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A reference architecture for Context-Aware Intelligent Traffic Management Platforms[1]

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Abstract

Smart cities have been heralded for improving traffic management by utilizing data for making better traffic management decisions. Multi-sided platforms collect data from sensors and citizen-generated data on one side and can provide input for decision-making using data analytics by governments and the public on the other side. However there is no guidance for creating developing Intelligent Traffic Management Systems (ITMS) platforms. The involvement of various actors having different interest and heterogeneous datasets hampers development. In this paper, we design a reference architecture (RA) to support intelligent traffic management system for providing better commute, safety and security during travel based on real-time information. The main three layers of this RA are Datasets, Processes, and Actors. The RA for ITMS provides guidance for designing and overcoming the challenges with 1) heterogeneous datasets 2) data gathering, 3) data processing, 4) data management and 5) supporting various types of data users. The illustration and evaluation of the architecture shows possible solutions of the aforementioned challenges. The RA helps to integrate the activities performed by the various actors. In this way it can be used to reduce traffic queues, increase the efficient use of resources, smooth and safe commute of the citizens.

Keywords

Intelligent traffic management system, e-government, multi-sided platform, reference architecture, big data, context-aware systems, smart city

Introduction

The increasing level of urbanization and growth in size and number of cities in different parts of the world has resulted in both challenges and opportunities. New ways for city planning are needed (Axelsson & Granath, 2018). Many governments at different levels – regional, national, international, have initiated programs on digital and smart cities (Anthopoulos, 2017). The initiatives contribute to national and international health, economy, infrastructure, resources and transportation to provide high quality of comfort to their citizens. Smart city has become one of the most promising, prominent and challenging application in the area of Wireless Sensor Networks (WSNs), Internet of Things (IoTs) and Big data analytics, but has been criticized for not being able to hold if promises (Anthopoulos, Janssen & Weerakkody, 2016). Smart Cities employ information and communication technology (ICT) to improve city operations and services and connect to citizens. IoT can be used to collect high quality data (Chatterjee, Kar & Gupta, 2018) and big data analytics can make sense of the data (Chong, Habib, Evangelopoulos & Park, 2018). Anthopoulos & Reddick (2016), it is found that six

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dimensions: people, government, economy, mobility, environment and living enhancing the urban life style. Smart cities can play a significant role to deal with these urban challenges. Lee and Lee (2014) provides a typology of different kinds of smart services ranging from automation to transformative. Today's cities are shifting and transforming into test beds where solutions driven by information and communication technologies (ICT) impact people interactions and vice versa (Gottschalk et al., 2016). Among various application areas of smart cities like smart water, energy, buildings, health, intelligent traffic management system (ITMS) can have significant impact on day to day life of the citizen (Anthopoulos & Reddick, 2016).

The limited capacity and uneven use of the existing transportation infrastructure can lead to the severe traffic congestion and in increasing travel times. The problems of road traffic can be resolved by either improving the existing road infrastructure or by using ITMS to improve the usage of existing infrastructure. The latter might require less investment and at the same time can reduce pollution and energy consumption and improve travelling time and convenience. For example in (http://urbact.eu/steering-real-time-city-through-urban-big-data-and-city-dashboards-0) and (Amaral et al., 2016) the smart city of Rio de Janeiro draws together real-time data streams from thirty agencies and try to manage a large, complex city. The dashboards are used by the city managers and analyst to monitor the system or the city how it works as a whole.

In addition to the economic advantages, one of the most critical consequences of traffic congestion impact the operation of emergency services, such as medical, fire, rescue operations and police services etc. These services demand efficient and timely response of emergency vehicles. Further, in parallel to the growth of population existing road sizes are not expanded in the same proportion. As a result, vehicle crashes are more often happened in the narrow, congested roads as the drivers or the travellers want to go fast to avoid congestion on road. In turn, it affects the social aspects of the city life. Finally, due to the modern city life-style demands shorten commuter journey, reliable and accurate traffic prediction, early detection of bottlenecks on road, parking management becomes more important.

The existing ITMS do not provide sufficient and accurate road information regarding traffic to control and timely monitoring and management of the traffic system. They are not context aware, although much data is available. Therefore, it is necessary to ensure that data can be collected and used for improving traffic management for providing better commute, safety and security during travel, green applications like reduce fuel consumption, reduce gas emissions based on real-time information. Context-awareness can be defined as the conceptual abstraction which analysed a set of collected data about certain circumstances to design a context-aware system (Perera et al., 2013). The raw data is being extracted as a meaningful context to use for a meaningful purpose. The term "Context" has many definitions over the years by researchers and mainly it is defined as "the interrelated conditions in which something exists" (Shishkov and Sinderen, 2008, p.1). Context can be used to 1) optimize system-internal processes, 2) maximize the user-perceived effectiveness of delivered services or 3) ensuring value-sensitivity when the society demands (Shishkov, Larsen, Warnier & Janssen). While Context-aware computing (CAC) allows applications to have meaningful information of the context from collected raw data and providing smart services to the user. The context may be network connectivity, resource accessibility, user profile, location, activity, traffic conditions, noise etc. Similar to the Big Data, Context-aware system generates large amount of data that require big and efficient storage spaces. These deluges of data need data analytics to infer knowledge of the scenario. A system is to be context-aware if it uses the context to provide relevant information and/or services to the user, depending on the application used by the user (Subbu and Vasilakos, 2017).

E-government and smart city projects are prone to failure (Anthopoulos, Reddick, Giannakidou & Mavridis, 2016) and require reforms and transformations (Purwanto, 2018). A reference architecture can help to prevent project failure and ensure that technical and organizational elements are taken into account when developing ITMS. The objective of this study is to design a RA to support intelligent traffic management system for providing better commute, safety and security during travel based on real-time information. The RA can be used to adopt any applications of smart traffic management system in which multiple actors play a role and ensure that stakeholders understand each other.

This paper is structured as follows. In Section 2, the research approach of this work is presented. In Section 3, a detailed review of relevant literature survey is given. The proposed RA for intelligent traffic management system is described in Section 4. An illustration and evaluation of the proposed RA is given in Section 5. Finally, we draw conclusions in Section 6.

Research Approach

The research objective is to design a Reference Architecture (RA) for ITMS. As our goal is to design a framework we adopt the design science research method in this paper. For this the design process model (Peffers et al. 2007) was used. The design science steps are 1) motivation, 2) problem identification, 3) artefact design and 4) illustration & evaluation. The development of the RA is both driven by the need of solving practical problem as enabled by the knowledge base. Insights from literature can be used to develop the RA. Figure 1 describes the step by step procedures used to design the artefact in this research. In our study the artefact that will be developed is the ITMS RA. Based on our first hunch, motivation and challenges are derived from literature study. We identified various challenges of ITMS through an inductive approach. After gathering knowledge and background detail, we proposed a RA for an ITMS, which is founded in practice and theory. Finally, an illustration and evaluation are described to demonstrate the added value of our RA.

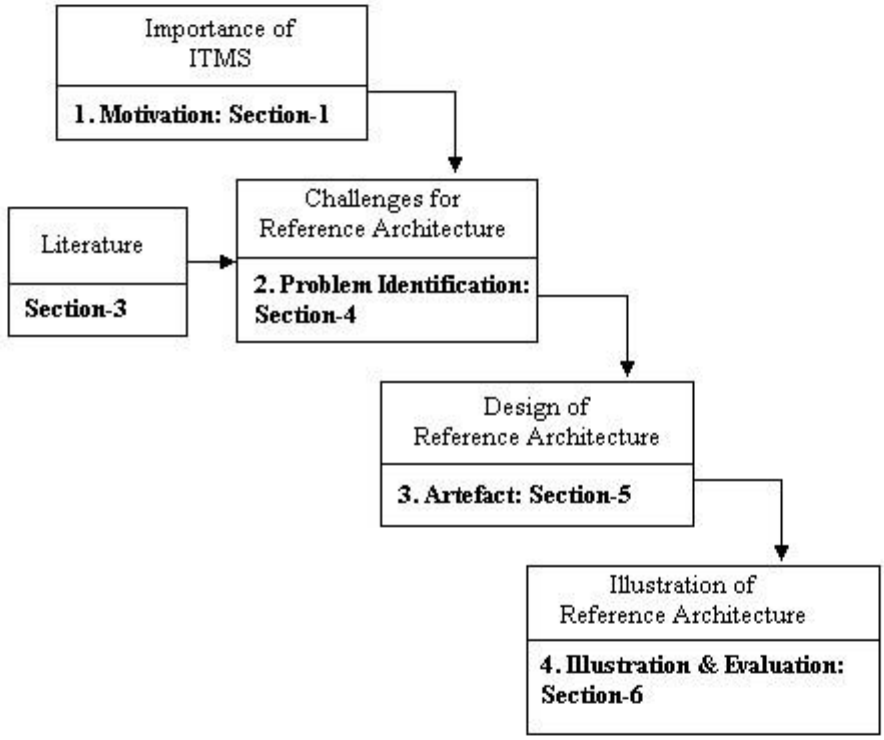

Figure 1: Design Science Research Approach

Related Work

The demand for good transportation increases with the increase in population and urbanization. Hence the number of vehicles in road also has risen day by day. In the very recent past many researcher have been worked a lot in different applications of ITMS. Also several surveys are found in the literature that discusses different aspects and challenges of Big Data in smart cities.

Djahel et al. (2015) conducted a survey on different technologies used in different phases of ITMS. They also discussed the potential use of smart cars and impact of social media to detection of traffic congestion and mitigation. In (Knorr et al., 2012) the authors dealt with the traffic jam issue. They used different strategies accessible for traffic administration such as video information analysis, infrared sensors, inductive circle recognition, remote sensor system, etc. Bazzi et al. (2013) presented on various factors are to be considering timely data by using VSNs vector distance routing algorithm for vehicle tracking system. Kammoun et al. (2011) proposed a hybrid method that makes use of adaptive vehicular guidance systems to analyse the road traffic network. The flow of traffic is adjusted intelligently by suggesting alternative path to the destination based on ant colony behaviour and hierarchical fuzzy system.

Another solution is offered by Shashikiran et al. (2011) where the authors tried to make use of Kruskal's algorithm for suggesting optimal path by mapping the traffic junctions to nodes and traffic flow as link weight by using Google maps. The optimal path selection is based on various parameters such as traffic rate, speed of the vehicle, shortest path etc. Nafi et al. (2014) propose a system using IEEE 802.11p based vehicle to infrastructure communications system to predict the future traffic intensities at intersections point on road. The vehicles are rerouted based on this prediction to reduce the traffic congestion and minimize the travelling time of the individual.

Jayapal et al. (2016) suggested the use of RSU (Road side units) and mobile phones to detect traffic congestion in a certain area. The mobile phone and RSU communicate with each other wirelessly via a vehicular ad hoc network. They also proposed that when vehicles approaching towards the congested route users are notified about the same using the mobile app or via a display near the traffic signals.

Patel et al. (2015) proposed an algorithm for automatic license plate detection. Video camera is used here to capture the images of all the incoming and outgoing vehicles. Misbahuddin et al. (2015) propose a system for cognitive traffic management that primarily focuses on smart traffic lights. The dynamic timing of these smart traffic lights is based on the conclusions drawn from the analysis of data obtained from cars and road sensors, as well as alternative sources of user data, such as social networks, the results of opinion polls and others.

Petrovska, and Stevanovic (2015) proposed the use of image processing to determine traffic density. They displayed the information on traffic congestion in various locations using their application for Smartphone. For

doing this they use Google's API for interfacing with the traffic layer of the Google maps. The traffic density in areas is then displayed using colour codes each denote very high congestion to no congestion.
All the above mentioned works have particular application for solving one problem of ITMS. These includes traffic jam, traffic density, alternative path to destination, license plate detection, minimize traffic congestion on road etc. None of these works are focussed on providing a framework or other reference where different sources of data are handled simultaneously to depict the road's scenario for different categories of users. Different sources of data are from different objects on road need to be collected.
In the next section a framework is proposed for context aware ITMS. The contribution of this research work is a conceptual framework and blueprint for envision the future traffic management system. Stakeholders like government and private may adopt this framework to which can facilitate communication between stakeholders (e.g. Axelsson & Granath, 2018).

Typical Challenges

All the above mentioned literature addresses some parts of solving ITMS. These includes traffic jam, traffic density, alternative path to destination, license plate detection, minimize traffic congestion on road etc. In the literature we did not found a framework where different sources of data are handled simultaneously to depict the road's scenario for different categories of users. Different sources of data are from different objects on road. So, there are heterogeneous sources that generate heterogeneous data which need to be identified clearly. This data need to be gathering, processing and then representing into a meaningful context for the different intended users. Thus, there is a gap to implementing a smart traffic management solution in a standardized way. Therefore, these challenges concluded in this work and are presented in terms of major stages related to traffic data acquisition, aggregation, processing and support system to the citizen.
Heterogeneous Datasets: Data is generated from many different sources and in many different formats which are mainly unstructured (e.g. images, audio, tweets, video, etc.). Figure 2 shows an example of a traffic junctions and various ways of collecting data, including sensors in cars, cameras and ways to display information on smart phones and on visual displays. For example, weigh-in-motion sensors (Traffic data collection and Analysis, Road Department, 2004) counts number of vehicle, weight and classify type of vehicles on road in motion. While, sensor pads can be used to get traffic speed. On the other hand, cameras provide video imaging of individual vehicles and also monitor multiple lanes simultaneously. So, all these sources have different type of context with different format and this makes it very challenging and complex system. Therefore, it is necessary to understand the relevancy of the data for traffic information. Thus, which types of relevant data are actually needed for providing and explaining the traffic conditions on road and also what is the quality of the data.
Data gathering from different sources and organizations: There is several numbers of entities which collect traffic information such as public transport companies, private companies, public traffic management authorities etc. As mentioned above, data sources are in-vehicles, in-road and rode-side sensors, traffic lights, cameras etc. Therefore, whom and or which are responsible for collecting such data from these heterogeneous sources.
Data integration: As mentioned before, data sources are heterogeneous thus the first hurdle is the amount of data collected which is increasing exponentially and second one is complexity of data. These both make data conversion time and resource consuming. Therefore, it is also a challenge how the integration on these gathered data on a single paradigm. Some data might be collected at various times and circumstances and integration might not be straightforward. Also there might be a lack of interoperability standards.
Real-time data Management: The road traffic data rely on traffic history, timing, road occupancy, traffic incidents etc. These real-time road information need to be managed for city planner, identifying and predicting traffic pattern in a city. Therefore, it also a challenge how to handle deluge of heterogeneous data from a huge number of variety of sources in real-time.
Variety of Data Users: There are various different types of users with different needs. Data need to be processed differently and visualized for the target audience.

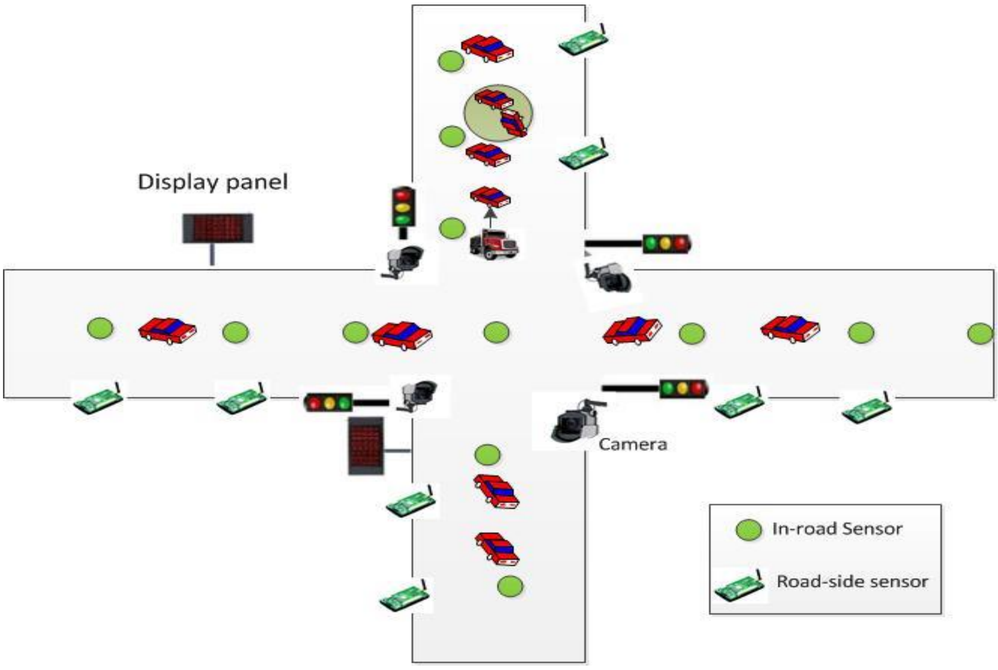

Figure 2: Scenario for data sensing and gathering

Proposed Reference Architecture

In this section we propose a RA for Context-aware ITMS. We use four layers for describing the RA, datasets, processes, actors and applications to capture elements ranging from technological to organizational. A layered approach is given to organize these subsystems or components in categories of similar objects. A layered approach is a systems approach aimed at dealing with the complexity. Ideally, a layered model has the following characteristics (Stallings, 2006).

1. Each layer performs a cohesive or closely related set of functions
2. Higher layers use services provided by the lower layers
3. Layers are sufficiently loosely coupled to allow changes in one layer without affecting other layers

For our RA layers are used to group and structure similar kind of items. The RA shown in Figure 3 has four main layers namely (1) Datasets, (2) Processes, (3) Actors and (4) Applications to deliver the collected road traffic information to the intended end users. These four layers are sufficient to handle the challenges mentioned in previous section. In the bottom layer l raw data generated from heterogeneous sensor nodes and or ICT devices. The possible entities of raw data are bridges, roads, vehicles, crossing point at road, people etc. The second layer, Processes, can be viewed as a Context-aware computing (CAC) which collects road traffic information from these heterogeneous data sources. It uses the services provided by the Layer 1 to gain access to the data, process and share data. The data sources are millions of sensors, CCTV, people etc. These data are fed and then aggregated and stored in databases. Due to the heterogeneity of the collected traffic data formats, a common data format is required to enable processing of the aggregated data. After processing of the real data, a meaningful context is generated, which users may extract for their need. Layer 3 is Actors who are the intended users of the CAC. The top layer (Layer 4) is called Applications which are developed to fulfil the need for the various kinds of actors (citizens, drivers, traffic police etc.). These applications are based on the processed Context-data which are generated at Layer 2 and the need of the various actors in layer 3.

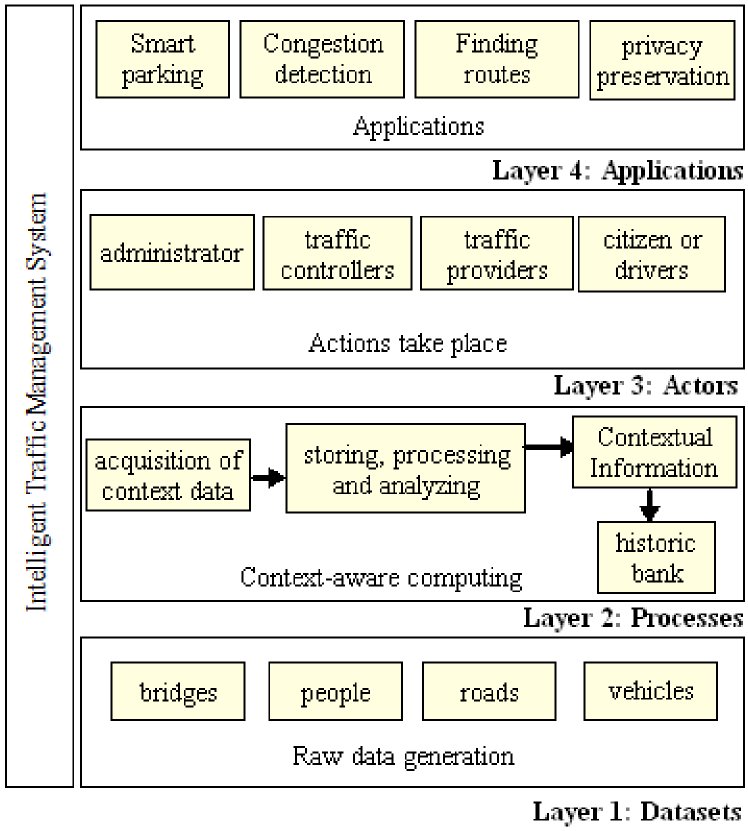

Figure 3: RA ITMS

Layer 1: Datasets

It is the bottom layer of our RA the types of data needed for ITMS are shown. Raw data are actually collected from millions of sensors which are installed on the vehicles or on the street junctions or from the travelers mobile phone or cars. Further, advance infrastructure like IoT also helps to capture the current data from the road. These data are then fed into the cloud. Pre-processing and processing of these raw data for establishing contexts are done in to the cloud.

Layer 2: Context-aware Computing

We already mentioned before that Processes can be viewed as Context-aware computing in our ITMS. This the middle layer of our RA and it is the central layer of the system. Basically, in Context-aware computing the system continuously monitors the environment and provides appropriate suggestions to users so they can take actions" (Subbu and Vasilakos, 2017).Thus, the use of CAC in ITMS could provide a better service environment. In fact, the context-awareness ITMS applications are built based on collecting data from different sources.
Here, we briefly describes the different stages of context life cycle which depicts how the raw data i.e. context moves to the context-aware system where the contexts are being extracted to a meaningful information. It can be assumed as the brain of the system. The life cycle consists of four modules to perform all the activities context-aware ITMS. These are (1) Data Acquisition or Data Collection, (2) Data classification and storing, (3) Data Processing and Decision Making and (4) Web and Mobile based Application.

Data Acquisition or Data Collection Module-Acquiring from diverse sources

Mainly sensors are used to measure a physical quantity and converted into digital signal for processing. Here data acquires from such type of heterogeneous sensors. Therefore, lot of different systems and sources the granular data are collected without having any integration among them. For a certain time interval, the huge amount of heterogeneous data collected with no standard format of these data. This makes it more challenging task. Further, measuring and collecting individual data in the dataset are also considered as challenges. For an example, identification of vehicle category or providing unique identification number for each vehicle is also necessary for this module. This module in ITMS provides accuracy, timeliness, and cost efficiency mechanism of data collection and also provides actual explanation of the root causes behind the increasing congestion level on the road. To implement this, sensing technologies like wireless sensor networks, cellular networks, mobile sensing have the potential solutions.

Data Classification and Store-Storing in databases

Pre-processing is done here. Due to the noise, sensor errors pre-processing of raw data is necessary. ITMS handles a huge amount of data. Data are collected from heterogeneous sources. Therefore, a standard classification of data representation is needed. Thus, ITMS should provide sophisticated mechanisms to fuse, aggregate, and exploit data as data have different data types from different sources. Further, data correlation is another challenge due to the lack of integration among different system. Thus, RDBMS may not be the proper solution. NoSQL or other unstructured databases (Hu et al., 2014) should be considered to store the data.

Data Processing and Decision making-Making inferences from contextual data

Data processing and making proper decision based on the processed data in another important task. After exploitation of data, it needs to be inference in a proper contextual meaning that demonstrates the real traffic condition otherwise it may incur wrong information. Therefore, it is necessary to converge many different data into single traffic condition. In addition, importance of data i.e. which data have more or less importance to the traffic is also a challenge to provide a better commute to the citizens. Furthermore, suggesting alternative route to avoid traffic congestion, availability of parking zone, average travel time are the very prominent decision making application to improve the overall traffic efficiency on road.

Web and Mobile based Application-Notifying Actors

It is already mentioned before that different user has different needs while travelling around the city. An efficient and reliable web and mobile based application may provide updated scenario of the traffic conditions. For an example, an incident on road police, rescue persons, medical team informed simultaneously and may reach to the incident point to provide the best efforts to handle the situation. This also improves the fast response time. In addition, citizens can calculate their travel cost, travel time before starts their journey.

Layer 3: Actors

In our proposed RA, actors are both internal as well as external component. They are categorized into four sub actors or users namely administrator, traffic controllers, traffic service providers and citizens or drivers. This is shown at the middle layer of the RA in Figure 3. They are accessing information regarding traffic system according their needs. For example, citizens are interested only cost effective journey without any delay during the travel.
Therefore, different users could take different actions. This is more likely to be a policy and management procedures. Administrators are on the top of it. They could decide policy and take actions to implement these policies for betterment of the citizens' urban city life style and funding for better infrastructural need. Traffic controllers control the real time traffic on road. Traffic service providers do advise and inform the citizens through TV, radio, websites regarding the current situation of the city. Table 1 shows the actors and example of the different needs that are typically activities by the different actors.
The activity diagram of different actors in RA is also depicted in Figure 4. It is also clear from the figure that processed data are used differently by the different actors intended for them. And it is also depicts diverse activity area of the actors.

Table 1: Lists of actors and their needs

Actors	Typical needs
Administrator	Policy Making: identify need for traffic policies and to understand impact of new polices. Statistical Report from historic database for the city Improving traffic flow
Traffic Controllers	Road traffic Route information panel

	Inform drivers Track vehicles
Traffic service providers	Advise Inform citizen and drivers using Radio, APP, TV, websites
Citizen or Drivers	Calculate fuel cost and travel time Find Parking Report road information such as accident

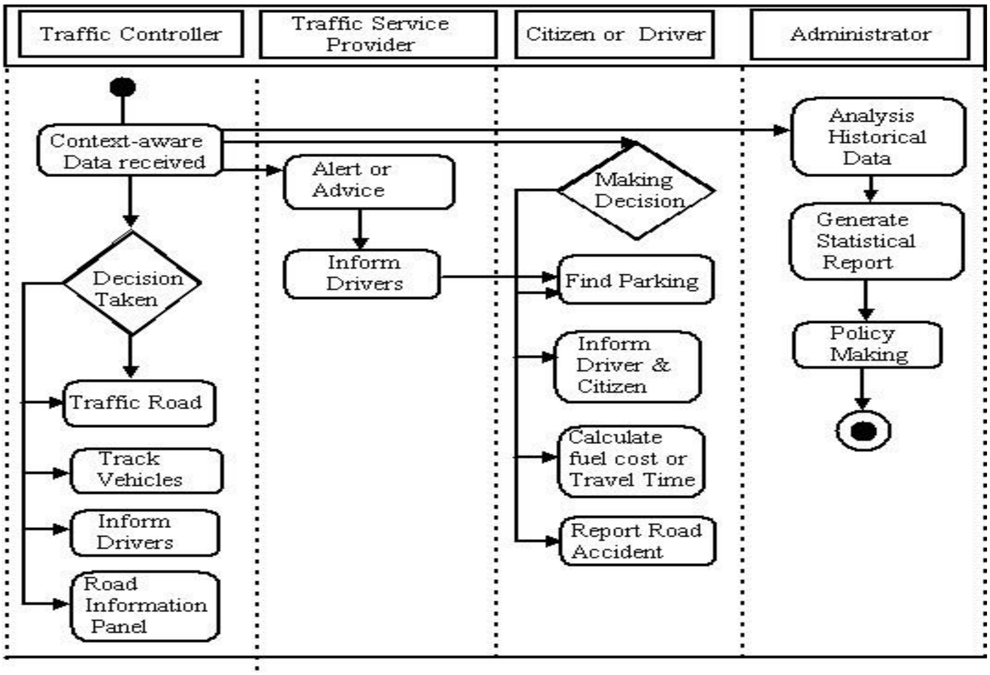

Figure 4: Activity diagram of the interactions among different actors

Layer 4: Applications

It is the top layer of our proposed RA. Different variety of applications is used based on the processed data in the third layer. Stakeholders have different needs and in this way can develop their own applications suiting their needs on top of the other layers. The applications include smart parking system, congestion detection, traffic flow detection, route planners, management information systems to detect congestion and pollutions and to simulate improvements and so on. The references architecture ensures that the privacy of the users can be guaranteed and that the data can be shared with others. In this way the needs of citizens, business and government can be accommodated.

Evaluation of the RA

In this section, ITMS RA is evaluated using an illustration. Outside the scope are the stakeholders hindering or contributing to the outcome (Axelsson & Granath, 2018). We selected the situation of a central traffic controller, but the RA is also suitable for decentralized control and other forms. For use the RA needs to be instantiated to a particular situation. The data source and actors need to be identified first. Figure 5 shows road traffic monitoring on road for the evaluation process. Following our framework, datasets generated on the road from installed sensors, CCTV cameras, in vehicle devices and with the help of the underlying infrastructure, can be collected and stored into a database. This is shown in the figure as marked 1 in the arrowhead line. The illustration shows the raw data generated on road such as type of vehicles which is measured by length of the vehicle, weight, chassis height, axle spacing, and axle weights etc., speed of the vehicles, number of vehicles on road at a certain time are sent to the database and the context are stored in different format and specification. XML-based or NoSQL based databases are used in this situation. Cleaning, error elimination, aggregation of all relevant data from different sources is done. Then processing of these data with the help of data mining and decision making algorithms are done. Privacy-enhanced mechanism ensures that privacy-sensitive data is into shared. Thereafter, contextual data are sent to the traffic controllers, historic databank, and traffic service providers. This is shown in the illustration by marking arrowhead lines as 2, 4 and 7 respectively.

The traffic controller controls and manages the road traffic according to the context and is marked as 3 in the figure. The traffic controller is sending the information related to traffic signal and controls the traffic lights. Information regarding bus route and arrival time to the bus stop is displayed on the display panel, control the speed limit of the vehicles for accident prone zone etc. The relevant contextual data also controls the traffic lights, display panels at the traffic junction. Data bout incidents and accidents are collected by the travellers and policy and directly send to the traffic controllers and to other travellers. This is depicted in the figure by marking 5.
Traffic service providers use some prediction algorithm on the data and then suggest advice and forecast the traffic condition, about incidents on road to the citizens. They may use web application, broadcast on TV and radio, mobile application i.e. sending emergency SMS to the citizens.
Finally, all aggregated and processed context is sent to the databank storing historic data for future analysis. The future analysis can help to predict the traffic pattern of the particular region in the city and can be used for making further policy of the ITMS. Table 2 describes the various challenges of traffic management system and explanation how the context-aware RA overcomes these challenges.

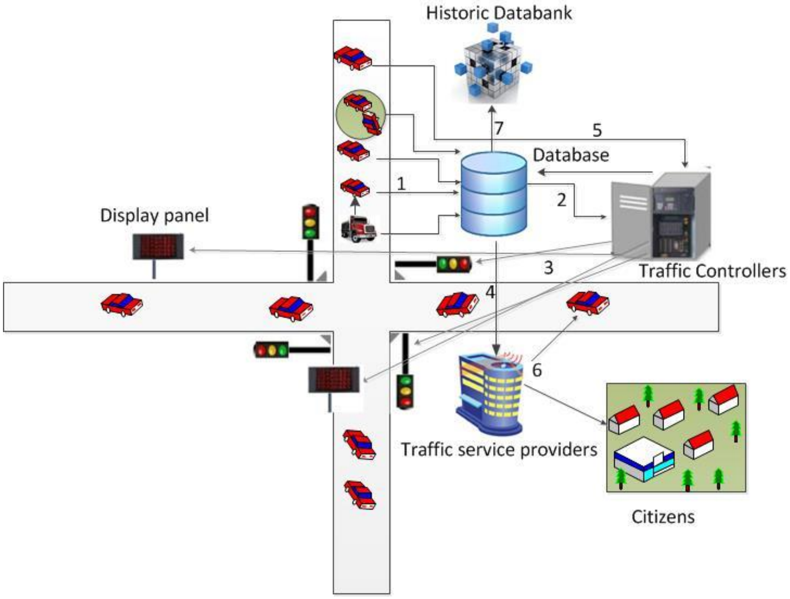

Figure 5: Process scenario for evaluation of the RA

Table 2: Evaluation of the Challenges

Challenges	Problem description	Solutions provided by RA
Heterogeneous datasets	Which type of data sources are needed for providing and explaining the traffic conditions on road.	The deployment of the wireless sensor nodes in the road environment, in-vehicle sensor devices, powerful cameras fitted in the roadside is capturing the significant amount of data for the ITMS.
Data gathering	Who is responsible for collecting data from heterogeneous sources?	In proposed RA, data acquisition and data collection module is responsible for the smooth collection of data gathering and conversion to a right format.
Data Processing and decisions	How can the data be integrated?	Data processing and decision making module processes data from various sources. Cleansing and verification techniques are used to identify the correct and accurate data. After generating a new knowledge of context, several prediction and decision making algorithms are used to make proper decision.
Data Management	How to handle a heterogeneous data deluge originating from a variety of sources in real-time.	This framework also capable of managing the huge amount of collected data. For heterogeneous data, the classification and storage module helps to manage these data.
Different Actors	What are the needs of the various users?	The framework also focused on data needs for different users or actors and it is to be

		processed differently and visualized for the target audience.

The goal of the RA is to codify experience in architecture to enable reuse by others. The RA ensure that essential components like storing historical data, use of data by different users like traffic controllers and travelers is included. Inclusion of these components is essential for gaining economic benefits like faster travelling time and less pollution. The RA integrates different layers and sub-system into a single architecture. It also provides comprehensive monitoring and visualizing of traffic in real-time. The RA can be used for central control of traffic, but also used for decentral control. It improves road safety through incident detection and response time thus provides value-added traffic information services to the citizen. It reduces road congestion by intelligently managing traffic on the roads. In addition, it also helps to demonstrate civil responsibility by disseminating the road information to the public via radio, TV, web portal etc. to improve traffic system.

Conclusion

Improving traffic congestion efficiency is an important economic problem resulting in wasting people's time and resulting in pollution. Traffic can be improved by either improving the existing road infrastructure or by using ITMS to improve the usage of existing infrastructure. The latter requires less economic investment and at the same time can reduce pollution and energy consumption. In this paper, we proposed a context-aware RA for ITMS providing guidance for designing ITMS to overcome the challenges of dealing with 1) heterogeneous datasets 2) data gathering, 3) data processing, 4) data management and 5) supporting various types of data users. The context-aware RA deals with these challenges. The RA deals to support the system to extract a meaningful context from the raw data. The ITMS has four hierarchical layers mainly 1) Datasets, 2) Processes, 3) Actors, and 4) applications to solve the above mentioned challenges and it is explained with an illustration. The RA can be used by decision-makers, architects and designers. It provides an understanding of the various actors about what their roles are, how the technology offered by these actors should be integrated and aligned and can be used for ITMS. The RA provides the means to overcome the 5 challenges and ensures that essential components like integrating data, storing historical data, use of data by different users is included and that projects do not find out at a later stage. Inclusion of these components is essential for gaining economic benefits like faster travelling time and less pollution. Significant challenges are in the middle layer in terms of data gathering, data storage, data aggregation and data processing and decision making. For data gathering, there is a need for developing standard formats.

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