A Framework of Future Innovative Urban Transport

Xisong Dong, *Member, IEEE*, Jiehan Zhou, Bin Hu, Jukka Riekki, *Member, IEEE,* Gang Xiong*, Senior Member*, *IEEE*, Feiyue Wang, *Fellow*, *IEEE,* and Fenghua Zhu, *Member, IEEE*

***Abstract*—Rapidly growing urbanization is putting more pressure on the well-being of citizens and the environment. Applying the latest ICT technology to address urban transport challenges is a key strategy to release the new innovation powerhouse of urbanization. This paper introduces a framework of future Innovative Urban Transport (IUT), to support next generation urban transport, based on IoT, 4G, Big Data, Cloud Computing and other novel ICT technologies. We present the construction of the framework, its reference architecture, and contribution to the environmental and socially important impacts. IUT aims to advance the existing smart city transport, to foster urban innovations that maximize the well-being of citizens while minimizing the negative effects like traffic congestion, air pollution high resource congestion, and traffic accidents.**

I. Introduction

Human society is rapidly urbanizing around the world. In Europe three out of every four people live in cities today, and by 2050, it will be four out of every five [1,2]. In China, from 2002 to 2011, the urban population increased by over 188 million and the average annual growth of urban population is about 19 million people. The average urbanization rate is 1.35% [3]. Ever-growing urbanization, on the one hand, is seen as the new powerhouse of innovation to overcome socio -economic challenges and to improve the quality of life [4]. On the other hand, urbanization is putting ever more pressure on the well-being of citizens and the environment. For example, with the accelerated process of urbanization, urban population and the amount of urban motor vehicles increase sharply. In 2014 China car sales reach 2.35 million, an annual increase of 6.86% [5]. In November 2015, the EU passenger car market recorded a very strong increase (+13.7%), marking the 27th consecutive month of growth and totaling over one million units [6]. As a result, the growth rate of transport demand exceeds the growth in road capacity, which results in serious traffic problems, such as urban traffic congestion, air pollution, high resource consumption, and reduced traffic safety. These prominent challenges hinder the sustainable development of urban transport.

American TRAVET, a real time route guidance and services system, consists of a traffic management center, an information and service center, and vehicles equipped with navigation systems [7]. In Britain, ITIS provides traffic information services based on floating vehicles (approximately 50,000 now), including vehicle travel time prediction and stolen vehicle tracking [8]. German VISUM Online platform is an advanced travel information system (ATIS), and its core algorithm combines data from sensors, floating vehicles and traffic accidents [9]. Trafficmaster provides real-time traffic information in Europe for automotive equipment, mobile service providers, and fixed or mobile network providers [10]. In Finland, a traffic portal provides navigation tools and presents real-time information about traffic situation from various sensors, including laser range sensors, GPS, and inductive magnetic loops [11]. Netherlands and Denmark are carrying out a small scale test based on dynamic traffic information using floating vehicles. Vehicle Information Communication System in Japan is a representative of advanced traffic information systems, including data collection, information processing, editing and publishing functionalities [12]. On-board device VICS is widely used in Japan. The OMNI project was carried out for addressing the problem of protecting investments in telematics infrastructure by facilitating the re-use of legacy infrastructure by new transport telematics applications [13]. TRANSPLUS addressed urban transportation challenges by integrating land use and transport planning at urban, regional and national level and by creating a common understanding of the issues at stake and the possible ways to tackle them [14]. SafeCloud studied Cloud infrastructures in transport data transmission, storage, and processing [15]. The project e-Awake addressed IUT challenges by developing a high performance embedded system that allows vehicle integrators to easily design and tailor their solutions [16]. The ongoing project EuTravel aims to provide mobility services by enabling travelers to organize multimodal trips, promote travelling experience, and support travel industry players towards realizing EU-wide shared seamless mobility [17]. Intelligence to drive (I2D) project aims to develop a car telematics platform to collect raw data from the driving dynamics, transform the data into valuable information, and make the information available to all potential road users [18]. OPTIMUM, Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility aims to provide the required interoperability, adaptability and dynamicity in modern transport systems [19]. The ongoing SocialCar

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X. Dong is with the State Key Laboratory of Management and Control for Complex Systems, Institute of Automation , Chinese Academy of Sciences, (e-mail: xisong.dong@ia.ac.cn).

J. Zhou and J. Riekki are with the Center for Ubiquitous Computing, University of Oulu, Oulu, Finland (e-mail: jiehan.zhou@ee.oulu.fi, jukka.riekki@oulu.fi,).

B. Hu is with the State Key Laboratory of Management and Control for Complex Systems, Institute of Automation , Chinese Academy of Sciences, Beijing, China (corresponding author to provide e-mail: binhu@ia.ac.cn).

G. Xiong is with the Cloud Computing Center, Chinese Academy of Sciences, Dongguan, China (e-mail: xionggang@casc.ac.cn).

F. Wang is with the Qingdao Academy of Intelligent Industries, Qingdao, China (e-mail: feiyue.wang@qaii.ac.cn)

F. Zhu is with the Beijing Engineering Research Center of Intelligent Systems and Technology, Institute of Automation, Chinese Academy of Sciences, Beijing, China (e-mail: zhufh@casc.ac.cn).

project aims to develop an ITS based on an innovative approach to transport demand management, and more specifically to carpooling in urban and peri-urban areas [20]. Enhancing real time services for an optimized multimodal mobility relying on cooperative networks and open data, TIMON aims to increase the safety, sustainability, flexibility and efficiency of road transport systems by taking advantage of cooperative communication and open data processing through a web based platform and mobile applications [21]. HyCloud presents a hybrid Cloud Hub solution to store, access and back-up digital content safer, faster and cheaper [22]. There are many other efforts that utilize modern communications, electronic, and computing capabilities to assist in the dissemination of information, management of traffic flow and transport networks, e.g. connected vehicles [23, 24], Cloud Computing [25], Internet of Things [26, 27], and Big Data [28-30].

The efforts to tackle the urban transportation challenges need to be continued in a more integrated and co-operative fashion. The crucial role of transport in urban areas places research and development for fostering sustainable development of urban transport in a major role to realize open and sustainable urban innovation ecosystems. This paper proposes a framework of Innovative Urban Transport (IUT), which has the potential to play a key role in the future of open and sustainable urban innovation ecosystems and releasing the innovation powerhouse.

II. INNOVATIVE URBAN TRANSPORT (IUT)

Innovative Urban Transport (IUT) aims to develop a reference architecture using IoT, 4G, Cloud Computing, and Big Data technologies which are identified as an important part of the ICT road mapping activities for innovative ecosystems. In particular, IUT focuses on studying and developing an optimized, operational, standardized and referable urban transportation environment through cooperation and utilizing the state of the art results and practices of innovation ecosystems. IUT can support also developing open and sustainable urban innovation ecosystems in innovating technologies, applications and services.

A. The construction of IUT

IUT has large-scale transport data processing in its core. Data produced by the comprehensive transport data sources is analyzed and integrated with data storages and data mining, to ultimately provide support and services for governmental decision-making and public transport. The IUT consists of the following sub-platforms:

1) IUT Network Platform

IUT Network Platform can provide a flexible, dynamic, high transfer capacity and coverage, and optimized communications for IUT services for collecting transport data based on wireless communication technology. IUT network platform consists of Wireless Sensor Networks (WSN) in transport (e.g. sensors in vehicles, infrastructures, DSRC, ZigBee, Wi-Fi-based networks), which provide significant improvements in the quality and quantity of data and performance measures, enabling a wide range of applications from traffic signal control, to freeway management, to traveler information systems, and parking management systems. IUT network platform also includes vehicle networking (Internet of Vehicles, IoV), which is an interactive network of vehicle position, speed and route information. Through IoV, all vehicles can be data sources. The resulting large amounts of IUT data can be analyzed and processed in order to calculate the best routes, road conditions and arrangements. Integrating IoT, WSN, IoV, and 4G-based data communication networks, IUT Network Platform can survey the state-of-the-art, select components for the platform and specify the additional components and APIs required to integrate these components together and to provide external interfaces. IUT Network Platform connects sensor nodes, other embedded devices and mobile terminals into minimum latency and optimized network. With the support of IUT Network Platform, every IUT “Thing” will be connected and able to exchange information by themselves, including IUT “People” who are using IUT services. The success of IUT will depend on a convergence broadband wireless access technologies with capabilities of supporting high speed data communication.

2) IUT Cloud Platform

Cloud Computing can strengthen IUT by storing and processing the collected information (from traffic lights, parking meters, cameras, urban sensors, etc.) and supporting the governmental department in making informed decisions on real-time traffic scheduling. Cloud-based transport management services are being provided based on the concepts of infrastructure as a service (IaaS), platform as a service (PaaS), and Software as a Service (SaaS). IUT Cloud Platform has multi-center structure, capability to expand elastically and merge sub-Clouds, VPN cluster across sub-Clouds, local hot backup for fault-tolerance, remote redundant backup mode, real time Cloud service monitoring, etc. Integrating with Cloud Computing, IUT Cloud Platform integrates mixed Cloud modes to create one high-available infrastructure in order to store and process data produced by the devices and to realize services, finally to support the intelligent transport for stable and efficient 24x7 services. The platform facilitates a new way of designing, developing, testing, deploying, running and maintaining applications on the Internet, and explores a global and scalable approach for the integration of IUT Big Data and on-demand Web services.

3) IUT Data Analytics Platform

IUT services are based on real-time data traffic collected by various sensors like radars, magnetometers, inductive loops, accelerometers, GPS, vehicle terminals, and cameras and by social media through IoT devices and mobile phones. IUT needs to handle vast amounts of complex and diverse data. IUT Data Analytics Platform communicates with IUT network platform, receives traffic information and integrates signal control systems, video surveillance systems, illegal evidence forensics systems, GPS vehicle location tracking system, traffic guidance system, vehicle information management systems, and so on. IUT Big Data include data on IUT people, things, places, and services. This data is characterized by large volumes, complex data sets, and time-constraints.

IUT Data Analytics Platform provides data applications and services by analyzing sensor data, by mining knowledge and by data modelling. The platform supports data analytics by applying Big Data analysis and machine learning approaches to recognize and optimize urban transport. Particularly, Big Data covers Big Data storage, Big Data analysis and Big Data management. Integrating with existing Big Data technologies such as Hadoop solutions and MapReduce mechanisms, IUT Data Analytics platform creates a basis for analyzing the integration of transport Big Data, data processing and multi-dimensional data mining and data security, to eventually build a comprehensive IUT information center to provide IUT information services. IUT Data Analytics Platform provides analysis results for services supporting the public, enterprises and governance. The IUT governance services include government departments regulatory support, mainly to provide sophisticated geographic information services, traffic management services, emergency response services, roadside parking space regulatory services, public transport and other regulatory services. The IUT public services include refined management information services, accurate real-time traffic information services, real-time vehicle information services, traffic guidance services, and parking information based on Web or mobile applications. The IUT enterprise services provide enterprises with value-added services, mainly refined geographic information, vehicle scheduling and decision support, and business data analysis.

4) *IUT Piloting*

The objective is to assemble the IUT platform from the selected components, implement the required additional components and APIs and to pilot the built prototypes. The pilots will focus on verifying the novel components and APIs integrating the selected existing components together. Infrastructures and systems deployed during previous projects will be used extensively. Typical pilots include intelligent infrastructures, intelligent parking, intelligent public transport, private car management, intelligent monitoring and administration, personalized guidance and services, and assisted/automatic driving. IUT would enhance and extend the existing pilots, particularly, focusing on piloting public transport, user-oriented information provisioning and Intelligent Monitoring and administration.

B. *The ITU Reference Architecture*

IUT aims to research and develop novel methods and tools for the support of the growing issues of urbanization, both through an analysis of the state-of-the-art of technology and research (SOTA) and state-of-the-art-practices (SOAP) and through the design and development of IUT Network Platform, IUT Data Analytics platform, and IUT Cloud Platform. IUT SOTA and IUT SOAP deals with an assessment of the available solutions and methodologies and links with IUT those that can be applied in the development, implementation, evaluation and monitoring of IUT solutions. In the SOAP study, also the legislation and regulation challenges will be surveyed.

IUT will target at understanding and identifying IUT instrumentation and infrastructure, IUT telecommunication, IUT legislation/regulation, IUT Big Data, IUT data analysis, and IUT services and applications. The combination of utilizing the existing results, fundamental theories research, and iterative experimental verification is the main methodology adopted to carry out it.

Finally, apart from the IUT technologies, the overall aim is also to review IUT governance mechanisms, IUT data usage and security policies, compare IUT legislation and regulation to define a common specification and identify the future collaboration opportunities seeking 4G and IoT in the key urban transport domain, and the integration with other ICT developments and applications/services (e.g. social networks, Information centric networking).

IUT Reference Architecture (Figure 1) defines an innovative operating environment where all IUT systems and applications cooperate. It has typical frontend features such as user authentication, administration management, and data management features (provisioned from the Cloud). To approach the concept of IUT, focus is on open Big Data, Network Platform, Cloud Platform, Data Analytics Platform, and mobile devices. Most IUT services are provided from the Cloud Platform. The system is modular so that features can be removed and new features added as needed.

A core element of the reference architecture is the IUT data repository where data from the people, vehicles, traffic infrastructure data, traffic geoinformation, road infrastructure, traffic services, and traffic infrastructure. The platforms facilitates the stakeholders' interaction with the IUT services through the following high level interactive environments:

- The data sharing and interactive environment offers the major stakeholders (government officials, politicians, public/activist groups, academic researchers, media, etc.) an environment for customization, exchange, integration, data exchange specification, service tracking, and quality monitoring.
- The IUT operating environment is the way to provide logic business processing for optimizing route, routing identification, information inquiry, transport destination, GIS information, GIS analysis, GIS map, GIS mapping, etc.

Taken together, these elements and architecture of integration will offer online all the necessary services and applications to assist the IUT.

IUT Applications and Services provide the public with personalized and value-added information and services through mobile Internet (i.e. mobile applications):

- Mobile-based IUT information services include traffic video, images and other multimedia, parking, real-time public transport, travel planning, subway information, taxis inquiry, driver training, and traffic information.
- Internet-based IUT information services include real-time traffic, traffic video, real-time bus, taxi distribution, online bus ticket inquiries, dynamic parking information, subway information and advice. These services also include scheduling transport and travel before the trip.
- Augmented Reality (AR)-based dynamic IUT navigation and intelligent IUT warning services. Instead of the traditional two-dimensional virtual navigation, AR-based intelligent transport,

according to real data collected in the field, are processed to reproduce realistic dynamic real three-dimensional road.

IUT will explore the future cooperation on transport infrastructure and real-time updates of data extraction, driving behavior analysis and early warnings, and forecasting travel behaviors.

C. Contribution to the environmental and socially important impacts

IUT will affect the broader social sphere by addressing urban transportation challenges. Contribution to creating urban innovation ecosystems will advance the development of services and applications and result in better quality of life. Providing innovation tools for citizens as well supports participatory and creative citizens, communities and social actors. In this sense, IUT will advance socially sustainable, vibrant and inclusive societies, endowing them with inherent innovation dynamics.

In economic terms, IUT platform yields very significant benefits. Through it, the governmental agencies can monitor transport and make schedules more efficiently. People can use transport and roads more proactively and productively. The enterprises and value-added service providers can promote their services in a more specific and customized way.

In environmental terms, IUT technology helps in tackling the environment related IUT challenges. IUT platforms are no socioeconomic or environmental panaceas. Nevertheless, it is expected that ITU will have a positive contribution in urban transportation, helping to advance urbanization innovation, enhance social inclusion and mitigate environmental degradation, overall contributing to the transport towards smart, sustainable and inclusive growth.

III. Conclusion

Ever-growing urbanization is putting ever more pressure on the well-being of citizens and the environment. Applying latest ICT technology to address urban transport challenges is a key strategy to release the new innovation powerhouse of urbanization.

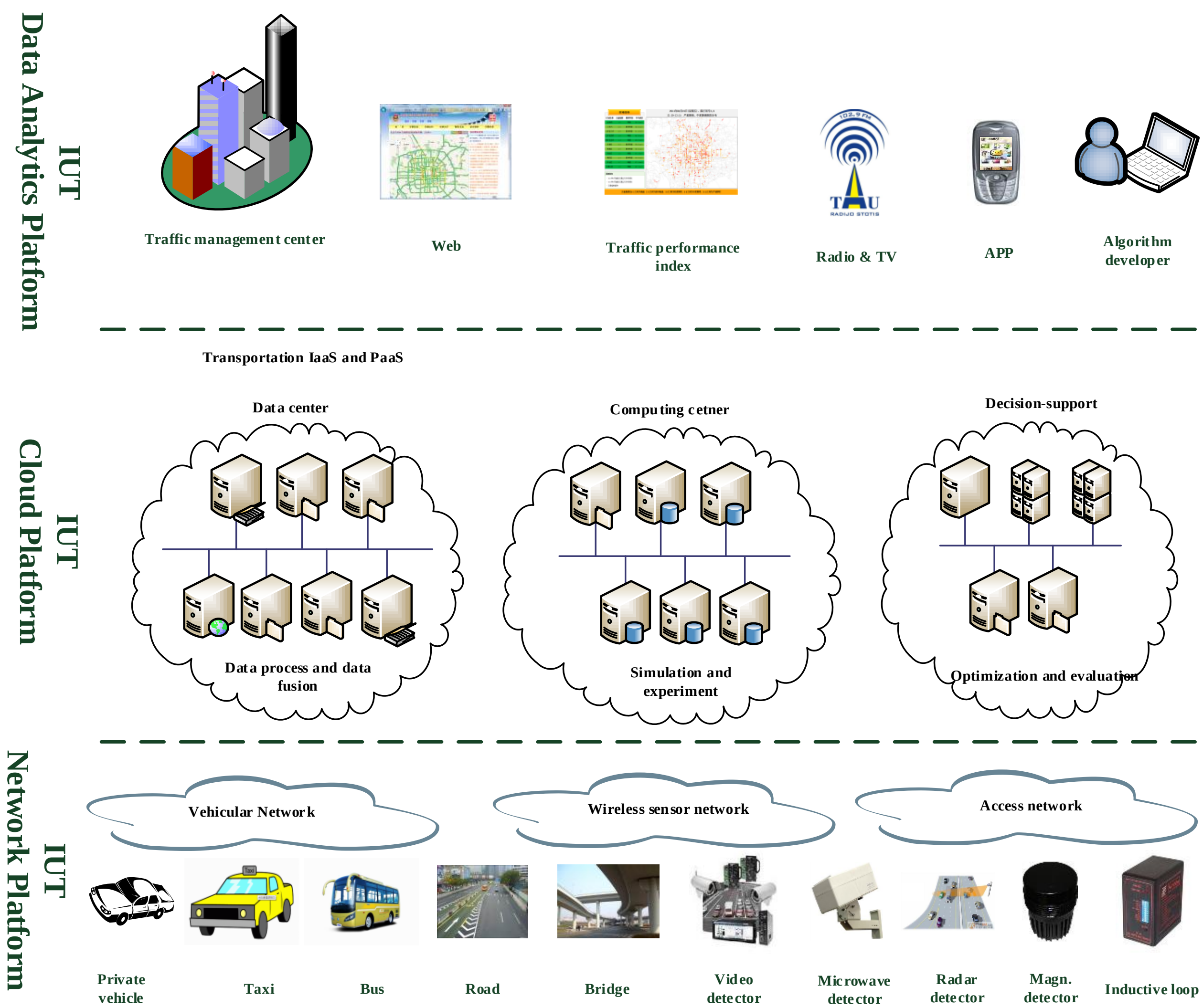

Figure 1. IUT Reference Architecture

Innovative Urban Transport (IUT) is the new development strategy of next generation urban transport, based on the state of the art practices of the project consortium, and based on the state of the art of the emerging information and communications technologies, in particular in the field of IoT, 4G, Big Data and Cloud Computing. IUT is the umbrella concept covering the foreseeing idea of the IUT driven tackling of challenges, the IUT technologies and the IUT services at a high level.

IUT aims to provide novel knowledge on information, methodologies, expertise and advice to explore optimized cooperation opportunities under the umbrella concept of IUT, as well as the identification of practical opportunities for future cooperation on a reciprocal basis. The proposed IUT specifies significant information on specific methodologies and tasks required to be performed within the process of collaboration on Future Internet design and implementation. IUT aims to provide updates to the existing smart city transport by integrating IUT data analytics platform, IUT network platform, IUT Cloud Platform for research and innovation ecosystems.

IUT applies emerging technologies (principally information and communication technology) and governmental policies in such a way that urban traffic becomes smoother. Through IUT those resources required to create innovation can be used and coordinated efficiently. IUT fosters urban innovations that maximize the well-being of citizens while minimizing the negative effects like traffic congestion, air pollution high resource congestion, and traffic accidents.

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