SMART CITIES – DEPENDENCE OF INTELLIGENT TRANSPORTATION SYSTEMS ON CLOUD COMPUTING AND TECHNOLOGIES

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Abstract: *With the development of Cloud technologies we finally have the tools and the solutions needed to start planning and executing an efficient urban transportation. The paper presents concepts and ideas toward Smart City intelligent transportation and traffic, namely agent-based traffic management systems and vehicular Cloud computing. It discusses their main characteristics, architecture and provides examples where such technologies are already implemented. Lastly, it outlines some challenges that arise from the application of Cloud computing and the change of the city into a Smart City.*

Keywords: SMART CITY, BIG DATA, CLOUD COMPUTING AND TECHNOLOGIES, INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

I. Introduction

We live in the era of Big Data, where knowledge lies inside of an unstructured, heterogeneous pool of information. In this regard, the rise of cloud computing makes it possible to build up a frame and infrastructure for analysis, storage and management of data and to unlock its full potential. Furthermore, this pool of resources will be available to everyone on-demand.

Cloud computing holds also great promises to solve global and local issues that are impossible with small-scale data.[1] The concept of smart cities, for instance, relies mainly on using big data for deeper insights about population behaviors and patterns to tackle today's biggest challenges in the urbanized world. According to IBM, it requires further mobile and social technologies to address problems immediately and for better engagement.[2] It should be, however, noted that there are also considerable number of challenges that should be solved to unleash the potential of this big data, including: managing diverse sources of unstructured data with no common schema, real-time analytics, suitable visualization, etc.

Intelligent infrastructure would improve the capacity, efficiency and quality of life in the city to make it more "livable". It could enhance travel experience, solve traffic and pollution issues and increase safety and security.[3] Barcelona is setting out a notable example in this regard. The city has stated that it will use smart technologies to reduce traffic and in addition to that to offer smart parking technologies. It will also setup sensors throughout the whole infrastructure to fight air pollution and noise. In this way, the city government plans to reduce traffic by 21% in the next years. This result only comes to show that cloud computing and big data is used to understand problems and trends related to the city traffic and infrastructure and to properly address them by processing in cloud-enabled large-scale sensor networks for gathering and analyzing relevant data.[4]

The paper presents concepts and ideas toward smart city transportation and traffic, namely agent-based traffic management system and vehicular cloud computing. It discusses their main characteristics, architecture and provides few examples where such technologies are already implemented. Lastly, it outlines few challenges that should arose from the usage of cloud computing and the turning of the city into a smart city.

II. Smart Cities and Cloud Computing

Cisco offers a general definition of the emergence of digitalization, calling it the "Internet of Everything" (IoE). IoE brings together "people, process, data, and things to gather relevant and valuable data and to turn information into action".[5] In this sense, cities globally have the potential to claim $1.9 trillion in value from IoE over the next decade, according to Cisco's study. In the smart city, everything will be optimized and improved, from education, health services and government to infrastructure, transport and traffic.

Smart urban transportation systems use secured cloud technologies to produce big data, involving billions of devices that communicates, computes and updates real time all together. By relying on cloud computing to store, manage, modify data, we could find numeral solutions for most of our society's transportation problems such as traffic, pollution inefficiency, etc. These problems would be tackled with service-generated-big-data and big-data-as-a-service that use cloud computing and effectively manages the data with a reduced cost.

In 2013, Zimmerman proposed integration model for service-oriented architecture (SOA) for systematic development, diagnostics and optimization for big data applications. His conceptual framework of urban smart city is based on multilayered Internet of Things (IoT) - vehicular data cloud platform with an intelligent parking cloud service and a vehicular data mining cloud service. Fig 1. describes the whole architecture.[6]

III. Agent Based Traffic Management System Technology

Nowadays, the use of motor vehicles is a widespread practice with people owning several different vehicles. This results in problems in infrastructure and traffic all over the word. Furthermore, traffic leads to environmental issues, financial loses and waste of time and above all, a significant increase in car accidents. Therefore, there is an urgent need to improve traffic

[1] Villars, R. L., Olofson, C. W., Eastwood, M. (2011). Big Data: What It Is and Why You ShouldCare. IDC, 6, 1–14.

[2] Harrison, C., B. Eckman, R. Hamilton, P. Hartswick, J. Kalagnanam, J. Paraszczak, and P. Williams. "Foundations for Smarter Cities." IBM Journal of Research and Development 54, no. 4 (2010): 1-16. doi:10.1147/jrd.2010.2048257.

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management and cloud computing provides the chance for intelligent traffic development.

Nowadays, many heterogonous devices are interconnected on the traffic monitoring system using IoT. The major issue of such systems is the transfer of data over different standards, formats, hardware, protocols etc. Another issue is the necessity of an intelligent interface and the ability to access different services and applications. It seems that mobile agents are a convenient tool to handle these issues, provide means for communication among such devices and handle the IoT interoperability. In this regard mobile agents are a great solution for low bandwidth and disconnection, passing messages to undefined destinations and across network.

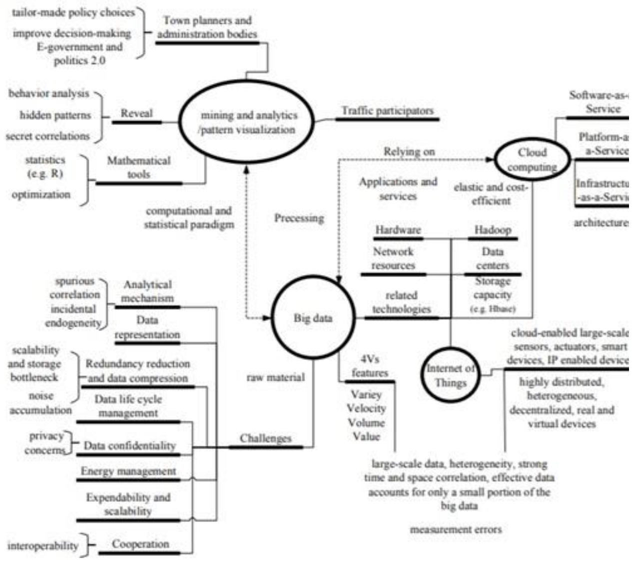

***Fig.1** The conceptual framework of urban smart transport based on Cloud and IoT*

Agent Technology was used back in 1992 in traffic management systems, however they started to become popular in 2004, especially when it comes to mobile multi-agent traffic system.[7] The characteristics of mobile agents are autonomy, mobile and adaptive. These features make them suitable to handle problems like inconsistencies and uncertainties. In 2005, the agent-based distributed and adaptive platforms for transportation system (ADAPTS) was proposed as an urban traffic management system. Currently ADAPTS is part of a system which takes advantage of mobile traffic strategy agents to manage and update a road map in real time. The concept of ADAPTs has three layers–organization, coordination and execution.[8]

The organization layer is the core of the system (Fig.2). Its characteristics are four major functions: agent-oriented task decomposition, agent scheduling, encapsulating traffic strategy and agent management. As one traffic strategy has been proposed, a strategy code is saved in the traffic strategy database. Typical traffic scenes, which are stored in typical intersections database, can determine the performance of various agents. If the urban management system cannot deal with a transportation scene with its existing agents, it will send a traffic task to the organization layer for help. The traffic task contains the information about the state of urban transportation. It can be decomposed into a combination of several typical traffic scenes. With the knowledge of the most appropriate traffic strategy agent to deal with any typical traffic scene, the system takes advantage of the strategy agent and manages a road map. The last part is setting up an applicant testing to test the performance of the urban-traffic management system based on the map showing the distribution of agents.[9]

In addition to what was said before, the urban traffic management system requires traffic control, detection, guidance, monitoring, and emergency subsystems to be completed. As for the performance, the improvements and the implementation of new subsystems, new traffic strategies must be introduced constantly.

So, they must generate, store, manage, test, optimize, and effectively use many mobile agents to support this complex cloud environment (Fig.3). Moreover, they need a comprehensive, powerful decision-

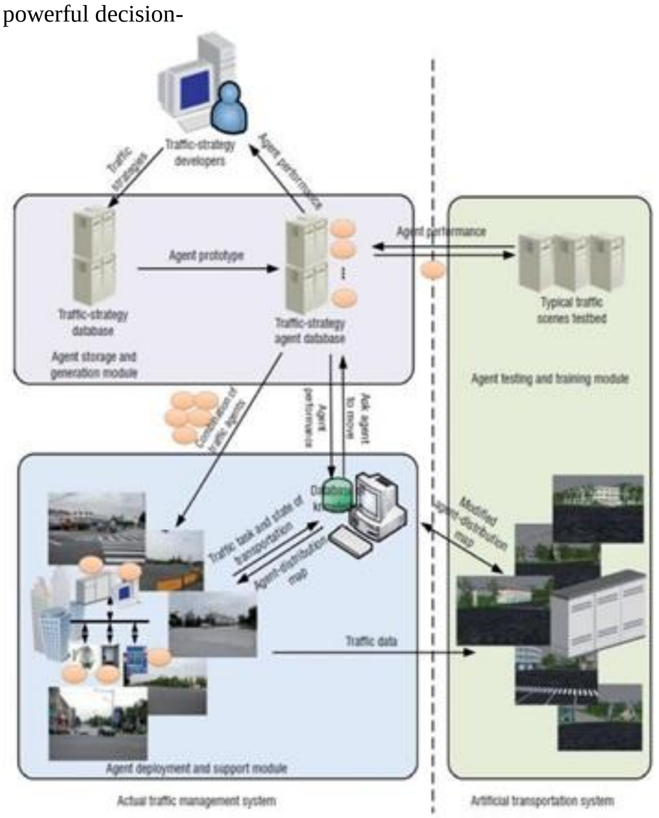

***Fig.2.** Organizational Layers of Agent Based Distributed Transportation System (Wang, 2005)*

support system with a friendly interface to communicate with traffic managers. To achieve this superior performance, however, testing a large amount of typical traffic scenes requires enormous computing resources.[10]

As an example, the transport for London (TfL) manages all public transportation in the capital, gathering data across all the city's transit services. Data collection keeps the transport sensitive to issues within the subway system. And in a case of an issue, it deals with the warnings from passengers about the disruptions along their route via their mobile device. This service is found by 83 percent of Londoners to be very useful.

Ridership data could also prevent overcrowding, as real-time updates about ridership and space on public transit could encourage people to re-think their route, clearing up some of the issues caused by volume in the major transit hubs.

[7] Chen, Bo, and Harry H. Cheng. "A Review of the Applications of Agent Technology in Traffic and Transportation Systems." IEEE Transactions on Intelligent Transportation Systems 11, no. 2 (2010): 485-97. doi:10.1109/tits.2010.2048313.

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[10] Yu, Xi, Fuquan Sun, and Xu Cheng. "Intelligent Urban Traffic Management System Based on Cloud Computing and Internet of Things." 2012 International Conference on Computer Science and Service System, 2012. doi:10.1109/csss.2012.539.

Fig.3. *Urban-Traffic Management Systems Based On Cloud Computing. (Fuguan, Cheng, 2012)*

Architecture

According to the basic structure of cloud computing, an intelligent traffic clouds have four architecture layers: application, platform, unified source, and fabric.[11] The application layer contains all applications that run in the clouds, such as agent generation, agent management, agent testing, agent optimization, and traffic decision support (Fig. 4).

The platform layer is made of advanced transportation system, or ATS. It runs a population synthesizer, weather simulator, path planner, 3D game engine, etc. to provide services to upper traffic applications and agent development. The unified source layer administrates the raw hardware resource in the fabric layer and provides infrastructure as a service. It uses virtualization technologies such as virtual machines to hide the physical characteristics of resources, ensuring also safety of data and equipment. Lastly, it provides an access to interface for the upper computing resources.

All those will help solve information silo problems in urban traffic and help gather useful information in the traffic data. Lastly, the fabric layer contains the raw hardware level resources such as computing, storage and network resources. The intelligent traffic clouds use these resources to provide the demand of urban-traffic management systems and testing, storage, and performance.[12]

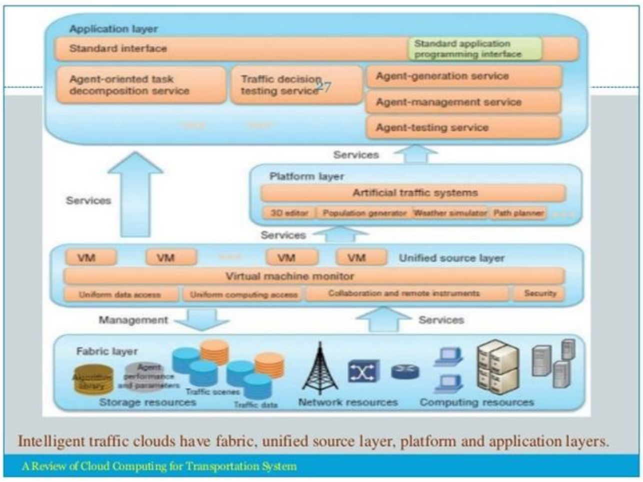

Fig.4. *Architecture of Urban-Traffic Management (Fuguan, Cheng, 2012)*

IV. Vehicular Cloud Computing

Improvements in city infrastructure, traffic and safety management would also require enhanced design and functionality of vehicles. Therefore, in the past years the concept of Vehicular Ad-Hoc Network (VANET) has gained attention. VANET is a set of moving vehicles in a wireless network that apply the Information and Communication Technology (ICT) to provide an advanced service of traffic management and transportation.[13]

There are a few solutions that have been proposed to tackle the challenges of these networks. Vehicular Cloud Computing (VCC), for instance is one such solution that could has a significant impact on traffic management and road safety by using resources, such as computing, storage and internet for decision making. This solution is an innovative approach that takes advantage of cloud computing to offer the drivers of VANETs in a pay-as-you-go way. VCC aims to minimize traffic as well as accidents travel time, pollution and to ensure energy safety and real time to drivers. Furthermore, VCC provides a technically feasible incorporation with the network for better road safety and secured intelligent urban traffic systems.[14]

1. Architecture

The architecture of vehicle cloud computing is based on three levels: in the vehicle, in communication and in the cloud. As shown in Fig. 5, the first layer is the inner layer of the vehicle, which is responsible for monitoring the health and mood of the driver and collecting information in the vehicle, such as pressure and temperature using body sensors, environmental sensors, smartphone sensors, internal vehicle sensors, inertial navigation sensors (INS), and driver behavior to predict the driver's intentions.[15]

The information is after that collected through sensors and sent to the cloud for storage or use to software programs in the application layer. Every vehicle has an on-board-unit (OBU) that contains a navigation system integrated with a map. OBUs has also wireless broadband communications to transmit data through 3G or 4G devices, Wi-Fi, WiMAx, wireless access in the vehicle or dedicated short-distance communications.[16]

The next layer is the communication layer, which includes the vehicular-to-vehicular (V2V) systems via DSRC Dedicated Short Range Communications, or DSRC. In the case of abnormal behavior on the road, Emergency Warning Messages (EWMs) will be created and forwarded to the cloud storage as well as the vehicles around. The messages will contain all valuable information of "offender", such as the location, speed and moving direction. The second component of the communication layer is vehicle-to-infrastructure (V2I), which enables the exchange of operational data among vehicles, infrastructures and the cloud over wireless networks. The V2I should increase safety level of vehicles on highways and reduce percentage of crashes, for instance.[17]

The cloud is the last layer of the VCC architecture, it can calculate massive and complex data in a minimum time. The cloud layer itself consists of three internal layers: application, cloud infrastructure and cloud platform. The application layer considers several applications to which drivers can access remotely, for example fuel feedback, environmental awareness, human activity

[11] I. Foster et al., “Cloud Computing and Grid Computing 360-Degree Compared,” Proc. Grid Computing Environments Workshop, IEEE Press, 2008, pp. 1–10.

[12] Yu, Xi, Fuquan Sun, and Xu Cheng. "Intelligent Urban Traffic Management System Based on Cloud Computing and Internet of Things." 2012 International Conference on Computer Science and Service System, 2012. doi:10.1109/csss.2012.539.

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[17] Bordley L, Cherry CR, Stephens D, Zimmer R, Petrolino J. Commercial Motor Vehicle Wireless Roadside Inspection Pilot Test, Part B: Stakeholder Perceptions. Transportation Research Board 91st Annual Meeting2012.

detection, etc. Furthermore, the cloud infrastructure has two components: cloud storage and cloud computation. The data gathered by the inside-vehicle layer will be stored in the geographic information system (GIS), a road traffic control device or a storage system based on the type of applications. The computation part is used to calculate the computational tasks which provides faster performance. Lastly, the sensors, for example, the health recognition sensors will send data to the driver behavior database in the cloud storage.

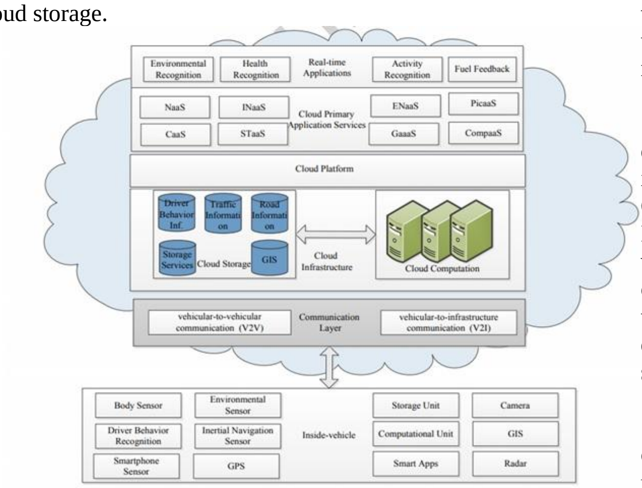

Fig. 5 *Architecture of Vehicular Cloud Computing (Lin, Zeng, Guo, 2013)*

Vehicular cloud can be deployed by a static infrastructure that is able to provide support and management of various events. In urban areas, such infrastructure contains cameras, traffic lights and utility or street-light poles. In this way, big data is helping for example Tel Aviv to improve and streamline its traffic through sensors, cameras and third-party applications that allow traffic control and the ability to see what is going on across the city. This gives them power to pinpoint and tackle any issues accordingly. One thing that is being done, for example, is to rearrange traffic lights scheme during a traffic jam and in this way to break up the congestion and potential accidents.

Tel Aviv has in general the potential to become a great example for road traffic and infrastructure efficiency. According to the design consultancy Moment, sensors could be placed to form an accessible transit system for those who cannot drive—children, the disabled, and the elderly people. To address coming needs, these sensors would be embedded into the infrastructure of the public transportation and would enable all parties in the public traffic to keep track of any dependents as they use public transit. Once a dependent party uses a public transport and has a device which sends signals to the sensors in the bus, train, or cab and vice versa, the caregiver would be able to know where they are in their journey.[18]

V. Challenges of Cloud Computing in Smart Cities

There are some notable challenges associated with cloud computing which might have a significant impact over the implementation of smart transport and traffic. Some of them may even cause a slowdown when delivering services in the cloud or security breaches which might be essentially harmful in the contest of public services and solution. On the other hand, if resolved in the planning stages, they also represent opportunities and could lead to greater technology advancements.[19] Hereby, some of the most important challenges towards smart city infrastructure will be mentioned:

1. Security and Privacy — these are two of the most mentioned issues surrounding cloud computing. The concern is related to storing a well-secured data and monitoring the use of the cloud by the service providers. Breach in security will lead to a slowdown in the deployment of cloud services.

Issues of such kind could be addressed, for example, by storing the information internal to the organization, but allowing it to be used in the cloud. For this to occur, though, the security mechanisms between organization and the cloud need to be strong.

2. Lack of Standards — cloud interfaces are well documented, however, no standards are associated with them, so it is unlikely cloud technologies to be compatible to each other. The Open Grid Forum is developing an Open Cloud Computing Interface to resolve this issue and the Open Cloud Consortium is working on cloud computing standards and practices. The findings of these groups will continue to develop over time, but it is unknown whether they will address the needs of the people deploying the services. However, keeping up to date with the latest standards as they evolve will be a step forward in solving the issue.

3. Continuously Evolving — user requirements are continuously evolving, as are the requirements for interfaces, networking and storage. This means that a “cloud,” especially a public one, does not remain static and is also continuously evolving.

4. Compliance Concerns — the Sarbanes-Oxley Act (SOX) in the US and Data Protection directives in the EU are just two examples of compliance issues affecting cloud computing, based on the type of data and application for which the cloud is being used. The EU has strict laws for data protection across all its members, but in the US data protection is different and can vary from state to state. One possible solution to this challenge is a Hybrid cloud deployment with one cloud storing the data internal to the organization.

VI. Conclusion

In the recent years, society is starting to understand the impact and significance of using data collected for our advantage. Emergent technologies in both big data and cloud storage have the potential to open possibilities in terms of what cities can do for their citizens.

Local authorities have long been aware of the need for integrated land-use transport models to make accurate estimates of travel and transportation demand and to reduce issue such as high traffic, pollution and healthcare problems. With cloud technologies they finally have the tools and the solutions needed to start planning and executing plans for making urban transportation more efficient. This process will involve all participants in the transportation system. Cars, buses, trucks, lights, sensors, infrastructure and even people will be interconnected to form the traffic management system of the future. Everything will be able to send and receive data and this communication will lead to a better transportation, infrastructure and a city. All of these would be possible only with the use of Cloud computing technologies, thus its importance will increase in the years to come.

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