# Semantic Enrichment of Routing Engines using Linked Data: A Case Study Using GraphHopper

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**Abstract**

Traveling is a basic part of our daily life and has challenges in terms of route planning and incorporating traveller's interest. When routing in a new neighbourhood a guiding system is required that suggests an optimal route according to traveller's interests i.e. answering semantic queries. Semantic web provides linked data as a source of semantic enrichment. This work serves as a proof of concept for how linked data can be used for semantic enrichment of vehicle routing networks and proposes a prototype routing framework and application. It is designed using open source technologies and supported with use cases where semantic routing queries are addressed.
*Keywords*: open source, vehicle routing, linked data, semantic enrichment, semantic web, GIS

## 1 Introduction

Travel route planning is a basic part of our daily life. It may be easy for any person in the local neighbourhood, however in a new neighbourhood and increasing number of options e.g. restaurants to visit, it can be challenging and time consuming (Gu et al. 2018), a guiding system is required that suggests an optimal route according to traveller's interests. Incorporation of traveller's interest requires a data set which can be used to add semantics to geometric routing graphs and hence answer semantic queries. Adding this information to a spatial dataset leads us to semantic enrichment (Janowicz et al. 2012) (Karastoyanova et al. 2007). GeoSpatial semantics is built upon the combination of GIS, Spatial Databases, Artificial Intelligence, cognitive science and the Semantic Web (Janowicz et al. 2012). Semantic enrichment can be also be done by statically binding the information of Points of Interest (PoIs) to respective edges (Fileto et al. 2015) based on proximity, however this results in a static relationship between POI and routing network, where the reflection of updated relations becomes very difficult. Data collection, standardization and enrichment e.g. through surveys can be very time consuming. Semantic enrichment can now be done through linked data. (Heath and Bizer 2011) describes linked data as publishing paradigm in which not only documents, but also data, can be a first class citizen of the Web, thereby enabling the extension of the Web with a global data space based on open standards - the Web of Data.

It's a study based on Islamabad and Rawalpindi cities of Pakistan and addresses to the following research objectives:
1. Semantic enrichment of routing network using linked data.
2. Answering semantic queries.
3. Packaging a prototype routing application.

## 2 Semantic enrichment and application design

A solution based on open-source technologies is implemented. It uses the existing routing network and answer semantic queries through a mechanism of semantic enrichment. For the purpose of semantic enrichment linked data has been used and routing scenarios including waypoints and greener route comparison are presented. Figure 1 shows the solution architecture.

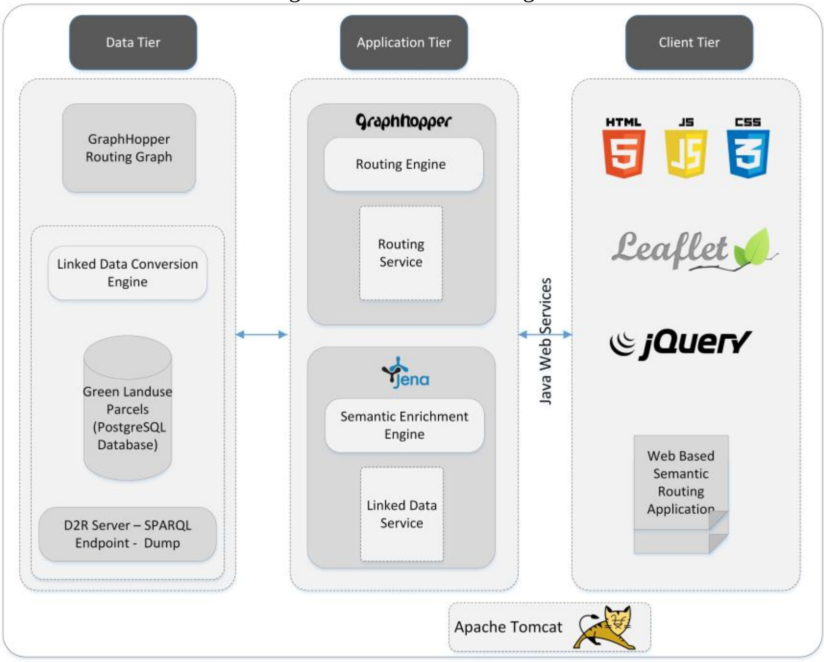
### 2.1 Data

The datasets used comprise of following:
1. Routing dataset: this dataset was provided by a local vehicle routing services provider – TPLMaps (Pvt.) Ltd.
2. Green land use dataset: green land use polygons were obtained from OpenStreetMap (OSM) and further digitized in QGIS using satellite imagery and then exported to the linked data format using D2R server.
3. LinkedGeoData: It uses OSM data, formatting it as RDF; an initiative to add spatial dimension to Semantic Web.

### 2.2 Waypoint Routing Scenario

In the waypoint routing scenario user specifies the origin and destination point of journey. The next input is to specify the route weighting i.e. the shortest, fastest or short_fastest route is required. Now user needs to select the waypoints category e.g. hotel and whether the places to be visited should be within the search buffer and closest to origin/destination or within the route buffer of the shortest/fastest route. If the user selects the origin/destination criteria, then a buffer of user specified distance is applied on the origin/destination point and linked data is queried to find the available PoIs. Similarly for the route buffer option, buffer is applied on the initial route geometry and available linked data PoIs are displayed to user for selection. Linked data query is executed using Jena Arq. The obtained linked data PoIs are passed to the GraphHopper routing engine as intermediate points and the result is displayed to user on map.

Figure 1: Architecture Diagram




## 2.3 Greener Route Comparison

The RDF green land use data was generated using PostgreSQL to RDF mapping file generated using D2R server. It is loaded in Apache Jena framework, where it is indexed using the Lucene indexing so that it can be queried effectively.

Application computes shortest, fastest and short_fastest routes for the origin and destination provided. Once the routes are obtained, route envelopes are calculated and passed to the spatial query that queries all the green parcels within that envelope. Now a buffer is applied on the green polygons to replicate the effect of green areas on surroundings and intersection is computed for the routes.

# 3 Results

This section shows a step by step usage of the routing application and results of semantic queries. Figure 2 shows initial layout of the routing application where user can specify routing criteria. The origin and destination points are also marked.

Figure 2: Front end of semantic routing application

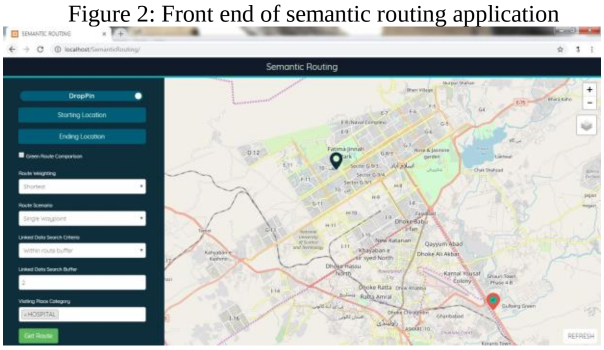



Figure 3 shows waypoint options form for the route buffer criteria to user with route summary, so that the user can choose the waypoint, display on map and travel accordingly.

Figure 3: Displaying routing waypoints

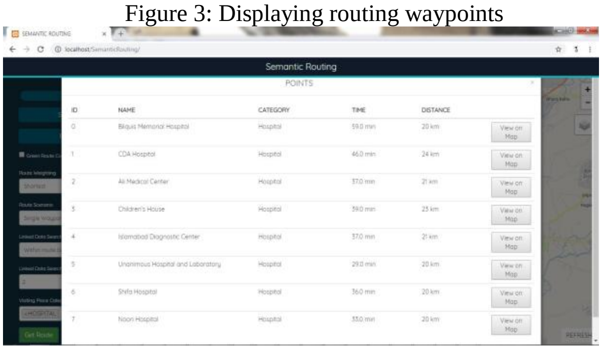



Figure 4 shows how the route is finally displayed along with the location of Hospital waypoint to the user.

Figure 4: Route displayed on map

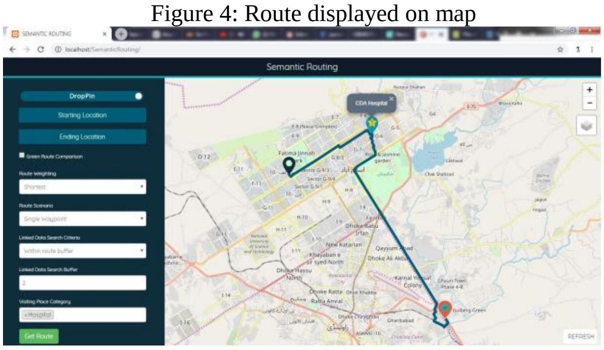


Figure 5 shows the output if user selects multiple waypoints option i.e. first visiting a restaurant and then a fuel station.

Figure 5: Multiple waypoints

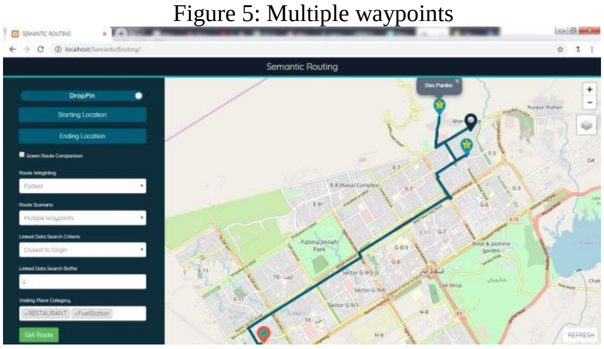
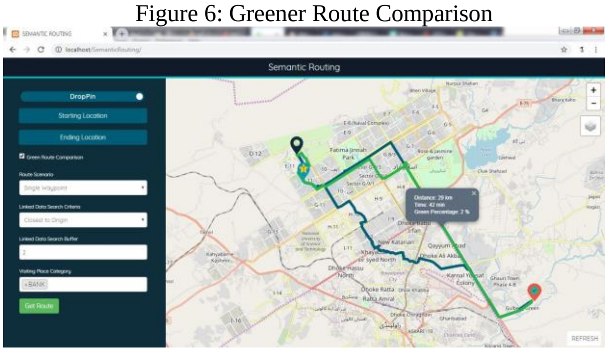



Figure 6 shows the output of greener route comparison, greenest route is displayed with green color.

Figure 6: Greener Route Comparison




## 4 Conclusion

In this research, we presented how linked data can be used for semantic enrichment of vehicle routing networks and supported the case with a working routing application that addresses semantic queries.

Future work consists of adding more scenario and traversing through the data links to further strengthen the enrichment process so that more semantic queries can be addressed. Another possible area of future work is the semantic enrichment of driving directions. This work can also serve as a motivating factor for data industries across Pakistan for publishing their data on semantic web, hence contributing to the increasing linked data cloud.

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