Communication aspect in ICT for Freight Transport System

Pushpendra Kumar, Belkacem Ould Bouamama
LAGIS UMR CNRS8219
Ecole Polytechnique Universitaire de Lille
Villeneuve d'Ascq, France
jahan.pushp@gmail.com
Belkacem.Ouldbouamama@polytech-lille.fr

Haffaf Hafid
Faculty of Science, Computer Science Department
Oran University
El M'Naouar, Oran, Algeria
Haffaf.hafid@univ-oran.dz

***Abstract*—In the last decade, Information and Communication Technology (ICT) proved to be a milestone in the field of freight transport with the appearance of tracking and tracing devices. Different ICTs viz. Radio Frequency Identification (RFID), wireless sensor nodes and localization systems play vital role to improve the performance of the freight transport system by saving energy consumption, reducing the service cost and increasing the cargo throughput. To achieve these requirements, the development of reliable heterogeneous communication system among all communicating objects becomes a paramount objective. In this paper, we describe different kind of existing communication technologies in Intelligent Transport System (ITS) domain. Also, we propose an intelligent infrastructure integrated with ICTs for the operations of Intelligent Automated Vehicle (IAV) in confined space like container terminal.**

Keywords-Freight transport system; Intelligent transport system; Information and communication technology; Intelligent automated vehicle; Port conatiner terminal.

I. INTRODUCTION

The convergence of conveying, storing and manipulating data has led to many new and exciting developments in the Intelligent Communication Technology (ICT). An Intelligent Transport System (ITS) is advanced application of ICT which aims to provide innovative and efficient services relating to different modes of transport. The optimal transport strategy based on real-time information, as well as assessments of the transport system demand and supply should be given more importance in order to improve the productivity of the system. In the information society, the ICTs are developing towards an infrastructure that will enable new kinds of practices also affecting the transport system, for example trucks integrated with advanced devices that link the driver cab to the haulage operators' systems.

Intelligent Automated Vehicles (IAVs) are cornerstone of the future ITS and can be seen as the logical transition of mobile robotics to the scale of vehicles in urban transport or in container terminals. In the context of urban transport, by enabling vehicles to communicate with each other (Vehicle-to-Vehicle or V2V) as well as with base stations (Vehicle-to-Infrastructure or V2I) via wireless communication networks can contribute to safer and more efficient roads by providing timely information to drivers and concerned authorities.

The problem in freight transport systems is to obtain information in ITS over Mobile Relay Network to facilitate the necessary information access for drivers on the road. The proposed network solution consists of all the RFID enabled mobile nodes on road such as RFID tag and reader on the traffic light pole, and Wireless Sensor Network (WSN). This enables cars to be aware of their position and of the vessel they transport. In our case, we are limited with a small platform such as seaport confined space where cars are IAV nodes, and further works aim to generalize to more complex infrastructure.

This work is performed in part of European project Weastflows [24]. The paper is organised as: In Section II, the role of ICT in sustainable transport system is described; then, in Section III, various ICTs are explained with their applications in freight transport system. In Section IV, a case of communication in container terminal is discussed. Concluding remarks are lead to the last section.

II. ROLE OF ICT IN SUSTAINABLE FREIGHT TRANSPORT

The key role of ICT for enabling sustainable freight transport is in establishing cooperation among logistics companies and various actors of freight transport system by enabling the real time flow of information. ICT helps to build trust among the various actors of the freight transport system by encouraging them to share information for achieving optimum transport strategies. Another important contribution of ICT towards sustainable freight transport system is its ability to support intermodal freight transport. Various practical applications of ICT in freight transport include vehicle tracking, monitoring and control, vehicle to vehicle communication, vehicle to infrastructure communication, security and safety purposes.

Ollo-López and Aramendía-Muneta [4] examined the impact of ICT on competitiveness, innovation and environment, and found that use of ICT seems to favor these issues. Several applications can be cited thanks to ICT development in ITS: Tracking and tracing, localization, Monitoring and control, dynamic scheduling, traffic flow (optimization**),** weather and congestion information, pollution control, safety and security. For example, a trailer could be automatically identified, given permission to enter a container yard and instructed where to drop its load. In [20], a framework of a devoted highway freight transport platform in China is described. Such platform can provide the availability of drivers to transport companies by destination requests, generating route plans, and returning the calculated plans to the users. Furthermore, the information is processed through a Geographic Information System (GIS) [19] capable to provide accurate and real-time weather information on a specific area.

There are recent trends towards Vehicular ad hoc Network (VANET) as they can leverage mobile nodes to bridge the gap between information isolated islands. It is a flexible and low-cost extension of wired infrastructure networks. With its ubiquitous feature, VANET is attracting intensive interests in many application areas. Nowadays, the spread of unmetered high-speed connections of internet allows greater flexibility and can be realized in working location. The Internet can be accessed almost anywhere by numerous means, including through mobile internet devices, mobile phones, data cards and cellular routers.

Figure 1 shows the flow of information in a freight transport network. All the information regarding the transport network is communicated to a central data base, which is updated with the current situation of the transport network. This information includes location of the cargo, congestion, incidents and vehicle breakdown. This information is useful for the different actors of the transport system, so that they can make the better business strategies according to the current situation of the transport network. This information flow allows real time control of the network to achieve the goal of sustainable transport system.

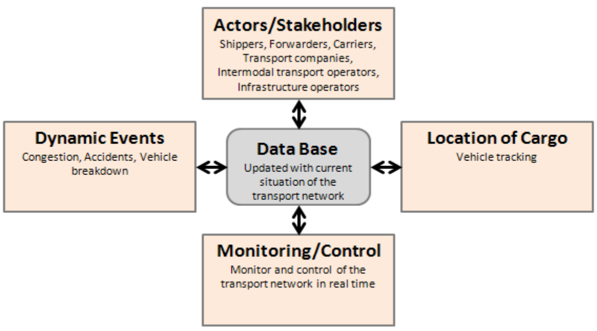

Figure 1. Information Flow in Freight Transport Network

However, some limitations have to be taken into account when choosing some plate-form. First of all, the quality of information delivery due to limited range in wireless protocols: Most conventional ITS technologies can only detect the vehicle in a fixed position. The second impediment is the lack of security data exchange, especially in wireless case. Coronado et al. [23] proposed secure service architecture for logistics covering road haulage, infrastructure and port operations. The various problems can occur with the implementation of technology including time delay to provide reliable information in critical situations, some network access are free and other not, lack of standardization especially when interoperability is needed, reliability, scalability (a huge number of vehicle), implementation cost and network security.

III. ICT TOOLS FOR FREIGT TRANSPORT SYSTEM

In this section, we discuss about the various technologies used in freight transport system. Vehicle telematics system which involves telecommunication aspects like GPS, or more generally web-based information system can be used in trailer tracking and on-board navigation. Also, RFID is a type of automatic identification technology, has been increasingly used with a great success since the 1990s [2] and RFID-RTLS (Real time locating system) is well suited for container tracking. Infrastructure-based wireless communication has experienced a huge diversification of radio access technologies while experiencing a steady increase of capacity. Table I shows different technologies used in freight transport.

TABLE I. ICT TOOLS IN FREIGHT TRANSPORT

Communica-tion Mode	**Most used tools**	**Applications**
Sensors	-Intrusive -non intrusive -embedded	Geo-fencing, Parameters evaluation: speed, distance, Safety guidance
Diffusion information	Panels or bulletin board electronic panels High speaker	Highway example
Localization	GPS, Galileo, Hertzien network, Vehicle Telematics	Vehicle tracking and tracing, Navigation, Geofencing
Tracking Identification and tracing	RFID, GSM 3+, RTLS, Gyrometer, Inertial center	Container tracking, Individual product tracking
Cooperative systems	GSM UMTS	Communication (V2V, V2I, IAVs)
Dedicated Transmission	GPRS (General Packet Radio Service) Radio Electric specific transmission	Confined space, Automatic toll collection, Safety Warning

Beyond third generation (B3G), wireless networks comprise of highly ubiquitous and fast mobile broadband access technologies such as WLAN (Wireless Local Area Network), HSPA (High Speed Packet Access), or Mobile WiMax. Sensor nodes (installed on each vehicle) can collect information in order to organize the traffic, especially at intersection where we have not traffic light. Sensors should be installed on both roadside and intersections. Then, the embedded unit can send vehicle parameters (location, speed, direction, etc.) using ZigBee (IEEE 802.15.4) to roadside units. The challenges today are: how could be developed new solutions and integrate them in the existing infrastructure communication and how can heterogeneous systems involving different technologies exchange information through the network, independently from the machines or devices they use i.e. interoperability.

Example of interoperable system communication is the it839/u-it839. Korea's "it839"3 project in 2004 has been one of the first national future Internet initiatives. It aims at funding research in eight different communication services (WiBro, DMB, home networks, Telematics, RFID-based, WCDMA, terrestrial DTV, and Internet telephony), three future network infrastructures (Broadband converged networks (BcN), soft infraware, the IPv6 architecture) and nine hardware-related businesses. From the point of view of services, the Location- and Context-Based Services (LCBS) are a new class of services with a high potential in the near future in freight transport. The key aspects of LCBS are their inherent relations between location coordinates or activity-contexts and applications.

Typical example classes for LCBS are:

• Intelligent navigation support for mobile users.

• Geography-dependent information systems and geographic multicast communications.

Configuration of ad hoc infrastructures for location or context dependent applications in case of rescue/emergency situations, spatially and time-limited operations requires a decentralized provision of location information within the terminal equipment through specific sensors (GPS, active badges, user input, etc.). The multi-network access of mobile terminal equipment (WLAN, GPRS, UMTS and Differential GPS) with horizontal and vertical handover capability can be used to improve the accuracy of the receiver by adding a local reference station to augment the information available from the satellites. Another technology RFID is mostly used in retailing and manufacturing environment but recently, it has been used in tracking vehicle as well, because using high frequency transmission enables readers to get information from great distance. The RFID chip typically is capable of carrying 2000 bytes of data or less. Table II summarizes different communications modes in RFID.

TABLE II. DIFFERENT RFID COMMUNICATION MODES

RFID Mode	Frequency /time	Characteristic	Application
Passive Time has non limited lifespan Tag energized by the reader	Low frequency	Least interference from metal, liquid	Access control (airport)
	High frequency	Tracking items everyday	Animal tracking
	Ultra high frequency	3.5 m and up Lowest price (no battery)	Pallet or case tracking (merchandise)
Active 200 m read-range 3-10 years tag life	Beacon	Presence or absence of items	Boolean applications or detection
	Real time location	The battery periodicaly transmits its signal	Find objects or people in real time

To resolve the problem of the large transmission overhead when the RFID tag information is transmitted in IEEE 802.11 wireless LANs, we can consider the frame aggregation method being discussed in the IEEE 802.11n Task Group. The frame aggregation method has two techniques called MSDU (MAC Service Data Unit) aggregation and MPDU (MAC Protocol Data Unit) aggregation.

For efficiently transmitting in real time RFID tag information in IEEE 802.11 wireless LANs, we need to combine the multipolling method [3], which enhances the PCF protocol using the connectivity information. The EPCglobal Network [14] (developed by the M.I.T) is the Auto ID international center's specification and specifies major aspects of operation of networked RFID system. The EPCglobal network architecture (middleware plate-form) can enable readers to identify and monitor RFID products and then, access crucial database to query cargos information shared through Internet. Furthermore, the system is regulated by international standard such as ISO 6346:1995 and ISO 17363:2007. In the traffic information management, RFID can be used to collect information about traffic jams. For instance, officials can track the travel time of cars on specific motorways, analyses that information and then distribute reports about average commuting times to drivers, helping them decide which route to take. There are two kinds of vehicle tracking: automatic vehicle tracking, when the vehicle transmits its location regularly (within time interval) and events activated tracking system when the tracking system is activated in reaction to some event [15].

Among tools for positioning problem or geo-localization, we can cite GPS (or DGPS), GIS and RTLS (Real Time Localization System). Also, optical character recognition (OCR) and biometric based technology are used for vehicle or product identification. A great number of physical embedded sensors exist to enhance safety guidance to driver (speed, distance, sound sensor etc.) and finally many kind of interface or electronic devices allow the driver to access to the infrastructure networks (computers, PDA, iPad, smart phone, embedded camera, digital billboard etc.). Some authors propose a Dedicated Short Range Communication (DSRC) such as the ETC system used to collect highway tolls. This promising wireless technology is capable of handling the information requirements associated to road transport. It could facilitate high-speed transmission of large volumes of data between a vehicle and equipment installed alongside the road.

IV. A CASE OF COMMUNICATION IN PORT CONTAINER TERMINAL

In the recent years, advanced ICTs and IAVs have been identified as possible candidates to implement Automated Container Terminals (ACT) to improve the performance of seaport management. New breakthrough of optimizing the port logistics are achieved for smart container terminals. In an ACT, three types of handling facilities are usually used: Automated Yard Cranes (AYCs), IAVs and Quay Cranes (QCs). IAVs are autonomous vehicles used for horizontal transportation and are powered by batteries, which are automatically charged at a charging station on the terminal apron. To be aware of its localisation at any time within the confined deployment space, an IAV node can include (but not necessarily) a GPS circuitry. RTLS is more suitable in this case which provides the exact position of a node to which the RTLS tag is attached at each time. At least three RTLS readers should receive signals from these tags to calculate the position by means of an engine which collects continuously the signals. In our case, the tags could be attached to AYC to play the role of readers, or “Anchor nodes”. Reduced Signals Strength Indicator (RSSI), Time of Arrival (ToA) and Angle of Arrival (AoA) give approximate location of the “tracked” nodes by using triangulation computation methods [10]. The second problem, in which RFID may play a major role, is the identification of an object tagged by a transponder. This RFID localization solution is based on radar principles [18], but it couldn’t go further than 200m.

Now, we discuss the technologies to deal with the communications between IAV-to-IAV, IAV-to-CBS (Central Base Station) and IAV-to-RFID. These can be applied in freight transport infrastructure communication. The European project CVIS (Cooperative Vehicle Infrastructure Systems) has been investigating the capability to link vehicles to the roadside infrastructure through seamless communications channels. We distinguish two types of links in IAV-2-IAV and IAV-2-CBS communications: low rate wireless link to exchange data that do not require high transfer speed such as periodic and cooperation/coordination based data and high rate wireless link to exchange data of important volume such as data to be stored in data base or multimedia data, that are known as on demand data.

Because of possible interferences, IAV nodes could be equipped with a second transceiver such as GSM/GPRS technology to allow direct communications without passing by CBS nodes or another intermediate IAV nodes. Powerful meshing technical equipment such as Meshlium product proposed by Libelium^{TM} company [25] exists today in the market. This equipment allows interconnecting several wireless technologies at the same time (Wifi, Bluetooth, Zigbee, GSM/GPRS) and wired Internet. GPRS [14] has been introduced specifically for packet communication in GSM, it is described as 2.5G (between 2 and 3 generation) and recently enhanced by EDGE (Enhanced Data rates for global evolution). It is, thus, much more adequate for the application case under consideration. Contrary to voice/data communication in GSM (where an FD channel is reserved irrespective of the traffic intensity in the uplink/downlink direction) all users of a cell share the bandwidth.

For identification problem, we use RFID system in which typically a reader is placed on IAV and a tag attached to the container [8]. RFID reader and tag communicate wirelessly using antennas (see Figure 2). OCR (Optical Character Recognition) based system is also used for vehicle number plate’s recognition. When a vehicle arrives at the terminal gate the OCR system captures its plate number, so that the control system records it together with the time and date, and verifies if the vehicle is allowed to get inside the area.

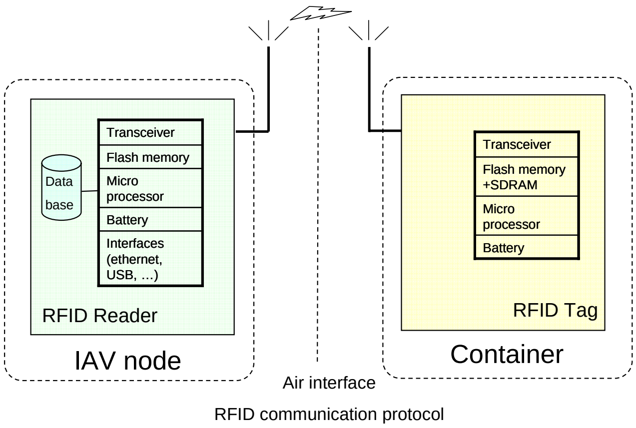

Figure 2. IAV- RFID Communication

With regard to the communication architecture, we see that there are many standard solutions related to RFID technology exists in practice [5][6]. Choosing the right RFID tag hardware able to ensure effective and efficient communication is critical to the overall solution. The choices depend on various factors like amount of container information to be stored on the tag, distance requirements, and confined space conditions. This communication takes place between each IAV and the corresponding container in loading/discharging operations using RFID. Real-time locating system can also be used for local positioning; it allows tracking and identifying the location of objects in real time. ISO/IEC 24730-5:2010 defines an air interface protocol which utilizes chirp spread spectrum (CSS) at frequencies from 2.4 GHz to 2.483 GHz.

Cellular systems such as UMTS are also good candidate for IAV-2-CBS communications because it accounts for protocol design mobility and data rates can reach up to 21 Mbps with high speed downlink packet (HSPDA). The imminent 4G technologies include Mobile WiMAX, Long term evolution (LTE) and HSPA+. The estimated coverage range is about 3 Km with a star network topology, LTE has a theoretical top download speed of 300Mbps and an Upload Speed of 75Mbps. Another candidate for IAV-2-CBS is Digital Media Broadcasting (DMB) which includes digital audio /video Broadcasting (DAB/DVB) however it only relies on single frequency and broadcasting [7]. Wireless sensor networks (WSN) [13] are a set of nodes that can communicate with each other. Sensor nodes measure a desired physical quantity and the base station node collects data to perform processing and to connect to the wired area network. In [17], two types of sensor nodes are used: mobile sinks (to which information is sent) and sensor nodes (sensing a physical phenomenon). The intelligent vehicular systems emerged as a good candidate for benefiting from the WSN's features. WSN can be used for detecting the formation of ice over the road, and many other applications.

TABLE III. TECHNOLOGIES FOR IAVS COMMUNICATION

Characteristic	**Wifi**	**Bluetooth**	**Zigbee**
IEEE Specification	802.11x	802.15.1	802.15.4
Operating frequency	2.4 GHz ISM, 5 GHz	2.4 GHz ISM	868 MHz, 902-928MHz, 2.4 GHz ISM
Data rate	600 Mb/s	1 Mb/s	20-250 Kb/s
Nominal TX power	15-20 dBm	0-10 dBm	(-25)-0 dBm
Nominal range	30-150 m	10-100 m	10-75 m
Max # of cell nodes	2007	8	65,000
Waking up time	-	3 s	15 ms
Characteristic	WIMAX	UWB	DSRC
IEEE Specification	802.16	802.15.3	802.11.p
Operating frequency	10-66 Ghz	3.1-10.6 GHz	5.9 Ghz
Data rate	Speed up to 70Mbps	100-500 Mb/s	27 Mb/s
Nominal TX power	13.5 db	-41.3 dBm/MHz	75 MHz
Nominal range	3-5 km And 50 km from Base-stat	10 m	1000 m
Max # of cell nodes		8	
Waking up time		Narrow pulse	

The solution we propose is to use wireless sensor technology to control merchandise in this phase. The technologies integrated in the nodes include some wireless sensor device (GPS, sensors and clock) which make it possible to control the operations in real time. This allows sending relevant alerts in some critic situations and report emergency situations. UWB spectrum 3.1-10.6 GHz supports high data rate communications up to 480Mbps at a short distance (10-15m). Table III summarizes these technology choices that can be potential candidates for IAVs based data communication system. WLAN is recommended for confined regions because of its 100m range and low mobility whereas Mobile Wimax (802.16.x) is good candidate for high rate of data transfer it supports high speed transmission (up to 1Mbps in high mobility and 70 Mbps in low mobility). The gain of complexity and mobility management is due to All-IP core future Networks allowing tolerance to multipath and self-interference. Currently, the IEEE MAC sublayer proposal for UltraWideBand (UWB), namely IEEE 802.15.a adopts the carrier sense multiple access/collision avoidance (CSMA/CA) technique.

V. CONCLUSION AND FUTURE WORKS

In the present work, we discussed about the role of ICT to achieve the goal of sustainable freight transport system. Various ICTs are described with their potential benefits and applications in freight transport system. A case is described on communication in port container terminal with specifying various suitable technologies. The communication among IAVs, and infrastructure is explained in a container terminal to enhance the productivity of the system. Through the container terminal application, we are convinced that WSN can be eventually incorporated into IAVs to overcome the problems associated to wired sensors.

In general, the transport system lies on the intersection of several domains, which naturally puts pressure on the transport sector to stay as sensitive to change. Although it has been a great development in this domain but still it is a long way to reach sustainability in freight transport. Implementation of this use case using a dedicated simulation language like NS2, in order to test the network communication performances is let to perspectives.

ACKNOWLEDGMENT

This work is performed in part of European Project 'Weastflows'. Weastflows is an Interreg IVB North West Europe (NWE) project funded by the European Regional Development Fund (ERDF) that aims to encourage a shift towards greener freight transport in the NWE region.

REFERENCES

[1] C-I. Liu, H. Jula, K. Vukadinovic and P. Ioannou, "Automated guided vehicle system for two container yard layouts", Transportation Research Part C 12 (Elsevier), pp. 349-368, 2004.

[2] S. Yong-Dong, P. Yuan-Yuan and L. Wei-Min, “The RFID application logistics and supply chain management”, Research Journal of Applied Sciences, Vol. 4, No.1, pp. 57-61, 2009.

[3] W. Y. Choi, An Efficient Polling Scheme for Enhancing IEEE 802.11 PCF Protocol, FREQUENZ 59: 268–271, 2005.

[4] A. Ollo-López and M. E. Aramendía-Muneta, ICT impact on competitiveness, innovation and environment, “Telematics and Informatics” (Article in press) 2011.

[5] S. J. Barro-Torres, T. M. Fernandez-Carames, M. Gonzalez-Lopez and C. J. Escudero-Cascon, “Maritime freight container management system using RFID”, The Third International EURASIP on RFID Technology, pp. 93-96, 2010.

[6] Y. Liang and X. Bai, “Design of RFID-Enabled Container Yard Management System”, G. Huang et al. (Eds.): DET2009 Proceedings, AISC 66 (Springer), pp. 1751–1758, 2009.

[7] F. Qu, F. Wang and L. Yang, “Intelligent transportation spaces: vehicles, traffic, communications, and beyond”, IEEE Communication Magazine, Nov. 2010. Vol. 48, No. 11, pp. 136-142, 2010.

[8] D. Mullen, “The application of RFID technology in a Port” http://www.aimglobal.org/technologies/rfid/resources/PortTech.pdf, [retrieved: July , 2011]

[9] Z. Luo, T. Zhang and C. Wang, RFID Enabled Vehicular Wireless Query for Travel Information in Intelligent Transportation System, IEEE International Conference on RFID-Technologies and Applications, 2011.

[10] K. S. Wong, I. W. Tsang, V. Cheung and J. T. Kwok Position Estimation for Wireless sensor networks; IEEE Global Telecommunications Conference, pp. 2772-2776, 2005.

[11] M. Forcolin, E. Fracasso, F. Tumanischvili and P. Lupieri, EURIDICE-IoT applied to Logistics using the Intelligent Cargo Concept, 17th International Conference on Concurrent Enterprising, Aachen, Germany, 2011.

[12] V. Boschian, M. P. Fanti, G. Iacobellis, and W. Ukovich, The Assessment of ICT Solutions in Customs Clearance Operations, IEEE International Conference on Systems Man and Cybernetics, Istanbul, 2010.

[13] C. Chong and S. Kumar, Sensor networks: Evolution, opportunities, and challenges” in Proceedings of the IEEE Vol. 91, pp. 1247-1256, 2003.

[14] EPC global Inc. The EPC global architecture framework 1.2, 2008.

[15] Y. Wang and A. Potter, “The application or real time tracking technologies in freight transport”, The Third International IEEE Conference on Signal Image Technologies and Internet Based-system 2008.

[16] M. Mansouri, B. Sauser and J. Boardman “Application of System Thinking for Resilience Study in Maritime Transportation System of Systems” IEEE International Systems Conference, Vancouver, Canada, March 23- 26, 2009 .

[17] D. Taccomi, D. Miorandi, I. Carreras, F. Chiti and R. Fantacci, Using wireless sensor networks to support intelligent transport systems, Adhoc Networks Journal (8), pp. 462-473, Elsevier 2010.

[18] M. I. Skolnik, Radar Handbook, New York: McGraw-Hill, 2007.

[19] F. Reclus and K. Drouad “Geofencing for fleet and freight management” 9th International Conference on Intelligent Transport Systems, Telecommunications, Lille 2009.

[20] L. Chen, T. Alfred and C. Wang, “A highway freight transport plate-form for the Chinese freight Market” IEEE Forum on Integrated and Sustainable Transport Systems, Vienna, Austria, June 29, 2011.

[21] A. M. Zanni and A. L. Bristow, Emissions of CO2 from road freight transport in London: Trends and policies for long run reductions, ENERGY Policy 38, pp. 1774-1786, Science Direct 2010.

[22] G. Zacharewicz, J. C. Deschamps and J. Francois, Distributed simulation platform to design advanced RFID based freight transportation systems. Computers in Industry 62, pp. 597–612, 2011.

[23] A. E. Coronado, C. S. Lalwani, E. S. Coronado and S. Cherkaoui, Wireless Vehicular Networks to Support Road Haulage and Port Operations in a Multimodal Logistics Environment, IEEE International Conference on Service Operations and Logistics and Informatics, Beijing, 2008.

[24] http://www.weastflows.eu [retrieved: June, 2012]

[25] www.libelium.com [retrieved: June, 2012]