A Public Transportation Journey Planner Enabled by IoT Data Analytics

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ABSTRACT

The scope of the paper is to present the application developed for Braşov public transportation company. The application provides route recommendations and incident notifications for the citizens who travel by bus. This is achieved by processing in real time the data streams about bus arrivals in stations and the incidents reported by citizens. The application was developed on top of the CityPulse framework.

I. INTRODUCTION

Communication, networking and computing technologies have a lot of impact and influence in the way we live today. Digital data and connected worlds of physical objects, people and devices are rapidly changing the way we work, travel, socialise and interact with our surroundings and a lot of influences can be seen on different domains such as healthcare, environmental monitoring, urban systems, and control and management applications [1].

Worldwide and with wide interest among the European cities, Information and Communication Technology (ICT) is used to enabled services with the scope of improving the operation of various infrastructure assets (e.g. traffic infrastructure, water distribution infrastructure, electrical energy grids). This data is generated by a wide and heterogeneous range of devices, and delivered in various forms and formats. There are a lot of custom made applications or frameworks used by the public companies and city administrations for monitoring their assets. Since 2007 a group of universities has ranked the smart European cities and the latest result can be found here in this report [2]. To achieve this, the group have defined a set of indicators which are used to asses the city. Two of the main categories defined are smart mobility and smart living.

The public transportation domain provides a lot of potential for developing new and innovative applications which can improve the services offered to the citizens and make it more attractive. This is possible because the transportation companies deploy new sensors for monitoring the buses (such as bus location or number of passengers sensors).

The smart city domain, including the public transportations, is highly dynamic in the sense of available data sources and requirement for the smart applications. Because of that generic and flexible frameworks are needed to handle the data heterogeneity, data quality variation and application fast development. The European universities and research institutes, with the support of companies, are taking a lot of initiatives for developing frameworks which enable and ease the development of smart city applications. Such projects and initiatives include CityPulse [1], OpenIoT [3], iCore [4], and SPITFIRE [5].

The scope of this paper is to present a public transportation application which provides bus route recommendations for the citizens of Braşov based on the city status. The application provides the recommendations by analysing the schedules data, the real-time bus locations data and the reported traffic incidents from the city of Braşov. The application was developed on top of the CityPulse framework [1].

The CityPulse framework supports smart city service creation by means of a distributed system for semantic discovery, data analytics, and interpretation of large-scale (near-)real-time Internet of Things data and social media data streams. To goal is to break away from silo applications and enable cross-domain data integration. The CityPulse framework integrates multimodal, mixed quality, uncertain and incomplete data to create reliable, dependable information and continuously adapts data processing techniques to meet the quality of information requirements from end users [1].

The remainder of this paper is organised as follows: Section II describes the current state of the art for public transportation applications. Section III details the architecture and the development process of the Braşov city transportation application. Section IV concludes the paper and provides an outlook of future work.

II. PUBLIC TRANSPORTATION APPLICATIONS ENABLED BY ICT TECHNOLOGIES

Lately more and more cities adopt smart city frameworks upon which they develop applications that serve multiple purposes, like in our paper case, for public transportation. As it is presented bellow there is a vast pallet of applications that can be developed for the future public transportation based on the information and communication technologies.

One of the application that is worth mentioning is the one developed upon the COSMOS framework for IoT devices [6], in the city of Madrid in collaboration with the local public transportation company. This application aims to provide a service of routing and indications for people with special needs that require protection and assistance during the journey by bus.

Another research activity has also been conducted by the intelligent transportation system community and implied the development of an assortment of different algorithms that seek to increase the predictions accuracy for arrival time of the next available buses or trains. In order to overcome sources of error in predictions such as stemming from variations in weather conditions, bus bunching, the application uses an alternative approach. Rather than endeavor to develop a superior method for prediction, it takes existing predictions from travel information systems(TISs) and treats the algorithm generating them as a black box [7].

Research and development was also aimed towards monitoring driving behaviour in public transportation through Mobile Crowd Sensing (MCS), as part of a long-term research project on Advanced Public Transportation System (APTS). The proposed concept makes use of mobile device's accelerometer and passengers' qualitative evaluation to identify aggressive driving behaviour, which is believed to be a major factor for unnecessary accidents and fuel consumption [8].

III. Application Architecture and Development

The CityPulse framework was used to develop the public transportation journey planner application. All the CityPulse components are open source and can be downloaded from the following GitHub account: https://github.com/CityPulse.

The public transportation application developed for city of Braşov has two main features. First of all, it provides bus route recommendations based on the current context of the city (bus locations and traffic incidents reported by the citizens). Second, while users are travelling by bus and there is a traffic incident reported on their route, they will be notified. As data sources we have used the static data provided by the transportation company about the bus routes and schedules, the streaming data about the bus arrival times on stations, and reported traffic incidents.

The development of the application implied the fulfilment of the following steps:

- selection of the CityPulse components based on the application needs;
- deployment, configuration and extension of the selected CityPulse components on an dedicated server available online;
- development of a client front-end application which consumes the data processing services exposed by the components.

Figure 1 depicts the CityPulse architecture where we have highlighted with green the components selected for our scenario.

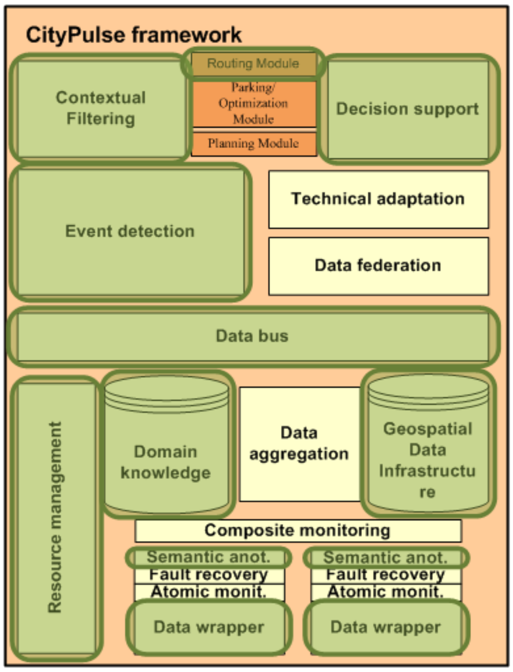

Figure 1. The CityPulse architecture with the components used for Braşov scenario (highlighted with green) [1].

The following paragraphs present the deployment steps of the selected components.

a) Data sources: For the development of our application we need to have access to a series of endpoints providing real-time the data about bus arrivals in stations. The public transportation is planning to expose these services in the near future. Meantime we have extracted this data from URBUS provider (http://www.urbus.ro/). The REST endpoints of the individual 219 bus stations provide information about the real-time status of buses that pass through each bus station in Braşov. Alongside the real-time status of the departure times in the current and the next hour, the endpoint also provides information about which busses have facilities for people with disabilities. In addition to these the citizens can use the mobile application to report traffic incidents while they are travelling.

b) Data wrappers: To consume the two different sources of streaming data, two different data wrappers are needed: one to consume the bus station REST endpoints and one to consume the traffic incidents reported by the users.

The bus station status information is published as REST endpoint providing the data on request. Internally the CityPulse framework expects the data to be available as a stream. Therefore the REST endpoints are polled regularly, the data is wrapped and sent to the data bus as a stream later. The data wrapper processes the data from the different bus stations separately. For each bus stopping at a bus station the following information is packaged into a sensor reading: bus stop name, bus line number, next departure times, and next departure times of buses with a ramp for wheelchairs.

```
@prefix station675: <http://ict-citypulse.eu/brasov_bus_station/675/>

station675:Observation-01fd1d9e> a sao:Point ;
sao:value "675" ;
ssn:observationResultTime station675:ResultTime-01fd1d9e> ;
ssn:observationSamplingTime station675:SamplingTime-01fd1d9e> ;
ssn:observedBy <http://ict-citypulse.eu/SensorID-087b34a0-ace4> ;
ssn:observedProperty ct:BusStation-087b34a0-ace4 .

station675:Observation-9a1f0d7b> a sao:Point ;
sao:value "23" ;
ssn:observationResultTime station675:ResultTime-01fd1d9e> ;
ssn:observationSamplingTime station675:SamplingTime-01fd1d9e> ;
ssn:observedBy <http://ict-citypulse.eu/SensorID-087b34a0-ace4> ;
ssn:observedProperty ct:BusLine-087b34a0-ace4 .

station675:Observation-b6ed9d0f> a sao:Point ;
sao:value "False" ;
ssn:observationResultTime station675:ResultTime-01fd1d9e> ;
ssn:observationSamplingTime station675:SamplingTime-01fd1d9e> ;
ssn:observedBy <http://ict-citypulse.eu/SensorID-087b34a0-ace4> ;
ssn:observedProperty ct:Handicapped-087b34a0-ace4 .

station675:Observation-eef72a5e> a sao:Point ;
sao:hasUnitOfMeasurement <http://ict-citypulse.eu/unit:time> ;
sao:value "12:33" ;
ssn:observationResultTime station675:ResultTime-01fd1d9e> ;
ssn:observationSamplingTime station675:SamplingTime-01fd1d9e> ;
ssn:observedBy <http://ict-citypulse.eu/SensorID-087b34a0-ace4> ;
ssn:observedProperty ct:EstimatedTime-087b34a0-ace4 .

station675:ResultTime-01fd1d9e> a tl:Instant ;
tl:at "1970-01-18T06:28:26"^^xsd:dateTime .

station675:SamplingTime-01fd1d9e> a tl:Instant ;
tl:at "2017-01-20T11:53:24"^^xsd:dateTime .
```

Listing 1. Semantically annotated example observation

We provide a REST endpoint which allows people to report traffic incidents, which significantly delay traffic, such as traffic congestion or car crash. The traffic incident REST endpoint provides for each reported traffic incident the location (retrieved automatically from the mobile application), a category selected by the user (e.g., traffic congestion or car crash) and a timestamp. The data wrapper regularly polls this REST endpoint and collects all the new incidents.

c) Semantic annotation and Resource management: Together with each data wrapper a sensor description is supplied. Every observation created by the data wrappers is semantically annotated automatically. The result is a sensor reading serialised in RDF. This sensor reading is then published on the Data bus by the Resource management component. Later other components such as event detection or contextual filtering will consume this sensor readings. Listing 1 shows an example observation as published to the data bus by the resource management component, reporting that bus line 23 departs from station 675 at 12:33 without handicapped facilities.

d) Event detection: The event detection component was used to detect which stations are located in the proximity of a reported incident. In other words: which are the stations affected by the incident. To achieve this we have developed and plugged in the component an event detection node. The node contains the pattern which is applied to detect if a bus station is affected by the incident.

In addition to the processing logic the event detection node contains the list of bus stations and their GPS locations. A graphic representation of the node is depicted in Figure 2.

```
insert into BrasovBusStationsIncidents select * from
    IncidentObservationStream where (
   BusStationLatitude - IncidentLatitude) * (
   BusStationLatitude - IncidentLatitude) + (
   BusStationLongitude - IncidentLongitude)*(
   BusStationLongitude - IncidentLongitude) <
   distanceThreshold * distanceThreshold
```

Listing 2. Closest bus station processing logic.

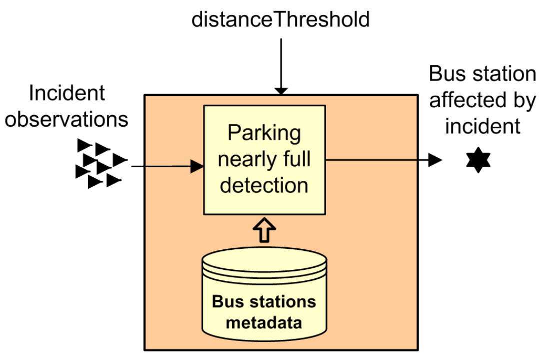

Figure 2. Structure of the event detection node used to detect which bus stations are affected by a traffic incident.

The CEP statement representing the processing logic is presented in Listing 2.

The event detection logic checks if the distance between the bus location and incident location is lower than the distanceThreshold parameter using the euclidean distance formula. If yes, it will generate an event for that specific bus station. The details about the bus stations and their locations are stored in the bus stations metadata.

e) Geospatial Data Infrastructure: For our specific scenario, the decision support and contextual filtering components need to have access to some of the functionalities exposed by the Geospatial Data Infrastructure component (GDI). Because of this we have decided not to use the CityPulse framework component, but to implement a tiny custom made application. The components job is to store the latest observations regarding the user reported incidents and also about the upcoming bus passes through the stations. These information were later used by contextual filtering and decision support components.

f) Routing component: The CityPulse routing component was not used because it is used to generate alternative routes while travelling by car/bicycle/foot. Instead of it, a custom application was developed, which is used to generate possible bus routes based on the static bus schedules provided by the transportation company.

g) Decision support: After the user enters a travel location, using the mobile application, it sends a route request to the decision support component (DS). The DS will then ask the routing component, to generate several alternative routes

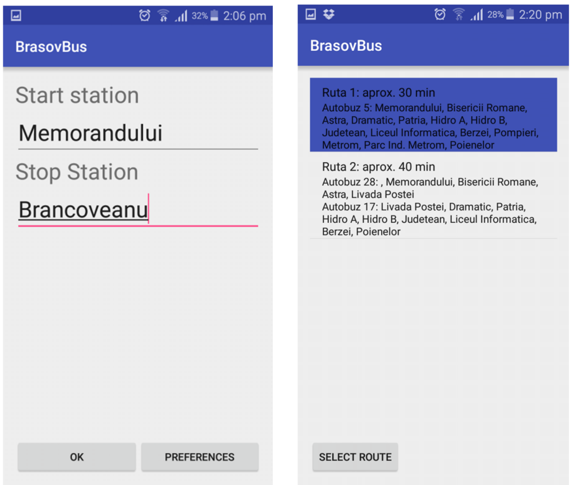

Figure 3. Snapshots of mobile application. Left: the panel where the citizen fills in the start and destination stations. Right: The recommendation generated by the system based on the status of buses from traffic.

from the users current location to the desired destination. The returned routes are then scored by exploiting bus line status information from the GDI replacement (which of the bus lines are available, which route is the shortest in time or length) and by the user preferences. Eventually a route is selected and sent back to the users mobile application. For the adaptation of this component it was necessary to change some built-in predicates used by the declarative ASP solver.

h) Contextual filtering: After receiving the route from the DS the mobile application will contact the Contextual filtering component (CF) with the route information. While the user is on the bus the CF will keep the connection open and inform the user via push when anything unusual happens on the route. These unusual events are either the traffic incidents reported by other users or otherwise delayed or cancelled buses. The CF will inform users only in the case these unusual events affect a users journey.

i) Mobile application: In the end a client mobile application was developed. On one hand the application allows the citizens to generate and to receive bus route recommendation (see Figure 3). On the other hand the application uses the data analytics services exposed by the deployed instance of CityPulse framework.

j) Components workflow: For maintaining the up to date status of the city, the components from the lower part of the architecture including the event detection are running continuously. The contextual filtering and decision support components are triggered only when an user generate a request. The components workflow for our application is similar to the one presented in the paper for the Aarhus traffic planer [1]. But in this case the CityPulse components were used to develop a car travel planner application.

IV. Conclusions

This paper presents the development activities done to develop the public transportation application for city of Braşov based on CityPulse framework.

Reuse of the CityPulse framework and its components enabled a quick implementation of the planner use case. The availability of all components in the Github open source repository was crucial for the adaptations to this use case. The CityPulse components are extensible and customisable enough to allow rather quick adaptations and thus provide a streaming infrastructure including ingesting data sources even if they are not given as stream but as REST endpoints, customized event detection and decision support, and publishing customizable endpoints. The integration of several data sources and services was well supported by the framework.

To evaluate the developed application and adapted infrastructure Siemens Romania organised a workshop with representatives of the local public transport company, departments of the city hall (IT and road safety), as well as local SMEs and members of th local IT cluster. The workshop participants were impressed with the development experience and the resulting system. As a direct result the public transport company takes over development of the Braşov us travel planner connecting it to more real time data flows and making it available to the citizens. Another attractive feature of the application, which came up during the workshop, is the possibility to report traffic incidents.

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