Traffic Information Systems for Smart Mobility as part of Smart Cities

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ABSTRACT

The unlimited and unrestricted mobility of people and goods in urban areas is one of the key factors for economic and social development of the city. Today with the availability of smart technologies and various intelligent transportation and telematics solutions the Smart Mobility as part of a Smart City is possible to maintain the mobility ecosystem in the city. But to make the urban mobility smart by assuring the sustainability, safety, low emission and comfort in urban transport new mobility concepts are required. This paper introduces an architecture for smart mobility systems and describes in general the requirements of such systems. The focus for this contribution is on the traffic information and management systems for public, private and shared mobility. In addition to the traffic information and data sources, this paper also deals with social media as new traffic data source as well as the environment data. Furthermore, some use cases selected from different national and international ITS projects are also presented.

Keywords: Smart mobility, architecture of smart mobility system, traffic information system, traffic management system, shared mobility, e-mobility

1. INTRODUCTION

The rapid motorization in Asian cities is significantly impacting the way people live as well as the environment. The rapid growth in private car ownership has led to excessive road constructions that are still insufficient and induce, for instance road accidents. New mobility concepts are of particular need to resolve the traffic and environmental problems in Asian cities. Intelligent Traffic Management Systems, e.g., variable traffic signs, traffic light prioritization, homogenization of traffic flow, etc., as well as traffic information systems promise to be the better solution, for example to avoid traffic congestion, to reduce air traffic pollution and other phenomena, since they have been successfully in operation in other cities [1].

This paper depicts a rough architecture of a Smart Mobility system in the context of a Smart City and describes the relevant requirements for such systems in detail. The focus is on the traffic management and information systems as integral part of the transportation system. Furthermore, some use cases for intelligent transportation systems (ITS) selected from different national and international project are presented.

The paper is structured as follows: Section 2 deals with the general information about a Smart Mobility and Smart City, section 3 describes the proposed architecture for Smart Mobility system as part of the Smart City and its components and section 4 introduces some selected use cases of mobility systems for Smart Cities realized in the scope of different national and international projects by the Institute of Transportation Systems of the German Aerospace Center (DLR). The paper is concluded in section 5 and gives some outlook on future works.

2. DEFINITION OF SMART CITY AND SMART MOBILITY

This section presents a general overview about Smart Mobility as part of a Smart City. Furthermore the requirements of Smart Mobility in the context of a Smart City are introduced.

A **Smart City** is a concept that has been used since the year 2000 by different actors in political, economic, administrative and urban planning to combine technology based change and innovation in urban areas. Giffinger et al. [2] define Smart City as “a city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, build on the smart combination of activities of self-decisive, independent and ware citizens” (see also [3]). Each city is smart as far as it is committed into the implementation of following characteristics as depicted in Figure 1: smart economy (competitiveness), smart environment (natural resources preservation), smart governance (participation), smart living (quality of life), smart mobility (transport and ICT) and smart people (social and human capital) [4]. The advanced Smart City can be seen as an “Internet of Things and Services”. The whole urban environment is equipped with sensors that make all collected data in the city (e.g., traffic, weather, infrastructure, and traffic participants) available, for example in the cloud using today’s existing information and communication technologies (ICT). The result is a permanent interaction in real time between the Smart City, their citizens, infrastructure, traffic and the surrounding technologies (e.g. smart phones, personal navigation devices, traveler assistance devices and the internet).
Smart Mobility as part of a Smart City is defined as an offer that allows an “energy efficient”, “low emission”, ”safe”, ”comfortable” and ”inexpensive” mobility and which is intelligently used by traffic participants. Smart Mobility focuses not on establishing new infrastructure, but instead on optimizing the infrastructure through the use of information and communication technologies (ICT) in a smart way [4]. In Figure 1 the characteristics of Smart Mobility are shown.

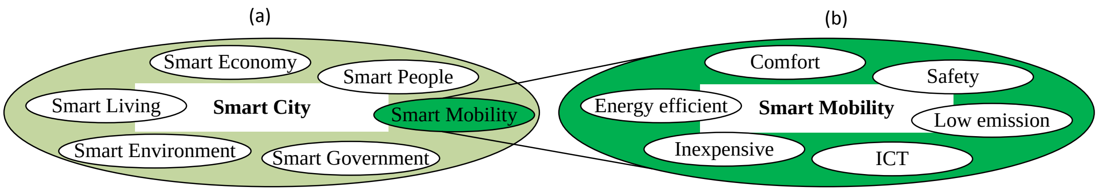

Figure 1: Characteristics of (a) Smart City adapted by [2] and (b) Smart Mobility adapted by [4]

3. MOBILITY ARCHITECTURE FOR SMART MOBILITY SYSTEM

This section describes in detail a proposed architecture of the Smart Mobility System for urban areas. Figure 2 gives an overview about the ITS components as part of the transportation system supporting the Smart Mobility of persons and goods in the context of a Smart City. Its components are described in the subsequent paragraphs.

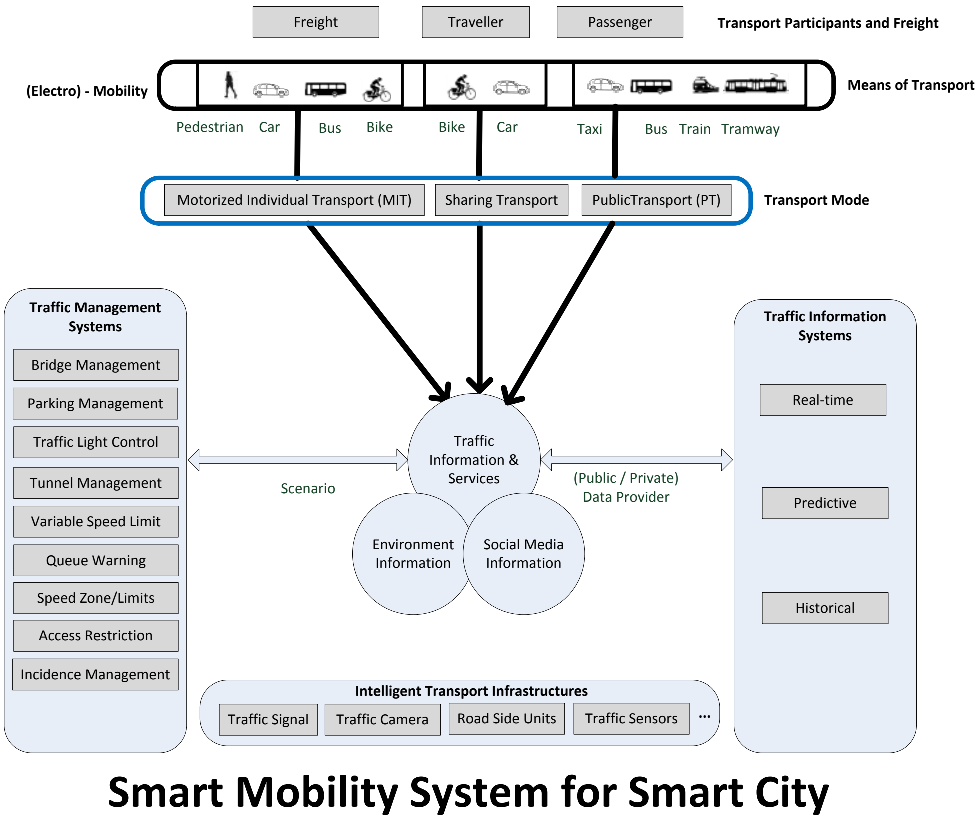

Figure 2: Architecture for Smart Mobility systems [DLR]

3.1 Transport Participants and Freight

The big challenge for a Smart City is the provision of adapting transport infrastructures to assure unrestricted and unlimited mobility of people and freight in the whole transportation network of the city. Using different transport modes, e.g., public transport, individual transport, goods and people can be taken from A to B. The unlimited and unrestricted mobility is one of the key factors for the economic and social development of the city. Many (smart-) traffic participants today are connected to the mobile internet (2G, 3G, 4G and in the future 5G too), enabling them to adopt ITS applications (e.g. traveler services, online booking portals, route guidance, public transport services, journey planners) by using mobile devices (e.g. smart phones, etc.) anytime and anywhere (e.g. at home, at work, before and during a trip, on vacation, etc.). Thus, traffic participants are capable of being in a position to book e-tickets for different transport modes (multimodal mobility user) or to plan their journey (Pre-trip or on-trip).

3.2 Means of Transport

The different means of transport like car, bike, bus, train and tramway have advantages and disadvantages depending among others on which transport mode (public transport, shared transport or motorized individual transport) is used.
To support, respectively promote Smart Urban Mobility the big challenge of vehicle manufacturers is to bring new intelligent vehicles on the market supporting the mobile internet technology (connected vehicles, car-to-car (C2C) or car-to-infrastructure (C2I)

communication, etc.) and provide following features like energy efficient fuel consumption, comfort and low pollutants emissions (e.g. electrical vehicle), safe driving, etc. To fulfill the requirement of Smart Mobility concerning the reduction of traffic air pollution in cities the proportion of electric vehicles on the road has to increase.

3.3 Transport Modes

The two most common used transport modes are public transport and motorized individual transport. Today the shared transport plays an important role in the context of Smart Mobility for a Smart City. (e)-Bike, (e)-Car and Ride sharing are alternatives to the common modes of transport. A detailed example of a shared mobility concept focuses on the car sharing for the district of Jiading in Shanghai, China, is presented in [5]. The results of this study show that shared mobility can help to reduce the number of private car owners on the road and therefore decrease the traffic volume and mileage in the city and contribute to sustainable mobility in urban areas. The transportation authorities–through the regulations and the introduction of some facilities for traffic participants—can promote the usage of public and shared transport in opposition to motorized individual private transport (reduction of the number of private car owners) in the city. The multimodal transport supply and a series of ITS services also play an important role in the urban transport and can be benefited from Smart Mobility of users in the city.

3.4 Traffic Information and Data Sources

In this section the traffic information and the data source are presented.

3.4.1 Traffic Information

The traffic information provided by the traffic information systems can be categorized in three groups as shown in Figure 4:

- Real time traffic information: Data obtained in real-time as a result of the data collection, processing of raw traffic data collected from the single data source like FOD (Floating Object Data), loop detectors or combined by the data fusion [6]. Real time traffic information like travel time, travel speed or traffic flow is relevant, for example to support the travelers during the trip (on-trip) or used by on-trip monitoring system like navigation system by the optimization of the traveled route.
- Predictive traffic information: Precise short term prediction of traffic parameters such as flow and travel time is a necessary component for many ITS applications. An example of short-term prediction applications is described in [7]. Prediction data are obtained using algorithms to simulate and predict the traffic situation for the next hours or days. The traffic prediction data is needed by the traveler to plan his trip (pre-trip).
- Historical traffic information: Historical traffic data, which is processed to generate, for example daily travel time or traffic flow curves of a selected road segment. Historical traffic information can be used for transport planning and to substitute missing real time data.

In Figure 7 the traffic information and related data sources are shown

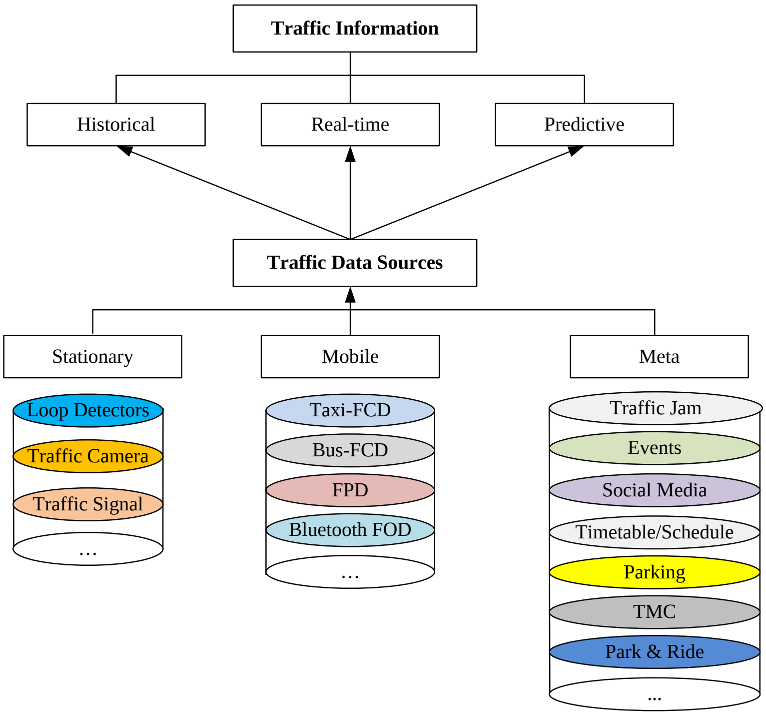

Figure 3: Traffic information and data sources [DLR]

3.4.2 Data Sources

Intelligent traffic data collection systems are required to collect traffic data from the various existing sources. Different data collection approaches exist using different technologies for local as well as area wide detection. Traffic data can be obtained from stationary, mobile as well as meta sources (see the Figure 4).
For a Smart City it will be interesting to install data collection systems that use alternative dynamic data collection approaches based on the mobile wireless communication technology and using short range radio like Bluetooth, Wi-Fi or TPMS (tire pressure monitoring systems) [13,18] to collect the traffic data in the city. An example of such system is "Bluetooth based floating car observer FCO" developed by DLR. It collects and processes the traffic data from the Bluetooth data and is described in section 4.3.

3.4 Environment Information

For Smart Cities the reduction of air pollution due to traffic is essential to guarantee the sustainability of the urban environment and therefore ensure a better life of citizens and preserve the mobility ecosystem. Green mobility is needed and for this purpose the Environment Information Systems are required to collect and provide environmental data in real time of the whole city, e.g., weather, CO_x and NO_x pollution. The analysis of such data provides information about the impact of traffic on urban environment through the emission of pollutants like CO, NO_x, SO_2, and PM2.5 [8]. Based on the environment information obtained from the traffic emission and street immission data, for which the processing tool set as designed by DLR, and the use of simulation tools like SUMO [9] (shown in Figure 5), public authorities in charge of transport can do some regulation decisions to solve the problem of pollution in the city. These can comprise introducing additional taxes for fuel and diesel vehicles, or introducing restricted zones in the city for certain categories of vehicles which has already been successfully tested in [10]. Using traffic information display systems like variable message signs (VMS) installed on the city main road information on the weather (e.g. “heavy fog, drive slowly!”) or environment (e.g. “CO2 330 ppm, reduce CO2 emission!”) can be displayed in real time to the drivers, which can also contribute to traffic safety.

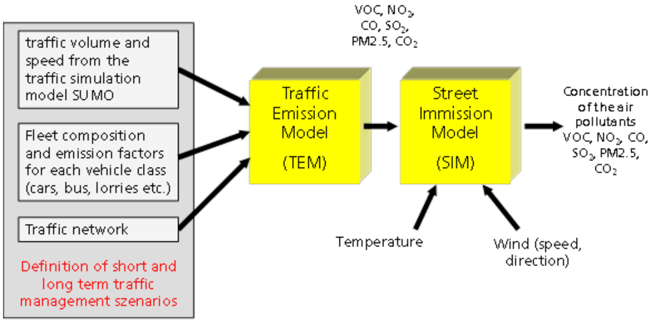

Figure 4: Processing tool set of environmental data [DLR]

3.5 Social Media Information

Until now traffic data is mostly obtained from conventional traffic sensors like inductive loop detectors, cameras or from on board units of vehicles (floating car data). Another important source of traffic information today is the data obtained from social media sources like Twitter or Facebook (see Figure 6). The trend for a Smart City with access to the information and mobile communication technology is to encourage the transport companies to build ITS applications in the private and the public sectors that deal with big data generated by the social media communication (“Social Media Harvesting” [11]). The purpose will be to filter, process and analyze such data in order to extract the traffic relevant information like accidents, road construction and road blockade related to the selected city or area and make these data available for all traffic participants and public authorities.

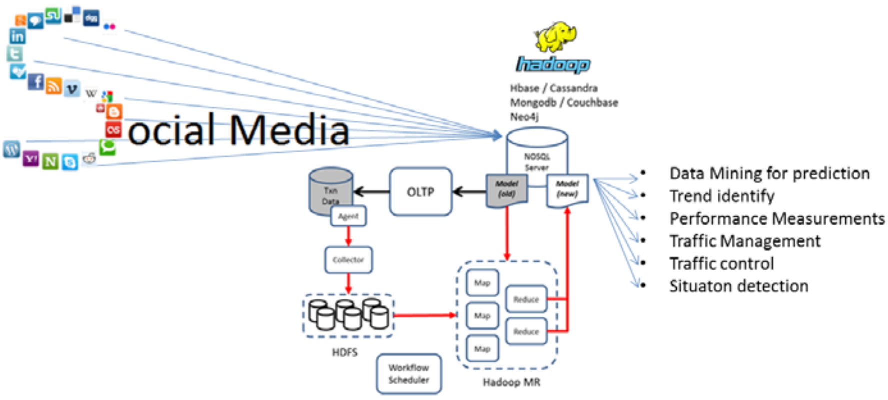

Figure 5: Infrastructure for the processing of social media [adapted by DLR]

3.6 Traffic Information System for Smart Cities

There are various types of Traffic Information Systems customized to support common transport modes (public transport, share transport and motorized individual private transport). Table 1 lists some selected traffic information systems required for an improved support of traffic participants before and during a trip (pre- and post-trip) as well as the public authorities that are concerned with traffic and transportation management. The traffic information generated from different Traffic Information Systems can be stored into a traffic data platform [12] or data pool, which is available for the public by mobile internet communication.

Table 1: Overview about selected Traffic Information Systems

No.	Traffic Information System	Description	Expected effect
1	Bus/Taxi/Motorbike FOD (floating car data)	Real time traffic information services that provide the traffic situation as level of service (LOS) on the roads in the city obtained from FCD (fleet of buses or taxis)	Enhance the traffic management accuracy by service monitoring of traffic flows and traffic situations
2	Bluetooth FCO (floating car observer) [13]	Real time traffic information services that provide the traffic situation as level of service (LOS) on the road in the city obtained from Bluetooth floating car observer data (fleet of Bluetooth mobile car observers)	Enhance the traffic management accuracy by service monitoring of traffic flows and traffic situations
3	Traffic Info Display System – Smart phone and web	Traffic information provision services like traffic flow, incident detection, location, delay and congestion, GIS information customized by the internet and mobile media at anytime and anywhere	Integrated traffic information services, public transport services for web and smart phone users. SMS text information services that provide incident information.
4	Traffic Info Display System – Bus Info Terminal (BIT)	Bus information terminal at bus stop for public transportation	Promote bus service for many citizens to feel convenience
5	Traffic Data Fusion System [Source]	Fusion of various traffic information to provide real-time traffic information to diverse media	Enhancement of the quality of data and traffic information
6	Traffic Camera (CCTV) Information System	Integrated Image control system by real time video collection and processing and connection at major city	Enhance the traffic management accuracy by real time video monitoring of

		roads (suburban incoming, outgoing main point)	incidents/traffic flows and traffic situations
7	Traffic Information Collection System (Road Side Equipment – RSE)	Intelligent traffic wireless Communication infrastructure (Wi-Fi) connected to urban-traffic information systems network (UTIS)	Car-to-Infrastructure (C2I) and Car-to-Car (C2C and C2I) communication
8	Traffic info Display System (Automatic Response System - ARS)	Provision of Traffic information guide ARS and bus information guide ARS to the traffic user by using mobile phone general phone	Provide fares by flow information and various traffic information access convenience
9	Traffic info display system - KIOSK	Integrated information guide KIOSK at public transport, transfer center or interactive traffic information guide KIOSK a public institution like expected bus arrival time, tour information (interactive touch screen)	Provide public transport convenience by providing transfer information, grand use of public transportation to citizen, visitor at a public institution
10	Dynamic parking lot info system	Real-time Information about the parking lot situation in different parking stations in the city	For efficient use of the parking lot
11	u-Bicycle system	A bike sharing system to support the green transport, in the city	For sightseeing purposes as well as an alternative to common means of transport
12	Car sharing System [5]	A car sharing system to support green transport, in the city. Provide services like car location and charging station information	For sightseeing purposes as well as an alternative to common means of transport
13	Traffic Information Display System - Variable Message Sign (VMS)	VMS provides real-time traffic flow situation and incident Information for traffic user on the road in the city	Optimization of traffic demand management by Incident and detour guidance
14	Traffic info collection System (dedicated short range communication - DSRC)	Provide region or local speed and traffic flow information obtained from the travelling vehicle equipped with OBU (on-board unit)	Enhance the accuracy of traffic information in the city area
15	Multimodal traveler assistant [14]	Provision of route information, alternatives	Support Pre-trip and on-trip and navigation on

		and dynamic traffic situation on the selected route	the route

3.7 Traffic Management Systems for Smart Cities

The traffic management is required to support the Smart Urban Mobility in Smart Cities. Traffic management is the influencing element of the traffic situation by a bundle of measures with the objective to harmonize traffic demand and supply of all transportation modes. The main purposes of traffic management are the following [10]:

- Safeguarding and improvement of the citizen’s mobility
- Safeguarding and improvement of economic transactions
- Improvement of the transportation compatibility with the environment and society
- Reduction of traffic jams / congestion
- Decrease of pollution (environmental impact)
- Increase of traffic safety
- Increase of traffic comfort
- Increase of public transport modal share
- Reduction of individual motorized private transport

Smart Cities essentially need traffic management systems to better manage traffic and transportation in the city. By using ICT today the high speed transfer of real time, predictive and historical traffic data collected from different data sources like taxi-FCD or loop detectors and obtained from private as well as from public data providers to the traffic management system is possible. The data can be used by public authorities, traffic operators, managers and decision makers by the management of the traffic demand in the city by the following actions: Tunnel management, urban road management, highway management, traffic signal management, Bus information management system, tunnel management, bridge management, restriction zone management, parking lot management.

(a) (b)

Figure 6: Traffic management Center – (a) Shanghai city, China, 2016 and (b) Busan city, Korea, 2010

To support Smart Mobility it is important for each city to have central or decentral traffic management center (TMC) or traffic information center (TIC). In addition to this task, the TMC must bundle all available data and fused traffic data of the city for a traffic integration and visualization system. Figure 7 shows two examples of the TMC (a) in Shanghai city, China, and (b) the TIC in Busan city, Korea.

4. USE CASES – TRAFFIC INFORMATION SYSTEMS

Some selected use cases for traffic information systems developed in different national and international projects by the Institute of Transportation Systems of the German Aerospace Center (DLR) in cooperation with project partners are presented in this section.

4.1 Traffic Information System for Hanoi, Vietnam

The Vietnamese-German Project REMON [15] worked on improving the traffic situation in Hanoi. Therefore, it is necessary to have a good overview of the existing traffic situation and to monitor the development of the traffic over longer time periods. Floating Car Data (FCD) systems can help to acquire area wide traffic information. Figure 8 depicts a result of this project as a prototype realization of an FCD system [16] for the city of Hanoi based on taxis, buses and motorcycles. It consists of web and app tools and a Hotspot-Monitoring for long term traffic analysis. Several different traffic data sources were fused and the derived information prepared for use by specific traffic specialists as well as for the public.

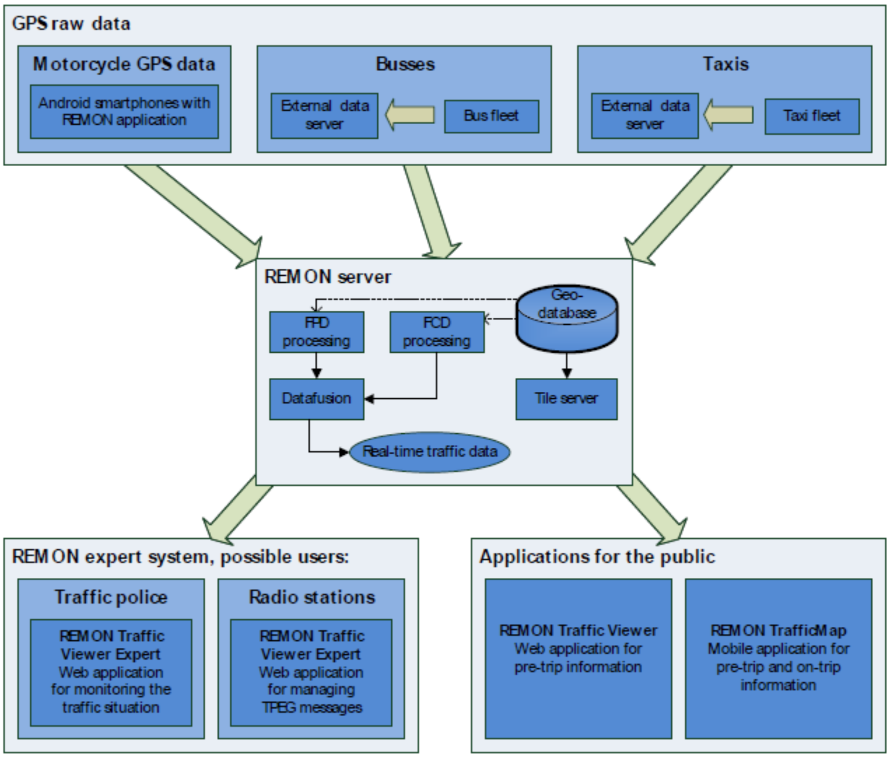

Figure 7: Traffic Information System for Hanoi city, Vietnam [16]

The REMON Traffic Information System delivers for the first time in Hanoi comprehensive information about the traffic in Hanoi in real-time. It is on the one hand a traffic-information-website and -App for all road-users, and on the other hand a monitoring tool for traffic operators and the traffic police, which can use it to have online information, and to get a detailed insight into the development of the situation over the time. The TIS can monitor known hotspots and identify new hotspots with the automatic hotspot detection. So it contributes to better traffic-situation knowledge and congestion detection and avoidance [16].

4.2 Traffic Information System for Hefei, China

The Chinese-German Project METRASYS [17] funded by the German ministry of education and research worked on the new concept of sustainable mobility in mega cities. The project focus was on sustainable planning and dynamic data collection using FCD and traffic management. Figure 9 depicts the architecture of a traffic information system [1] developed in the scope of this project for the city of Hefei in China.

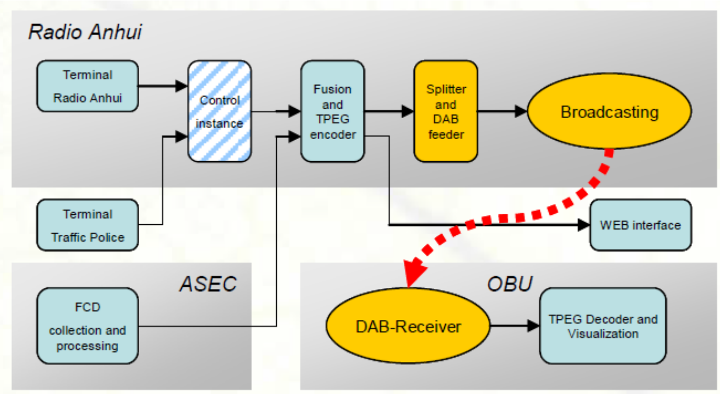

Figure 8: Traffic Information System for Hefei city, China [1]

METRASYS gave means to decision-makers to implement and control sustainable transport in Hefei effectively. For this, a broad approach was implemented in close cooperation with the relevant Chinese parties. The cooperation has provided valuable insights into the development process of Hefei and led to the development of an integrated approach to transport and urban planning involving local decision-makers.

4.3 Bluetooth based FCO system

Research and prototype realization of Bluetooth based floating car observer (FCO) [13] as an alternative dynamic indirect data collection system using mobile wireless (short range radio) communication technology like Bluetooth or Wi-Fi has been done in the scope of the German project I.MoVe funded by the Helmholtz research foundation. The system architecture depicted in Figure 10 consists of hardware and software for the data collection, data import, data processing, data fusion, data management and visualization of traffic data obtained from Bluetooth data.

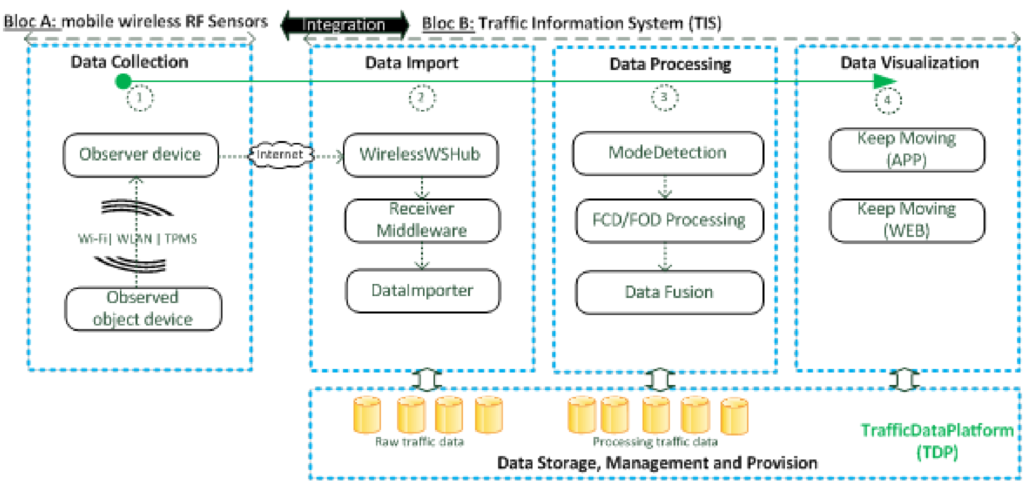

Figure 9: Architecture of Bluetooth based FCO system.

The traffic data collection using the Bluetooth or Wi-Fi technology allows for local and area wide measurement of traffic data (e.g. travel times and speed, route paths and flows, origin destination (OD) matrices). It can be used for different transport modes (e.g. car, bike, train) as well as for mobile and stationary detection. The benefit here compared to the traditional traffic data collection systems like loop detection or FCD is that most of the existing Bluetooth or Wi-Fi enabled mobile devices can be observed as traffic object, and the functionalities of some devices like smart-phone and personal navigation devices can be extended to act as floating or stationary traffic observer devices. Therefore the installation and deployment of such system for the acquisition of traffic data in the urban areas required low effort and cost.

4.4 Mobile Intermodal Travel Assistant system

The German pilot project MobiLind funded by the German Aerospace Center (DLR) had the purpose to enable a shift towards Smart Mobility for the 1000+ employees in the city of Cologne by various means. One brick of the solution is a mobile intermodal travel assistant. Figure 11 shows a modular three layers architecture of the realized KeepMoving system for this purpose [14]. The system has data interfaces to import traffic data from public transport (PT) motorized individual transport (MIT) as well as the weather data in the city. The KeepMoving system provides various value-added ITS services for smartphone, web and interactive touch screen for public institutions (PSP – public screen portal) to support the multimodal mobility of commuting and traveling employees before (pre-trip), during (on-trip) and after the trip (post-trip). Furthermore, the user preferences are taken into account and the quality of provided traffic information is enhanced by the data fusion module as integral part of the KeepMoving system.

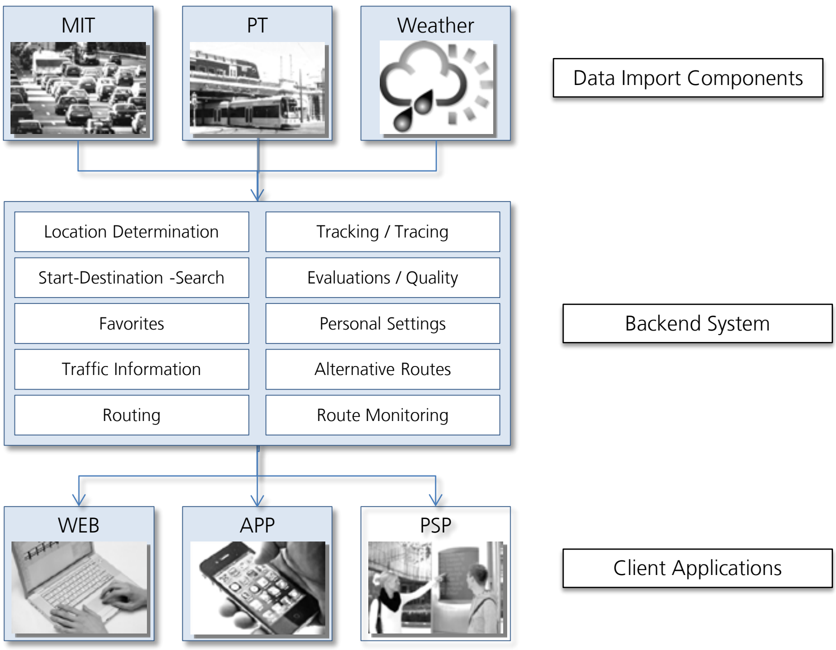

Figure 10: KeepMoving – Mobile Intermodal Traveler Assistant System [14].

5. CONCLUSION AND OUTLOOK

The development of a Smart City requires and provides intelligent transport infrastructures to support the mobility of people and goods in urban areas in a sustainable, environmentally friendly, energy efficient and safe way. The problem generated by traffic and transportation like traffic congestion and transport-induced environmental pollution remains and needs to be solved. Intelligent transport systems and ITS services can help to make transport in cities more energy efficient and sustainable. In this paper an architecture of an Intelligent Transport System to support the Smart Mobility for a Smart City was introduced. The focus was put on the traffic information and management systems. For Smart Mobility as an integral part of Smart City the environmental aspects as well as the social media like Facebook and Twitter as new data sources for the generation of traffic data were discussed. Furthermore, some use cases for intelligent transportation systems selected from different national and international project of the DLR were presented to illustrate the benefits of such mobility systems to economic and social life of people in the city.
There is not an ITS solution that fits for all cities. First, the characteristic of the traffic in the city must be analyzed with the local decision-makers. Based on this status quo should an individual integrated approach be worked out that takes all road users into account, strengthens public transport and protects the environment. Thus, the (smart) City is made fit for the transport needs of the future.

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