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TOWARDS A FRAMEWORK FOR SMART CITY WIRELESS COMMUNICATION: CONCLUSIONS DRAWN FROM SMART TRANSPORT CASE STUDY

Fatima Hanani[1], Aziz Soulhi[2] and Rabiae Saidi[1]
[1]Laboratory LASTIMI, CEDOC EMI, Rabat, Morocco
[2]National Higher School of Mines, Rabat, Morocco
E-Mail: hanani@enim.ac.ma

ABSTRACT

The efficiency and reliability of any smart transport initiative is highly dependent on those of the underlying communication sub-system used for transfer and exchange of traffic related data. However, most of the literature on smart transport proposes communication solutions for specific ITS applications, without addressing communication issues in a comprehensive way. To fill the gap we propose in this paper, a referential framework to design a communication sub-system for any ITS initiative whatever the application. This framework groups together seven main communication sub-system characteristics: deployment zone, density of sensors, type of sensors, communication type, communication method, network architecture and wireless technology. The objective is, on one hand to identify the relationship between these different characteristics as well as to assess the degree of influence on each other, and to allow city managers understand technical and technological issues related to the connectivity domain when enabling any smart city initiative on the other.

Keywords: smart city, smart transport, ITS, wwireless communication, V2V.

1. INTRODUCTION

More and more, the majority of human activities are concentrated in the cities. Indeed, according to United Nation Development Programme report (2014) the world's resident population in urban areas has grown from 30% in 1950 to 54% in 2014 to reach 66% of the world's population in 2050. To follow and support this growth, all the city's services and infrastructures have been put under a great deal of strain. In the case of urban mobility, the number of vehicles and the need for efficient transportation in the cities keep increasing. However, considering the limitation of urban space and budget, cities cannot always build new roads to deal with this growing need and existing road infrastructure can no longer keep up with this pace. Cities are therefore constantly confronted with several problems of congestion, high consumption of fuels, pollution, the loss of time, accidents [1]. Given the importance and vital role of transport in the city, the leaders of the city must attach to it more attention and make innovative and intelligent solutions to put right this situation. Smart transportation or smart mobility, based on intelligent transport systems (ITS), is a concept that can deal with this situation. ITS use information and communication technologies (ICT) to monitor road infrastructure and manage transport and traffic in the city to make efficient use of the existing infrastructures [2], improve the quality of life of citizens and preserve the city environmental and economic capital as well as providing a microscopic and real-time overview of traffic. The relevance of an ITS is highly dependent on the accuracy and relevance of the information collected or exchanged through the underling network and communication infrastructure. Given the multitude of telecommunication standards and technologies as well as the different possibilities of network infrastructures, how can we make an informed choice of the communication solution for an effective ITS? What are the important technical and technological characteristics of this communication solution? In this paper, we will tray to answer these questions with the aim of helping city managers to understand ITS communication issues and make an informed choice of the communication solution for any smart transport initiatives.

The remainder of this paper is organized as follows: in section 2, we will present the concept of intelligent transport, its services and we will place it in the general context of the smart city, and we will give a brief presentation of some relevant ITS applications. The section 3 will be dedicated to a description of the ITS Sub-Systems as well as technical and technological characteristics that should be dressed and defined when designing a communication solution for any smart transport initiative. In section 4, we will discuss the interdependence relations between certain characteristics as well as the challenges related to the choice of the V2V communication type. In section 5, we will conclude and give some future work.

2. ICT LEVERAGE EFFECT ON SMART TRANSPORT

2.1 Smart transport: An important component of the smart city

The continuous and rapid growth of the urban population generates several challenges in the city in particular, as cited in [4]. « Scarcity of resources, inadequate and deteriorating infrastructure, energy shortages, environmental and human health concerns, demand for better economic opportunities and social benefits ». To deal with these issues, city managers are forced to look for innovative and intelligent solutions, taking into account their limited resources and budgets.

Beyond that, the Smart City concept emerges as an approach based on and trusting the roles that ICT can help in improving the management of the city and improving the quality of life of its occupants. As in [4] a smart city can be defined as follows “The use of Smart Computing technologies to make the critical infrastructure components and services of a city - which include city administration, education, healthcare, public safety, real estate, transportation, and utilities - more intelligent, interconnected, and efficient.”

After analysis of more than a hundred definitions emanating from academic, industry and international organizations domain, the International Telecommunication Union (ITU) gave in [5] the following definition that takes into account the aspect of sustainable development: “smart sustainable city (SSC) is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness. While ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.”

Therefore, in a smart city, an Information and Communication Technologies (ICT) based infrastructure is necessary and imperative. This infrastructure will the framework to integrate all of its components (citizens, businesses, elected officials and the public, environment and infrastructure), and will create coherence and synergy between stakeholders in the city, thus improving the services offered and the quality of life of its citizens.

In addition, a group of relevant features as identified in [3] characterizes a smart city, it include smart economy, smart people, smart governance, smart mobility, smart environment and smart living. Figure-1 illustrates features cited above. As we can see smart mobility or smart transport, as an application of smart city concept in transportation field is based on ITC to improve traffic management and the mobility of citizen.

2.2 Smart transport aims

With the increase in the urban population coupled with the increase in the number of vehicles and the growing need for travel for personal or professional reasons, solicitations and pressure on existing road infrastructures are constantly increasing. This situation will accentuate the problems of congestion, pollution, noise, fuel consumption and economical losses [7] and subsequently will degrade the condition of road infrastructures as well as the quality of transport services. The ITS-based Smart Transport concept has emerged with the objective of enabling optimal and efficient use of road infrastructure. As mentioned above Intelligent Transport Systems (ITS), consist of the use of computer science, electronics and communication techniques in an integrated manner in transport management strategies. These systems require interaction and cooperation between vehicles, drivers, passengers, infrastructure and transport managers, public and private authorities around a complex ICT infrastructure to improve safety and the capacity of road infrastructure [8].

By implementing smart transport, cities can achieve these following objectives:

- High-quality services for the users: improve public transport, ensure the multi-modal transport, disseminate information on transport to aid people choice, reducing trip time
- Providing the driver with relevant and useful information helping him in choosing the appropriate paths
- Efficient traffic management: reduce congestion, minimize accidents and improve public safety
- Collection of information for wise decision-making
- Sustainability: reduce pollution, encourage green transport, improve public transport

These improvements will increase the attractiveness of the city and make it more competitive by attracting more heels and more companies.

2.3 ICT in smart transport

Thanks to advances in computing and communication techniques especially wireless, several solutions and possibilities are offered to improve the safety and efficiency of transport systems. These solutions deal with different domains related to traffic regulation, congestion minimization, incident management, parking management, road monitoring and emergency prioritization. In this paper, we will focus on three most important areas of ITS application in the management of urban traffic, which are traffic light control, emergency traffic management and parking management. In following, we will present each of them and some relevant applications that show the role of ICT in particular Wireless Communication to improve traffic management in the city and offer services that cannot be achieved otherwise. Application surveyed in this paper and their related outcomes are presented in Table 1 for reference purposes.

2.3.1 Traffic light control

The role of such system is to manage traffic in order to avoid congestion and optimize traffic flow in intersections while ensuring security. This system can handle each intersection separately resulting in an isolated strategy, or can manage multiple intersections using coordinated strategy [9]. In addition, these systems can be categorized into two main families [10]: Fixed-time traffic light control and Adaptive traffic light control. The first one relays on historical data traffic to create its control

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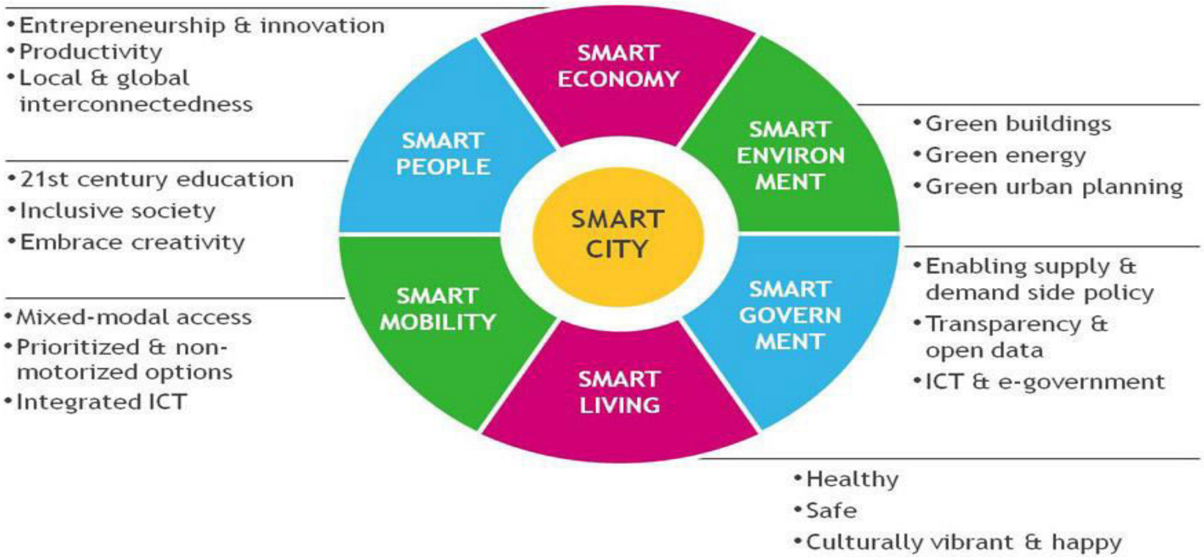

Figure-1. Smart city characteristics [6].

strategy and suffers from rigidity and their non-adaptation to traffic fluctuations. The second, based on Wireless communication networks and sensor networks, uses real-time measurements to generate its adaptive monitoring and control strategy. One application of this system is presented in [10]. The author present an adaptive traffic light control system based on VANET (Vehicular Adhoc Network) for data exchange between vehicles (short-range wireless communication). In addition, traffic light controller use wireless communication with the approaching vehicles to determines the optimum values for the traffic lights phases. Also in [11] the author propose an Adaptive traffic light control system based on Wireless Sensor Network (WSN) and instead of traditional wired sensors as well as an adaptive algorithms to optimize a traffic light control. This system can deal with the dynamic behavior of traffic densities and as a result reduce the time what vehicle has to wait at the intersection before passing it.

2.3.2 Emergency traffic management

In traffic of management, it is necessary to take into account the priority traffic (fire fighters, police, and ambulance) to allow the emergency vehicles to get the site of emergency in time to save lives or protect important assets. Otherwise, a simple delay can put many lives at risk. This kind of ITS application can consist of collecting and exchanging data about an emergency to facilitate and organize emergency response. It can also consist of giving priority to the circulation of emergency vehicles in junction. Therefore, when the controller of the intersection receives the approach of an emergency vehicle through the detectors on the road it forces lights to go green to allow its passage.

Several applications have addressed these needs. In [12].giving priority to emergency vehicle service is implemented by RFID and wireless technology. All emergency vehicles will be equipped with active RFID tag. Moreover, in each intersection sensors with RFID reader will be installed in each direction. These sensors communicate Wiressely (long range) with a traffic light controller to inform it about the presence of emergency vehicle. For traffic safety purpose [13] present surveillance system that can collect and disseminate emergency data in tunnel environment to avoid accident. The system is based on hybrid wireless network using WiFi (IEEE 802.11b/g/e) and mobile WiMAX (IEEE 802.16e) technologies to ensure communication between vehicles and base stations installed at the tunnel's edge

2.3.3 Smart parking

With the increase in the number of cars in the city, the problem of parking continues to intensify, aggravating problems of congestion and pollution in the city and causing time loss for drivers. Several applications have addressed this problem by offering smart parking. Smart Parking is the way to allow drivers to find parking spaces in an efficient and satisfying way using ICT [14]

In [15] the author introduces a Mesh and ZigBee wireless sensor network to collect information on the availability of parking space and display the result at the parking entrance. The author in [16] address a solution, which consists of four components. Wireless sensor Network (WSN) that collect information about a parking zone and send them to the Embeded Web-Server (EWS) responsible for the zone. The Central Web-Server (CWS) consolidates the information from the EWS of the different zones and disseminates information to the drivers via the Mobile Phone Application (MPA). The solution uses ZeegBee (IEEE 802.15.4) for communication between WSN-EWS, Wifi technology for EWS-CWS and Wifi or 3G technology for CWS-MPA.

3. COMMUNICATION SUB-SYSTEM: ROLE AND CHARACTERISTICS

3.1 Smart transport sub-systems

As said in [17], ITS is built on three sub-systems:

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Table-1. Surveyed smart transport application and related outcomes.

Reference	Domain of application	Approach and method	Outcomes
Gradinescu *et al.* [10]	traffic light control	VANET platform for data exchange between vehicles Wireless communication for between traffic light controller and approaching vehicles	- Decrease of the total average delay - Reducing fuel consumption and pollutant emissions,
Srivastava et al. [11]	traffic light control	Wireless Sensor Network instead of wired sensor combined with adaptive algorithms	Reducing the average waiting time of vehicles at a junction
Salama *et al*. [12]	Emergency traffic management	RFID technology for emergency vehicle detection. Wireless technology for Sensors and traffic light controller communication	Reducing the waiting time at traffic lights and guarantying the fluency of traffic for emergency cases
Charitos *et al.* [13]	Emergency traffic management	Combining WiFi and WiMAX technologies to exchange emergency data between vehicles	Reliability and Robustness of communication by combining WiMax and Wifi technologies
Vishnubhotla *et al*. [14]	Smart Parking	a Mesh topology to organize networked wireless sensors and the use of ZeegBee technology for communication between sensors to exchange information on the status of parking spaces	- Information about availability of parking place - Real time identification of the location of the free space in the parking lot
Yang *et al* [15].	Smart Parking	Use of wireless technologies (ZeegBee, Wifi, 3G) to ensure system-components communication	finding vacant parking place in effectively and satisfying manner for drivers

1) Surveillance Sub-system (SS). 2) Analysis and Strategy Sub-system (ASS). 3) Execution Sub-system (ES). SS is formed by sensors that allow the collection of specific data and information about traffic. Several types of sensors exist e.g. video camera or image sensor, infrared, microwave or ultrasonic sensor. The ASS consists of data processing platform that optimizes traffic based on information collected by SS. This sub-system uses algorithms based on artificial intelligence technologies (e.g. fuzzy logic, neural networks, and expert systems). The ES execute ASS decisions, e.g., traffic light control system, navigation and guiding system, variable messaging signs (VMS).

However, to ensure the functioning of these three sub-systems, there must be another sub-system that should handle the communication and ensure the transfer of data between them called the Communication Sub-system (CS) [18]. It consists of communication infrastructure (technologies, network infrastructures, etc.) used to enable the transfer and exchange of data in suitable way between the different communicating entities (sensor, stations, treatment center, vehicles, drives,).

To ensure the provision of ITS services, a reliable and efficient communication sub-system connecting other three sub-systems is necessary. Wired networks are efficient and reliable but require significant investments for installation and maintenance, heavy to implement and lack of flexibility and scalability. Hence, wireless communications are destined to play a major role in providing cities with communication infrastructure through the ease of deployment, flexibility, scalability and the existence of multiple wireless communication standards and technologies. However, these networks have several weaknesses and limitations, e.g., interference, limited coverage, affected by environment condition, latency according to architecture and topology, security. This implies increased vigilance when choosing the wireless-based communication sub-system to meet the requirements of ITS applications. With the multitude of technology and intensive marketing strategies from technology vendor, the choice is no longer easy The purpose of this paper is, in one hand to address the issues related to the wireless-based communication sub-system and to define basic attributes and characteristics that this sub-sytem must have. In the other it aims inform and assist city managers on the important considerations that should be taken in account when setting up an ITS.

3.2 Communication sub-system characteristics

As said before, the reliability and success of an ITS will depend heavily on those of its wireless-based communications sub-system and the telecommunication infrastructure that supports it. Relevant characteristics that define this sub-system will be considered and will be elaborated in what follows.

3.2.1 Communication method

To enable the ASS to make decisions, the sensors of SS must send the collected traffic data to it. In other hand to execute ASS decisions, the ES should receive these decisions. Two methods of communication are possible:

- Direct: ASS communicates directly with the SS and ES via a direct long-range wireless link. Considering the distance between sub-systems, have a direct communication can be performed at substantial cost, because in this case to pass through a telecom operator is mandatory.

- Hierarchical: the communication goes through intermediate gateways that will consolidate data from several sensors before returning them to the ASS using the combination of short and long-range wireless link. In this case, we should consider some issues among others, latency caused by multi hop to reach destination and reliability that can be affected by errors increased by multi hop.

3.2.2 Communication type

One of the specificities of ITS, is that it must deal with the connectivity of cars, whatever in stationary state or in motion. In other words, one of the key objectives of Intelligent Transportation Services is to provide connectivity to vehicles to improve efficiency (help reduce congestion) and safety (provide safety warnings and alerts to vehicle users to avoid accidents and collision) of road transportation systems [19]. Vehicle can communicate with each other’s through vehicle-to-vehicle (V2V) communication or communicate with the equipment installed on the roadside through vehicle to infrastructure (V2I) communication. Thus forming what we call Vehicular ad-hoc networks (VANET) [20]. Traditionally for infrastructure-to-infrastructure communication, wired or wireless technology can be used. However when considering communication where vehicle is part, the use of wireless technologies is mandatory [8] and a respect of certain distance to allow communication.

3.2.3 The deployment area

The deployment zone is the operating area that will be supervised. The extent of this area will depend on the functional needs and requirements of the ITS application, it may be few roads or a total roads and vehicles of the city. When speaking about deployment zone two parameters should be considered here. The first one is the radio propagation characteristics. In other words, it is necessary to inspect the existence of obstacle or barriers to radio frequency (RF) propagation or the existence of other source of RF that will cause interferences [21]. The second one is the extent that should be covered. Considering the environmental, geographical and urban area conditions; we should dress which technologies (long, medium, short, licensed or unlicensed frequency bands), are suitable to minimize interferences, overcome geographic or urban obstacles, maximize effective range and how should deal with spatial diversity to ensure a large cover.

3.2.4 Network architecture

The purpose of the deployment architecture is to organize communicating entities to reach the optimal means in term of range, latency and reliability to ensure communication. This setting will depend on the number and type of sensor, the propagation environment, and the extent of the deployment area. Three architectures are possible [9]:

- Infrastructure: requires the deployment a backbone made up of base station (BS) that will act as a gateway that relays information from sensors to each other or to the backend system.

- Ad-hoc: it is a point-to-point architecture; sensors exchange data from one to other (multi hop communication) until reaching the backend system. This architecture does not require any infrastructure.

- Hybrid: a combination of the two above architectures. Sensors use infrastructure (BS) when it is present, otherwise ad-hoc communication.

3.2.5 Sensors type

To meet the different needs of ITS applications, several types of sensors can be used, video camera or image for monitoring traffic and road infrastructure, microwave, ultrasonic or magnetic sensor to detect the presence of cars or pedestrians, the speed of cars, etc. These sensors can be fixe when installed on the roads and in some cases; they can be mobile especially installed in cars. The mobility of communicating entities is a challenge and advantage at the same time in ITS. Mobility will generate additional constraints in the choice of the communication solution. Firstly, how to ensure a certain performance and quality of communication for the moving vehicle? Secondly how to manage this mobility in case of the need of continuous connectivity while moving (roaming)? In case of VANET, the high speed of vehicle adds another aspect to take in consideration [22].

3.2.6 Sensors density

The number of sensors and their distribution will depend strongly on the use cases and the needs of each application. Therefore, the density of deployment is one point that merit to be considered to achieve a certain reliability and accuracy and the desired level of granularity of collected data. In addition, the chosen solution must be flexible and scalable to ensure change or addition of the sensor. In case of high density, the adequate required bandwidth to support data transfer should be considered because it can generate degradation in the capacity of the network caused by contention and interference [22]. Also in the high number of sensors, the solution should deal with need of concurrent access to the media support.

3.2.7 Wireless technologies and standards

Several wireless communication technologies and standards exist and can be candidates towards the realization of and ITS communication sub-system. By follows, we will give a brief description of them according to the classification by extent: Wireless Personal Area Networks, Wireless local Area Networks, Wireless metropolitan Area Networks and Wireless wide Area Networks.

- Wireless personal area networks (WPAN)

WPANs seek to provide short-range communication solutions for applications low rate and low latency requirement. We will focus on two main technologies: Bluetooth and ZigBee. Table-1 shows specifications and attributes of these two technologies [24] [25] [26].

Bluetooth technology: Bluetooth [26] is a technology developed and supported by the Bluetooth Special Interest Group (SIG). The Bluetooth system is operating in the 2.4 GHz band and can achieve throughput up to 3 Mbps with network range up to 100m depending on transmitted power. Bluetooth support tree topologies, point-to-point, point-to-multipoint and mesh topology. In the second case the channel is shared between the devices and forms a piconet with one device as master and the others slaves. Bluetooth technology can support up to eight devices in a piconet. Several piconets can be interconnected and thus form a scatternet, since a device can be both a master in one piconet and a slave in another. Bluetooth technology offers two versions, the Bluetooth Low Energy (LE) and Basic Rate/Enhanced Data Rate (BR/EDR).

ZigBee technology: Developed and supported by the Zigbee Alliance, ZigBee technology is based on the 802.15.4 standard, it operates in unlicensed three frequency bands, 868 MHz, 915 MHz, and 2.4 GHz and allows transmitting rates of 10 to 250 Kbs [23] The standard defines two types of nodes: full-function devices (FFD) and reduced-function devices (RFD). The FFD can play three roles, ZigBee router capable of routing the messages, ZigBee Coordinator the main controller of PAN and ZigBee End Device (neither router nor coordinator). RFD can only play the role of End Device [24]. ZigBee offers the two basic P2P and Star topology defined by the IEEE 802.15.4 standard. To improve range and to ensure reliability and robustness of the network, ZigBee offers two other possibilities [25]: 1) Mesh topology imply multi-hop communication to reach the destination ZigBee router as intermediate devices. 2) Tree topology, which is hierarchical architecture, composed by ZigBee coordinator as the root, ZigBee routers that form the branches and relay messages and ZigBee end devices as leaves of the tree.

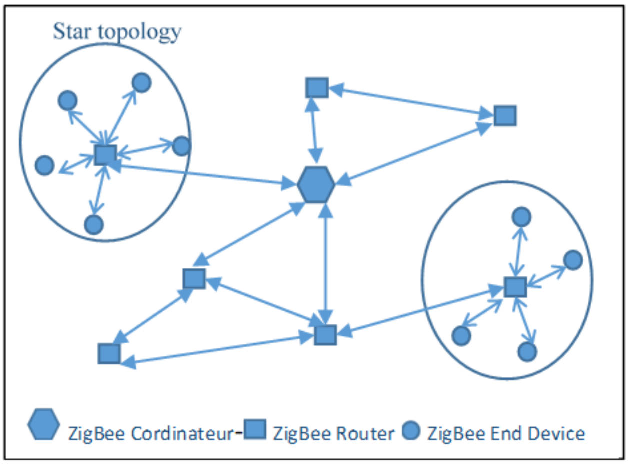

Figure-2. ZigBee mesh topology.

Table-2. WPAN specifications and attributes.

Standard	**IEEE 802.15.4**	**Bluetooth**	
Technology	**ZigBee**	**Low Energy** (BLE)	**Bluetooth BR/EDR**
Support	ZigBee alliance	Bluetooth Special Interest Group (SIG)	
spectrum	868 Mhz - 915 Mhz - 2,4 Ghz	2,4 Ghz	2,4 Ghz
License frequency	Unlicensed Frequency		
Data rate	Up to250 Kps	125 Kps to 2 Mps	1 to 3 Mps
Range	10–100 m		
Topology	P2P, star, mesh, tree	P2P, Mesh Piconet, Sratternet,	P2P, Piconet
Mobility	Cell zone		

- Wireless Local Area Networks (WLAN):

Based on IEEE 802.11 standard and operating in 2.4 and/or 5 GHz unlicensed band, WLANs aim to connecting an infrastructure of equipment in a short large area (up to 300m) by offering high data rates (up to 1Gbs). IEEE 802.11 networks are composed of tree components (Stations, Access Point and Distribution System) and have cellular structure [21]. Indeed the network is composed of several cells and each cell, controlled by access point, known as a basic service set (BSS). In addition, the LAN can be extended by combining several BSS to make what called Extended Service Set (ESS). Since its inception, this standard has continued to evolve. Several versions were then made to address issues such as security, quality of service, interoperability, as well as other improvements regarding throughput. Indeed, the bit rates have gone from 11Mbs with the IEEE 802.11b (WiFi) standard, to 1.3 Gbs with IEEE 802.11ac. In addition, the IEEE 802.11n amendment allows rates up to 600Mbs with the possibility of using both 2.4GHz and 5GHz bands simultaneously.

WLANs are enormously successful thanks to the ease and reduced cost of implementation as well as use of unlicensed frequency bands (2.4 and 5 GHz). However theirs coverage are limited due to many constraints, e.g., regulatory limit of power transmission and geographical or urban nature. To overcome this situation, a mesh architecture, in which the data can be forwarded in multi wireless hop to reach the destination, can be a solution. To support a mesh network IEEE 802.11s amendment has been developed to add mesh capabilities to the wireless local area networking (WLAN) standard [27] [28].

Operating in the 5GHz (5.850-5.925 GHz) band, the amendment IEEE 802.11p, known as WAVE (Wireless Access in Vehicular Environments) allow WLAN connection in a vehicular environment characterized by a dynamic topology given the mobility of vehicles as well as very high latency requirements. IEEE 802.11p based systems consist of two king of equipment, on-board units (OBUs) located in the car and roadside units (RSUs) installed on the road. The IEEE 802.11p permit high data rate (27 Mb/s) and allow ad hoc communication among OBUs also between OBUs and RSUs [29]. The communication is allowed for distances up to 1000 m (in line-of-sight) between RSUs and mobile or stationary OBUs as well as between mobile OBUs [30].

DSRC: (Dedicated Short-Range Communication) based on IEEE 802.11p standard, is a technology developed for vehicular environment, it allow vehicle to vehicle and vehicle to infrastructure communication [31]. DSRC operate in 5,9GHz band and provides capability to high-speed vehicles to exchange high data rate with low latency and high reliability [32]. Table-3 shows specifications and attributes of different amendments of IEEE 802.11 standard [27] [28] [29] [30] [31] [32].

Table-3. WLAN specifications and attributes.

Standard	**IEEE 802.11** (WiFi)			
Amendment	**IEEE 802.11a/b/g**	**IEEE 802.11n**	**IEEE 802.11ac**	**IEEE 802.11p**
Support	IEEE 802 LAN/MAN Standards Committee			
Spectrum	2,4 Ghz - 5 Ghz	2,4 Ghz - 5 Ghz	5 GHz	5.9 GHz
License frequency	Unlicensed			
Data rate	11-54 Mps	150 Mps	1 Gbps	27 Mps
Range	35m up to 140m	35m up to 250m	35m	1000m LOS
Topology	Ad-hoc, BSS			P2P, Mesh
Mobility	BS Zone			

- Wireless metropolitan area networks (WMAN)

WMANs are similar to WLANs (Cellular architecture) but with large coverage that can reach kilometres [8]. These networks are based on the IEEE 802.16 standard family also known as WiMAx networks. IEEE 802.16 based network can operate in from 10 to 60 GHz frequency band for line-of-sight zones (LOS) and can offer a bit rate up to 134 Mbit/s with a possible rage of 5 km. IEEE 802.16 based network can also operate from 2 to 11 GHz for non-line-of-sight zones (NLOS) and offers a data rate up to 70 Mobs for nomadic or stationary stations in rage of 10 km [33]. The standard has evolved with the IEEE 802.16e (Mobile WiMAX) amendment that brought the possibility of managing the mobility and roaming of stations at vehicular speeds (up to 125 k m/h) [21], and with the IEEE802.16m amendment that aim to provide enhancement to fulfil IMT-Advanced requirements, which are 100 Mbs in high mobility application and 1Gbs in stationary environment [34] Table-4 presents specifications and attributes of different amendments of IEEE 802.16 standard [8] [33] [34].

Table-4. WMAN specifications and attributes.

Standard	**IEEE 802.16** (WiMax)		
Amendment	**IEEE 802.16a**	**Mobile IEEE 802.16e**	**IEEE 802.16m**
Support	IEEE 802 LAN/MAN Standards Committee		
Spectrum	2 to 11 GHz	2 to 6 GHz	2 to 6 GHz
License frequency	Licensed		
Data rate	75 Mps	15 Mps	1 Gps
Range	10 Km (up to 50 Km)	5 km	5 km
Topology	BSS, Mesh		
Mobility	BS Zone	BS Zone and Handover	

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- Wireless wide area networks (WWAN)

WWANs are very high coverage data networks using satellite or cellular technologies. These networks use the facilities of one or more operators to offer different kind of applications and services with capability to manage high mobility and seamless handover allowing users to hand of between base stations. However, the use of these networks generates costs. Since the 1980s, the technologies used by these networks have not stopped evolving. In beginning, 2G characterized by the GSM technology and its improvement GPRS and EDGE allowed sending the voice and data with a speed in the range of 300Kb/s [35]. Then came the 3G characterized by UMTS technologies and its improvement HSPA and $HSPA^+$, allowed speed up to 14Mb/s [36]. Nowadays with networks purely IP based, 4G LTE technology with the LTE-Advanced and LTE-Advanced Pro improvements opened the door to the broadband (1, 5 Gbs) and to wide-ranging application fields e.g. critical communications services (emergency services), Smart Transportation (VANET), IoT, M2M [37]. Table-5 presents specifications and attributes of different WWAN technologies [35] [36] [37]

Table-5. WWAN specifications and attributes.

Technology	**GSM** (2G)	**UMTS** (3G)	**LTE** (4G)
Improvement	**GPRS/EDGE /EDGE+**	**HSPA/HSPA+**	**LTE/ LTE A/LTE A pro**
Support	3rd Generation Partnership Project (3GPP)		
Spectrum	900Mhz/1800MHz	900MHz 2100MHz	450 MHz to 3,8 GHz
License frequency	Licensed		
Data rate	171 Kps to 1,3 Mps	14,4 Mps- 21 Mps	1,5 Gps
Range	30 Km		
Topology	BSS		
Mobility	BS Zone and Handover/Roaming		

4. DISCUSSIONS

After analysing these characteristics, they can be categorized according to their importance and according to their criticality. Some can be simple i.e. defined based on the functional requirements of ITS application (e.g. data rate, fixe or mobile sensors). Other, however, require more attention because of their complexity (e.g. vehicle connectivity) or because of their interaction and influence on other characteristics (e.g. the deployment area). From this analysis will emerge our proposed design framework (figure-3) for any ITS communication solution, bringing together the seven features cited above and showing their interaction and influence? Given their major role in the ITS application, we chose to discuss in detail two characteristics: communication type and deployment area.

One specificity of ITS applications, is the possibility of using or involving cars (the presumed ITS clients) and their mobility to improve traffic management and offer improved services. Thus vehicle connectivity has attracted a great interest in ITS. Mainly VANETs are expected to play very important roles especially for ITS applications that require real-time data collection as well as for applications related to road safety and traffic management efficiency [20]. However deploying a VANET faces huge challenges as it was detailed in [19]. The first one is the very hostile communication environment because of the Non line-of Sight caused by existence of obstacles e.g. buildings and trucks. The second is a high dynamic network topology caused by vehicle mobility. The third is disconnection of communication caused by the V2V communication-coverage-limit. The fourth is the real-time requirements for safety applications based on inter-vehicle communications. The fifth one is the risk of interference with a large number of vehicles transmitting at the same time. In addition, the last one is to ensure the protection of the vehicle network from any attack or intrusion. We can see that the complexity of the communication environment is the root of the challenges mentioned above. So understanding and defining, in the most accurate way the communication environment is the foundation for establishing a reliable VANET.

In regards to the deployment area, it can be considered as a meta-characteristic of the ITS communication sub-system as it affects and interacts with most of its other characteristics. Indeed propagation properties of the deployment zone can affect the communication method characteristic. Thus, direct method should be used when we cannot set up a network infrastructure and we use services of a telecom operator whereas hierarchical method should be used when setting up a network infrastructure is possible. In this later case, the choice of the network topology will depend on both the propagation properties and the extent of the deployment zone. An infrastructure topology is to be chosen when the range does not exceed a hundred meters and when the visibility is good. An ad hoc topology could be used to cover larger areas with visibility problems yet one can also opt for hybrid architecture when we need to combine the advantages of the two architectures above. In addition, the zone of deployment will likewise affect the communication technology choice. Indeed the extent of the area will define which wireless technology to choose according to the coverage capacity offered by each category of technology (WWAN, WMAN, WLAN, and WPAN). In addition the density and the type (mobile, fixed, camera, ..) of sensors to set up in deployment zone will add other criteria of choice of the communication technology especially those related to the required flow, the size of the network (number of sensors) as well as mobility management and roaming.

Through all the foregoing we can say that the good mastery and the definition of the geographical, spatial and urban properties of the deployment zone as well as the understanding of the constraints related to the choice of the type of communication, in particular the V2V, is a necessary condition for designing a reliable ITS.

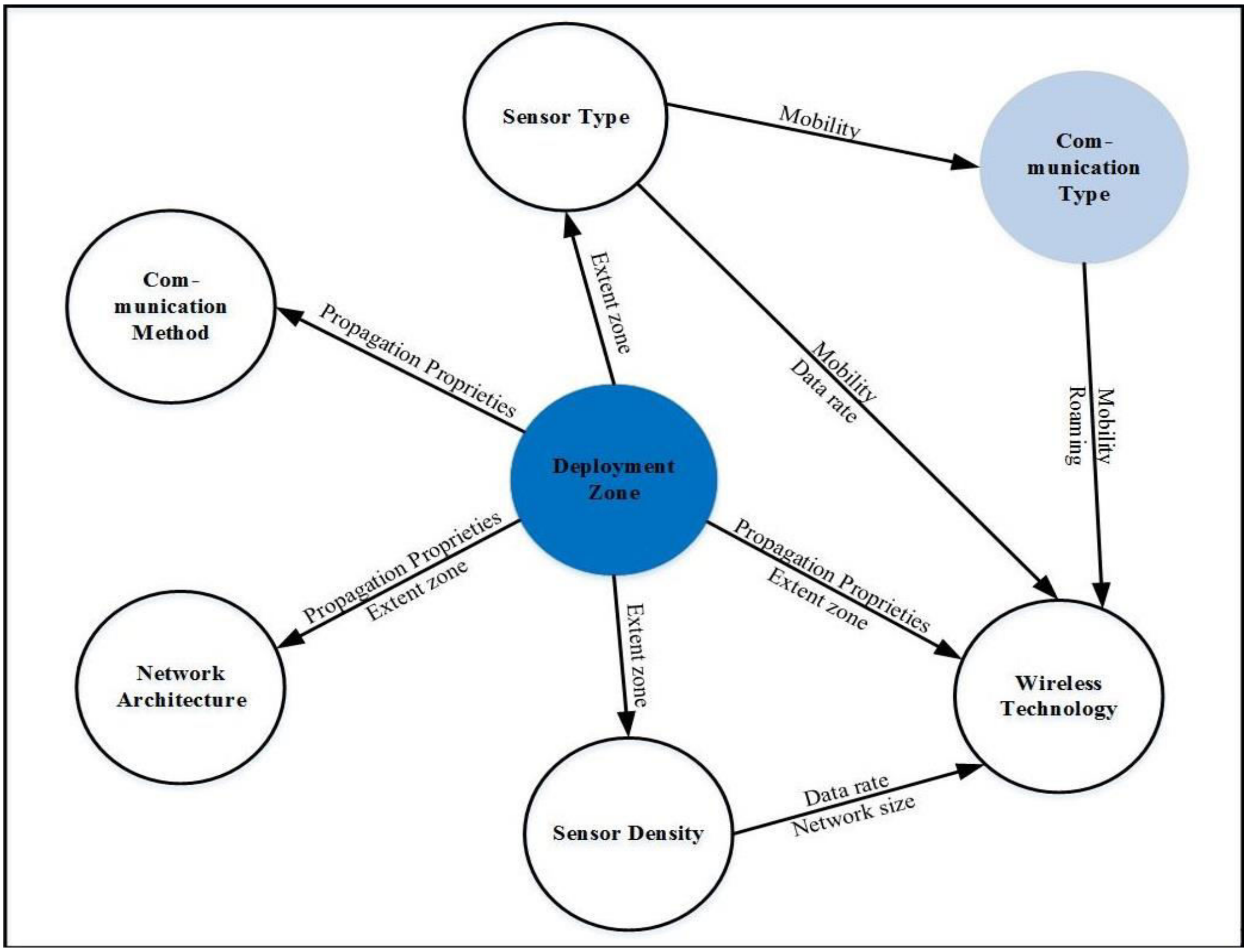

Figure-3. Communication sub-system framework (elaborate by the author). The direction of the arrows represents in which way the characteristics affect one another and the color represents the importance of the characteristic.

5. CONCLUSIONS

In this paper, we have shown that thanks to ITC - in particular wireless communication technologies- Smart Transport can solve many problems related to traffic management and can offer services to improve citizen's life quality. As the design of an ITS communication sub-system is far from being an easy task, we have suggested a design framework gathering the most important communication characteristics that should be taken into account when implementing a smart transport initiative. After analysing these characteristics and their interactions, we have highlighted the major role played by deployment zone as a meta-characteristic in defining and influencing the most of the other characteristics on one hand. In the other hand, we have pointed out the advantage and importance of V2V communications and at the same time the complexity of its implementation. We have come to the conclusion that the definition and mastery of the deployment area and the communication environment are key parameters for designing a reliable ITS communication sub-system. We would also like to point out that although our work was focused on smart transport domain, the approach can be used when studding any other smart city initiative that requires wireless communication without forgetting to take into consideration the specificities of each domain.

One of the main objectives of ITS is to minimize the risk and the problems related to congestion which is closely linked to the density of traffic (number of vehicles traveling on the road in a given area) [1]. Thereby the requirements of an ITS application change from one locality to another depending on each's traffic density. In

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fact, density traffic is related to: 1) the socioeconomic status of the area (rich-middle-poor class housing area, industrial area, administration offices area). 2) The hour in the day (rush hours). 3) The state and the capacity of the road infrastructure (wide, narrow, ageing road). Before designing an ITS and scaling its communication sub-system, it would be useful to have a spatial and temporal mapping of density traffic for all city areas. Our next work is to study how far this indicator, which is traffic density, can affect the choice of the ITS Communication Sub-system, and how can we built a density-traffic map for each city areas.

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