config.sumo.cfg --fcd-output sumoTraceBarcelona.xml
python ../tools/traceExporter.py --orig-ids --fcd-input sumoTraceBarcelona.xml --ns2mobility-output mobility.tcl

Each line corresponds to an action, which has got its own configuration file
Some of the files (e.g. typemaps.xml, a basic one is 36 lines) MUST be filled up for each scenario
```

Figure 6 – SUMO configuration

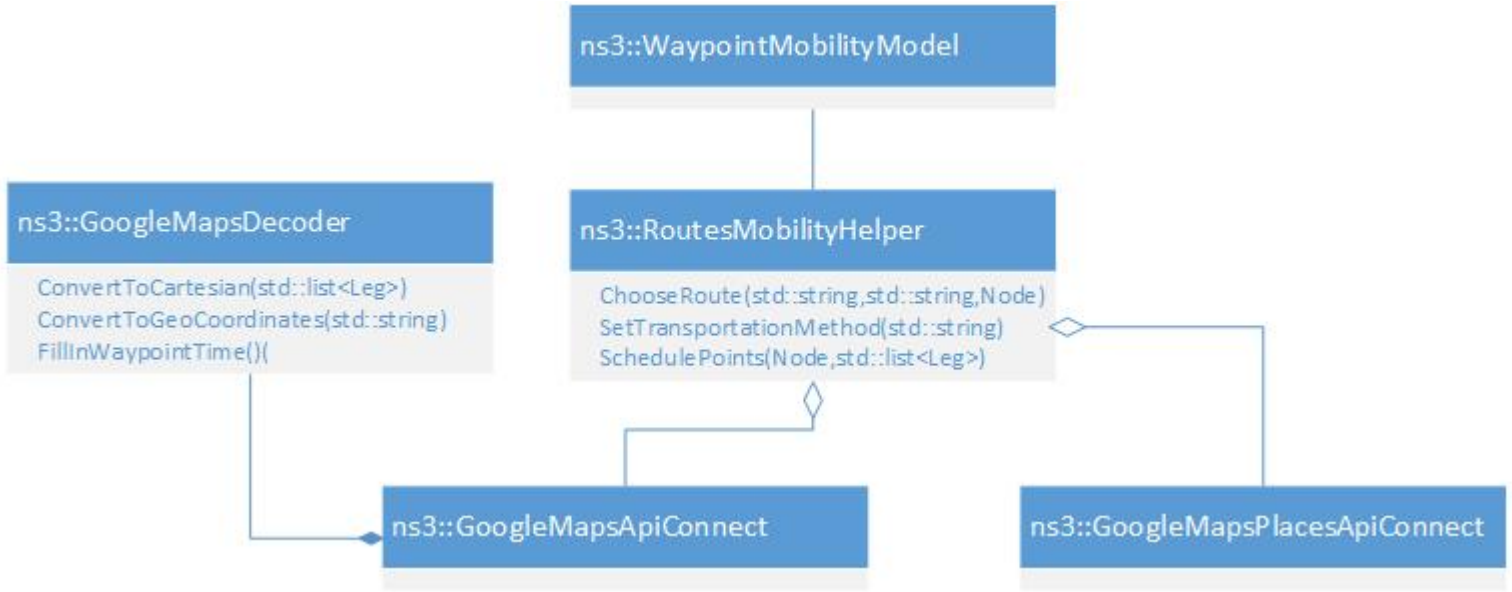
Internals 1/2

- The module was designed to import the routes via ns3::WaypointMobilityModel
  - Our module retrieves Geodetic points provided by Google Maps and converts them to Cartesian points, which can then be added to the WaypointMobilityModel



Internals 2/2

- The design of the module allows to download travel plans from different services, e.g. OSM
  - Module implemented using the Strategy Design Pattern, to adapt to additional external directions services
    - New strategy to access the service and parse the retrieved travel plan
  - Currently only the Google Maps services are being used



Limitations

- Current release of the module can/will be improved:
  - Only possible to generate mobility for node containers up to 30 nodes
    - Due to a limitation of the Places API
  - The module takes a long time to parse XML responses into mobility for large node containers
    - Still much faster than the execution of any non-trivial ns-3 simulation
  - No serialization is implemented
  - No bidirectional coupling with ns-3 is implemented
    - Currently, mobility impacts on what happens ICT-side
    - We want to allow ICT (car's computations) to lead to decision in changing car's routes
  - Traffic information is not available in the free version of the API

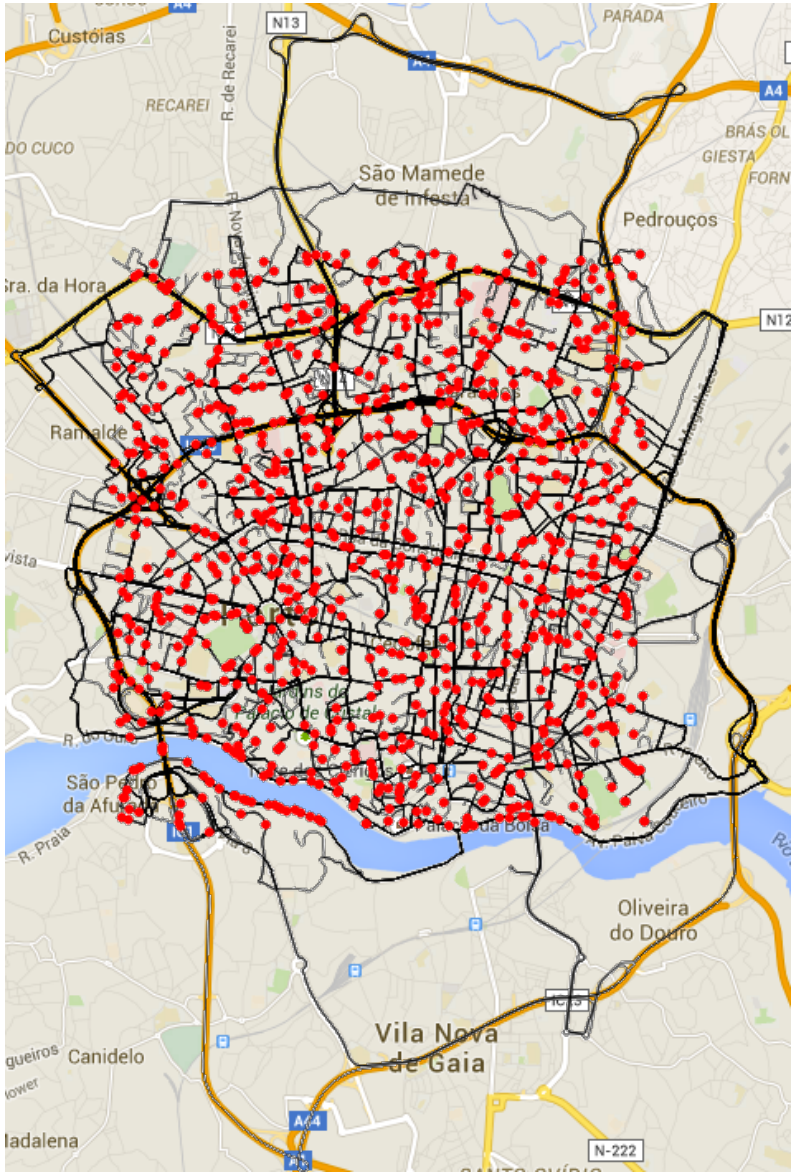
Future/current work

- Removing the 30 node limitation
- Switch from XML to JSON
  - Potential of speeding up the parsing of mobility data
- Implement serialization
  - To allow the user to repeat the simulation using the exact same mobility
- Bidirectional coupling with the simulator
- Thorough evaluation of the module
  - Other metrics
  - Other mobility models

Sneak preview of the next release

- Already available in the repository
  - NOT under review for ns-3 inclusion
  - Will not be included in ns-3's next version
    - Hopefully will be included later on
- The 30 node limitation was removed
  - By combining the 60 places returned by the Places API at random
  - By combining user specified locations at random
  - By randomly choose coordinates in a user specified location
- Serialization
  - In the current release if a user manually downloads a travel plan, the module can already parse it as mobility

Sneak preview of the next release



Thank you for your attention

- Current testing repository
  - https://bitbucket.org/TiagoCerqueira/routesmobilitymodel
- Wiki
  - https://www.nsnam.org/wiki/RoutesMobilityModel
- Code review issue
  - https://codereview.appspot.com/176430044/

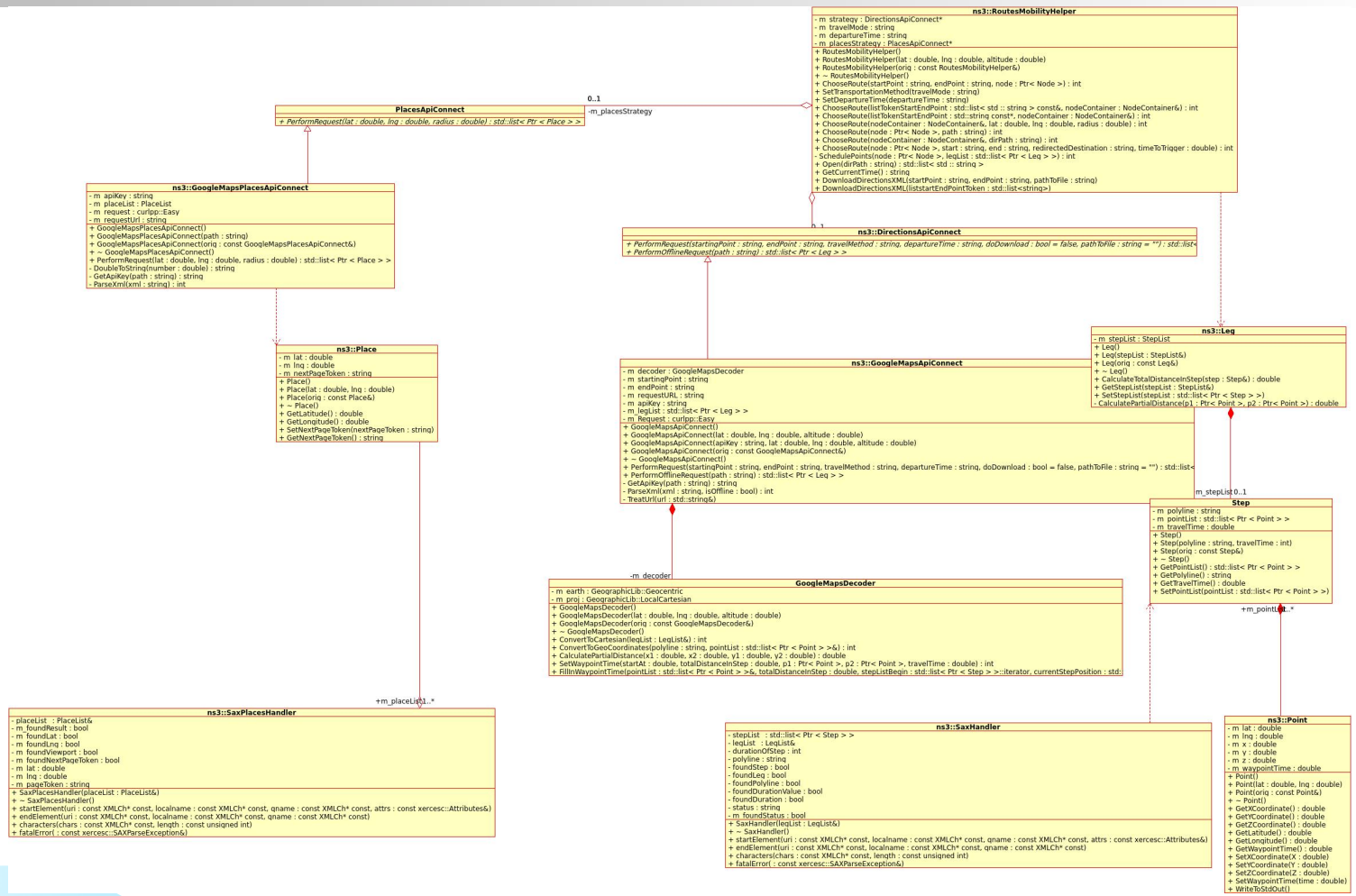
More material

- Both these APIs are free and have usage quotas
  - Directions API
    - 2.500 Directions requests per 24 hour period
    - 2 requests per second
    - No traffic information is available on the free version
  - Places API
    - 1000 requests per 24 hour period, which can be increased to 150 000 requests by verifying the user's identity with a credit card.
    - Unfortunately it's only able to return up to 60 places in any query (despite the fact that there are more locations in that area)

More material

- Caching the API's responses for more than 30 days is a direct violation of the ToS. Because of this, no caching feature was implemented. However, it is possible to load XML responses from the filesystem

More material



MacPhy overhead comparison

- An analysis of the performance of the routing protocol AODV was performed using vanet-routing-compare script, in order to further validate the results
  - Three scenarios where tested:
    - A scenario using the ns3::RoutesMobilityModel on Downtown Barcelona
    - A scenario using SUMO on Downtown Barcelona
    - A scenario using the ns3::RandomWaypointMobilityModel using the same area as the area in the scenarios using SUMO and the RoutesMobilityModel.
- The simulations where ran using 99 nodes, for 300 simulated seconds. The vehicles randomly chose the route to take.