Comparative analysis among vehicles tracking technologies

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Abstract: - The objective of the comparative analysis among vehicles tracking technologies is to study the main characteristics and analyze the advantage and disadvantage of each technology.Day by day communication is more necessary and improves the way and speed-up the information between people and process. The track systems are fundamental to compare the planned route with the actual situation. Telecommunication and Information Technology optimize routes, avoid accidents and actuate sending warning, alerts and field team to isolate a given zone. The research is based on five feasible technologies to track vehicles: a)RFID Radio Frequency IDentification technology; b)Cell Phone carriers using GSM, GPRS, WCDMA or LTE in commercial networks; c) Global Positioning Satellite; d)Vehicle network, V2X technology, IEEE 802.11p standard; e) Surveillance camera to catch the trucks identification

Keywords: - Telecommunication, tracking, RFID, Cell phone, GPS, WAVE, DSRC, image processing.

1 Introduction

The transport of dangerous goods faces a pool of problems, mainly the fact the cargo is not tracked all the time by the responsible authority, which cannot take preventive measures.

There are not integrated systems that can update all tracks and tracing information in the same database, it can raise the delay to identify, response and control a supposed accident on a given zone.
The most usual technology to track vehicles is the GPS system navigation and GPRS data transmition. There are other technologies that can provide better results on tracking system improving the reliability, security and availability with the lowest cost.

2 Problem formulation

According Traffic Engineering Company, the dangerous good transport faces three problems:

(a) There is not enough surveillance;
(b) The trucks are not tracked on real time;
(c) The police department, civil defense department, road system department and traffic engineering company are not receive the alerts fast enough to make preventi

In order to compare the advantages and disadvantages of each track telecommunication technology, seven aspects were chosen:

(a) Security
(b) Latency
(c) Coverage area
(d) Throughput
(e) Radio frequency interference
(f) Cost
(g) Availability, reliability and feasibility to implement and track vehicles

There are many ways to track trucks. The main technologies are five:

(a) RFID: Radio Frequency Identification technology
(b) Cell Phone carriers using GSM, GPRS, WCDMA or LTE in commercial networks
(c) Global Positioning Satellite
(d) Surveillance camera to catch trucks identification
(e) Vehicle network, V2X technology, IEEE 802.11p standard.

2.1 RFID – Radio Frequency Identification

The RFID technology is an architecture supported by active readers with antennas that send electrical waves to transponders. There are three types of transponders:

a) Actives: Transponders with internal battery that is the power supply to send the information to toll antennas all the time.
b) Passives: Transponders without internal battery, the transponder has an internal antenna that

Works like a power supply. The internal antenna catches the energy sent by the toll antenna and transforms it in energy to feed the microprocessor and send the information to toll antennas during a short time. Figure 1 shows the 2-way data transmission:

a. Antenna – transponder : Energy + data
b. Transponder – antenna : Data

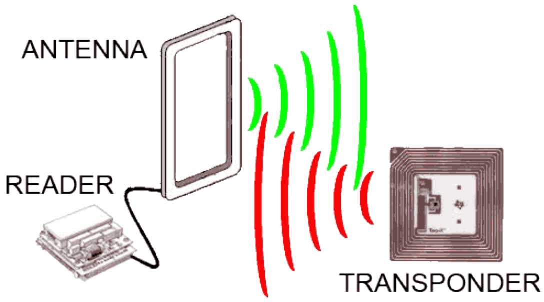


Figure 1. Passive RFID [1]

c) Passives with internal battery or semi-actives. It is the most usual type of transport tracking transponder. The internal antenna catches the energy from the tolls and turns on the circuit of internal power supply. The reason to use internal battery is that it increases the transmission power to allow high-speed pass tracking and more distant tracking.

One RFID technology project is “Brasil-ID” designed by a technical cooperation agreement signed among the Ministry of Science and Technology, the Federal taxes and fees Ministry and all Brazilian states of the Union through their Departments of Finance, formalized the start of the Identification System and Tracking Goods Authentication. "Brazil-ID" is based on the use of Radio Frequency Identification technology (RFID), and other complementary integrated to perform, within a single standard, the identification, tracking and authentication of goods in production and in circulation by the country. The project is based on SINIAV- National System for Automatic Vehicle Identification - It uses electronic boards for vehicle identification.

The figure 2 illustrates the SINIAV- National System for Automatic Vehicle Identification working

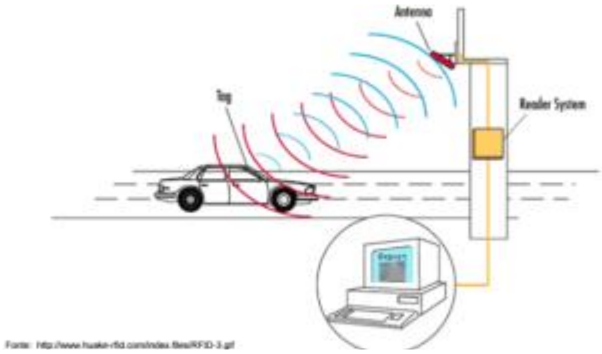


Figure 2. RFID system data transmission [1]

The RFID system operates in the frequency range of 900 MHz, 2.4 GHz, 5.8 GHz and 24 GHz.
The factual transponders are able to transmit until 100 Km/h. It works in ASK modulation with cryptographic AES-128 bits and effective rate of transmission until 640 kbps.
RFID technology complies with the ISO 18000-6 standard.

2.1.1 Advantages of RFID system

There are four main advantages:

a) Technology that is independent of cell phone carriers and US, Russia or China government satellite constellation.
b) Has a dedicated and independent network of communication, i.e., does not compete with other users
c) Response time and latency relatively low
d) Cost of devices, transponders, relatively low

2.1.2 Disadvantages of RFID system

There are four main disadvantages:

a) It needs to implement and maintain an own network
b) Frequency band could be interfered from open telecommunications – ISM band (Instrumental Scientific and medical)
c) Range limited to few meters
d) Low data rate capacity

2.2 Cell phone carriers UMTS technology - GSM / GPRS / EDGE / LTE

The Cell phone carriers’ technology is used to get information from cargo trucks through UMTS – Universal Mobile Telecommunication System - radio frequency standard adopted by cell phone carriers using GSM, GPRS, EDGE, WCDMA or LTE commercial networks. Figure 3 shows the mobile technologies evolution in seven steps:

a) AMPS: Advanced Mobile Phone System was the first generation technology and it is not used anymore.
b) GSM: Global System for Mobile communications, the second generation of mobile communication
c) GPRS: General Packet Radio Services is the packet data communication for GSM technology.
d) EDGE: Enhanced Date Rates for GSM Evolution is an evolution of GPRS technology
e) WCDMA: Wideband Code Division Multiple Access is the third generation of mobile communication
f) LTE: Long Term Evolution is the fourth generation of mobile communication.

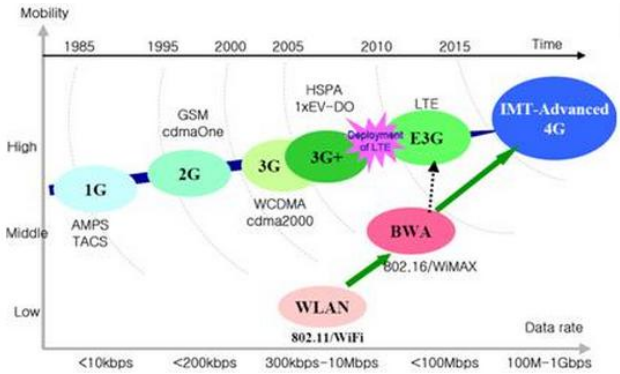


Figure 3: Mobile technologies evolution [11]

These technology are widely used by the population and the tracking systems has to share the transmission capacity with other users, this fact gains economies of scale, but it is a bottleneck in extreme situations where it is necessary to access the tracking system and the shared network is fully occupied by other users.

This technology uses frequencies bands granted by ITU – International Telecommunication Union.

In Brazil ANATEL (Brazilian telecommunication regulatory agency) is in compliance with ITU and the carriers explore the frequencies between 700 MHz and 2.6 GHz to explore mobile service, as identified by the figure 4:

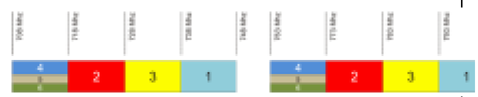
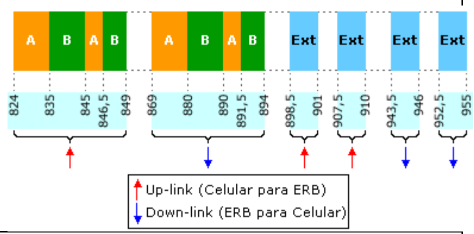
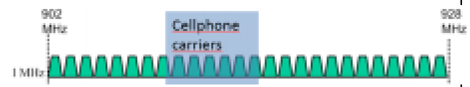
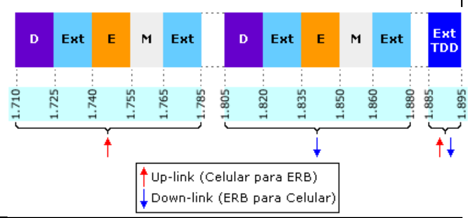
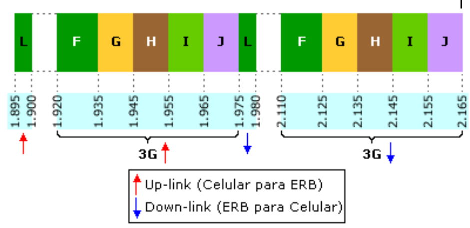
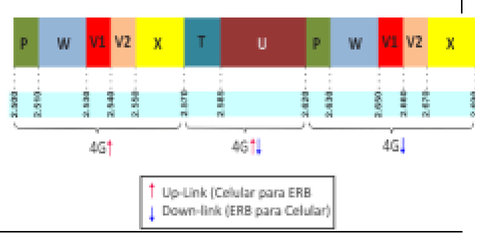
700 MHz band: 4G (LTE)	
850 MHz band: 2G (GSM / GPRS / EDGE)	
900 MHz band: 2G (GSM/GPRS/ EDGE)	Collision with ISM band from 902 MHz to 928 MHz 
1800 MHz band: 2G (GSM / GPRS / EDGE)	
2100 MHz band: 3G (WCDMA)	
2600 MHz band: 4G (LTE)	

Figure 4: Frequency bands of cell phone carriers granted by ANATEL [8]

The topology of the carrier track system is detailed in three steps:

a) The car with a built-in SIM-CARD device transmits data to a base station.
b) The base stations which cover determinate area tracks the vehicle and send information to carrier´s database. Figure 5 illustrates a coverage area of a center cell, named best server, according the vehicle moves the other cells named candidates could become the best server.

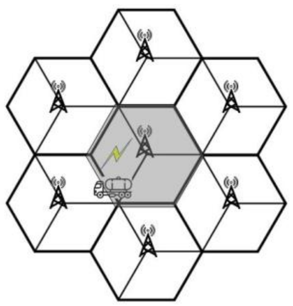


Figure 5: Cell coverage of mobile carriers

c) Figure 6 shows the handover process. The mobile station moves off the best server cell and the signal level of the neighbor candidate cell becomes stronger and makes it be the best server cell.

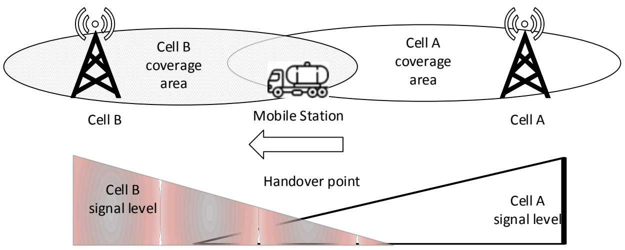


Figure 6: The handover process

d) Figure 7 shows the carrier´s data base integrated with a national database where companies can request and report the tracking vehicles.

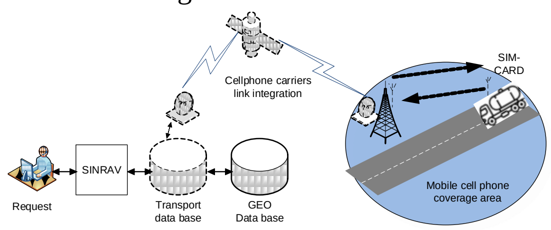


Figure 7: System monitoring using cell phone networks.

2.2.1 Advantages of Advantages of tracking system using cell phone carriers' networks

There are four main advantages:

a) It does not need a dedicated tracking network;
b) There are dedicated frequency bands to each service. It means no frequency interference;
c) Some kilometers of coverage area per cell;
d) High rate data transmission

2.2.2 Disadvantages of Advantages of tracking system using cell phone carriers' networks

There are three main disadvantages:

a) Very dependent of cell phone carriers and agreements between carriers and government.
b) The network is shared with more users i.e. competing with other users, especially in crisis or high density situations without a guaranteed transmission bandwidth.
c) Response time and latency relatively high

2.3 Global Positioning System (GPS)

The tracking system by satellite is based on satellite coverage and the receiver segment that needs to be tracked.

The most used satellite system is the United States constellation, Global Positioning System – GPS.

Besides the US government system - GPS, there are the Russian - GLONASS, the Chinese - Compass and the Europe Union - Galileo (in progress).

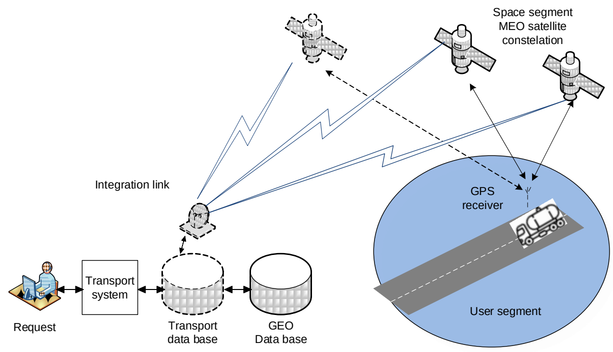


Figure 8. GPS System Operation [6]

The GPS system is based on 24 satellites placed in a medium earth orbit (MEO), also known as Intermediate Circular Orbit (ICO) is the region of space around the Earth above the low orbit altitude (2,000 km) and below the altitude of geosynchronous orbit (35,786 km), or between the two Van Allen belts, formed from particles emitted by the sun, protons and electrons that make up the solar wind and are prevented from colliding with the Earth thanks the shell formed by the Earth's magnetic field. The Van Allen belts are located approximately between 1000 km and 25,000 km from the Earth's surface and the inner region formed mainly of protons and the outer of electrons.

The average satellite orbits have features like the possibility to cover the globe with only 10 satellites, i.e. much less than the 50 satellites of the low orbits and have the advantage of lower latency (90 ms) compared to geosynchronous satellite latency (270 ms) as shown at figure 9.

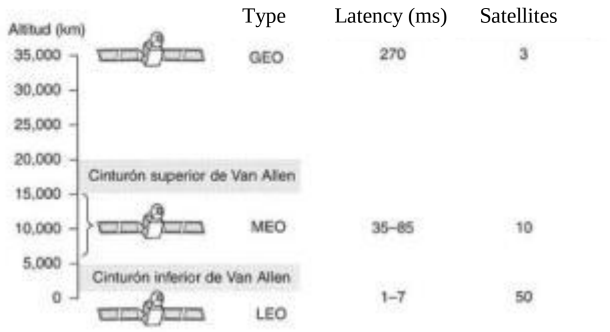


Figure 9: Comparative table of the satellites orbits [6]

Brazil belongs to region 2-Americas- defined by ITU-International Telecommunication Union, as shown in Figure 10.

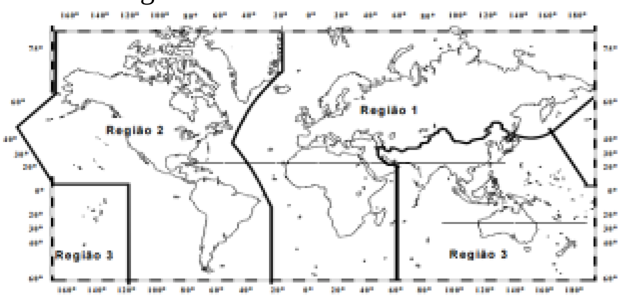


Figure 10. Classification of satellite regions as ITU [7].

GPS satellites transmit two low power radio signals, designated L1 and L2. Civilian GPS receivers use the L1 frequency of 1575.42 MHz UHF. The L2 signal is assigned to military use only.

These signals travel to Earth passing through clouds, but may suffer delays due to heavy rain, dense fog and pollution, does not pass through solid barriers such as buildings, tunnels and mountains.

A GPS signal contains 03 different codes of information:

a) A pseudo-random code that is simply an identification code that shows which satellite is transmitting information. The code (a two-digit number) is seen in the satellite page of GPS receiver, it identifies from which satellite the signal is received.
b) The Ephemeris data, which are constantly transmitted by each satellite, contains important information about the status of each of them (good or bad) and the current date and time. This part of the signal is essential to determining a position.
c) The Almanac data inform the receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data, sending information about its orbit for each satellite system. Each satellite sends the data containing its exact position (position and elevation) and the time to start the transmission of data.

The GPS receiver interprets all these data that is possible to measure the elapsed time interval between the time of signal transmission and its reception in order to determine the distance between the receiver and the satellite. Calculating the distance to at least 03 satellites you can determine the current position on Earth where the receiver is placed.

This technique is known as triangulation, detailed in three stages:

1) The receiver picks up signals from the first satellite, it is possible to set a circle around the first satellite. The radius of the circle is calculated as a function of time between the GPS satellite and the receiver shown in Figure 11.

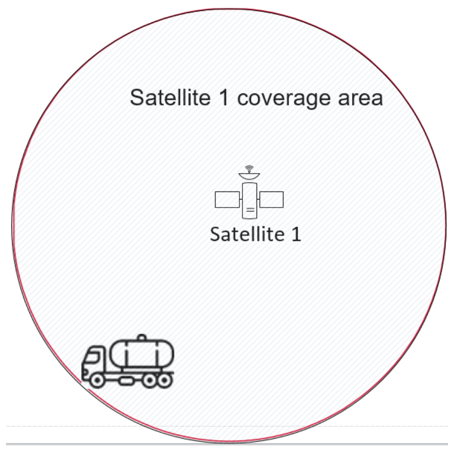


Figure 11: One satellite coverage area

2) With the location of the second satellite , you can set the second satellite coverage area and hence the area of intersection between the two satellites , shown in Figure 12 .

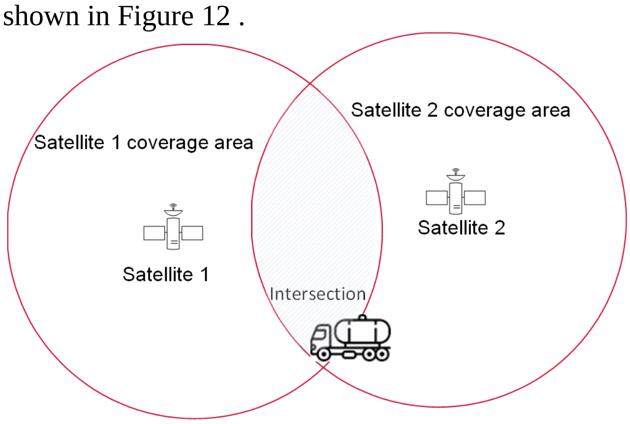


Figure 12: Two satellite coverage area

3) From the third satellite location, you can set the third satellite coverage area and the area of intersection between the three satellites. The more satellites are located, the more accurate becomes the intersecting area shown in Figure 13.

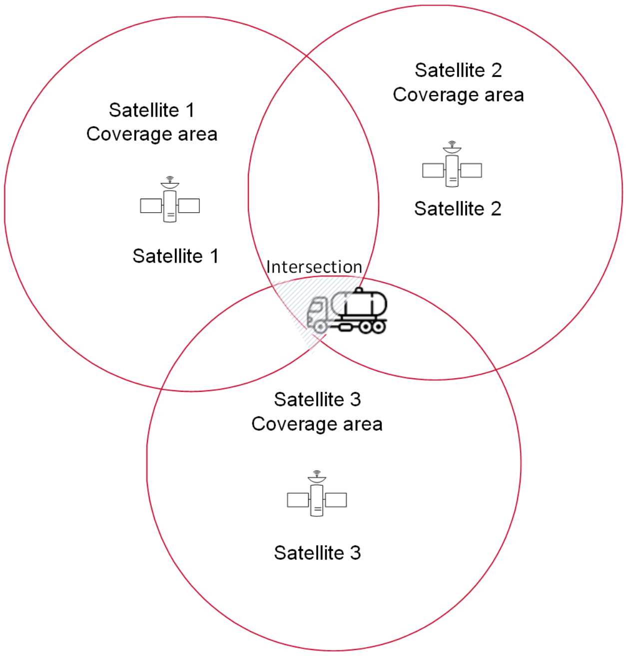


Figure 13: Three satellite coverage area

Due to the feature of using the triangulation based positioning, the GPS system consists in a constellation of 24 satellites that any earth surface is always covered for at least 03 satellites, which have 12-hour revolution time and 55º elevation. It means that at least 04 satellites are simultaneously visible at any point on Earth. Figure 14 illustrates the GPS satellite constellation.

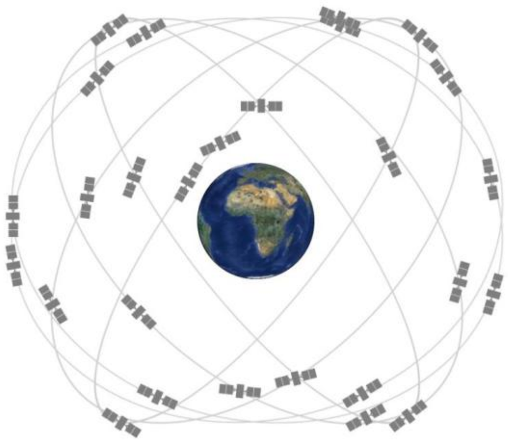


Figure 14: GPS System satellite constellation [6]

These receptors have, on average, a 15 meters precision. There are seven factors that can degrade the GPS signal and affect accuracy:

a) Change of delays in the ionosphere and troposphere : Also known as Zenith delay . The satellite signals undergo refraction as they pass through the atmosphere , as there is variation in the layers composing the atmosphere , the system is able to calculate an average delay to partially correct this type of error . Tropospheric delay is calculated by the equation (1) DTROP and shown in Figure 15.

$$DTROP = \rho_0 - \rho_g = 10^{-6} \int N \, d\rho \quad (1)$$

Where:

ρ_0= path length effectively covered by the sign
ρ_g = Length of the geometric path
N = Change in atmospheric refractivity

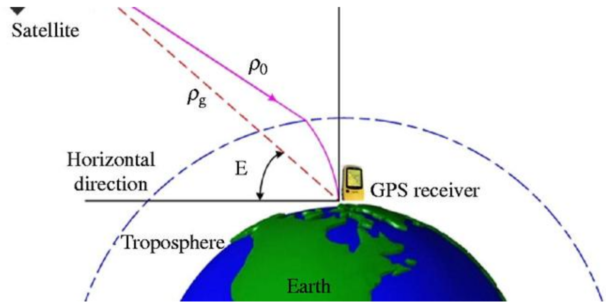


Figure 15: Tropospheric delay

b) Sign with multiple paths: This occurs when the GPS signal is reflected by objects such as tall buildings or mountains, before reaching the receiver. This increases the time it takes the signal from the satellite to the receiver, causing errors.
c) Receiver Clock Errors: The internal clock of the receiver is not as accurate as the atomic clock of GPS satellites. Thus, small errors may occur in the measurement of time.
d) Orbit errors: Also known as ephemeris errors, orbit errors mean errors in the information of the positions of satellites.
e) Number of visible satellites: The more satellites a GPS receiver can see in the sky, the better the accuracy. Buildings, tunnels, mountains, electronic interference or a dense coverage of a forest, for example, can block the signal reception, causing position errors or possibly no position reading at the receiver.
f) Geometry of the satellites: This refers to the relative position of the satellites at any time. The optimum geometry of the satellites is achieved when located at large angles with respect to other satellites. Bad satellite geometry

occurs when they are aligned in a straight line or a very close group.

g) Intentional: Selective Availability (SA - Selective Availability) is an intentional degradation of the signal imposed by the US Defense Department, created to prevent US military enemies using a high-precision GPS signal.

2.3.1 Advantages of GPS system

There are three main advantages:

a) It does not need to structure and maintain an own network
b) Frequency bands are dedicated to the GPS service
c) Coverage area: all the globe

2.3.2 Disadvantages of GPS system

There are five main disadvantages:

a) It depends of the US government satellite constellation or China (Compass) or Europe(Galileo) or Russia(GLONASS).
b) Coverage gaps due to obstructions.
c) Response time and latency very high
d) Low data transmission rate
e) GPS does not have a security protocol. It makes easy to be defrauded
f) High cost to be an uplink system (receiver-satellite). Usually it is applied only on downlink system (satellite-receiver) and needs another technology to send the vehicle location information.

2.4 Surveillance Cameras

The supervisory system based on cameras is composed of two subsystems:

a) SLP-Subsystem boards Reading
b) OCR: Optical Character Recognition

This system does not use radio frequencies. It works using wavelengths of infrared or visible light.

The system captures the license plate of the vehicles that pass through the portal chambers. The procedure can capture faceplates or rear plates of the vehicle. The system transmits the image plate shape to an optical character recognition, OCR, station where it is converted to a text file that sends the information to the central processing system. In the central system processing the information are processed in accordance to the requirements of the premises and can be added with other information like speed meters, rotation schedule, registration in the police department, FISCO, pollution control or others that are interest to city, state or federal governments.

Figure 16 illustrates the image processing:

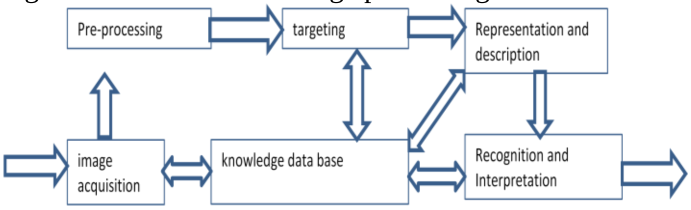


Figure 16: Image processing [13]

Computer vision depends of various methods to get reliable information with considerable success rate. Since image acquisition to a decision-making, some negotiations have to be implemented:

a) Image acquisition: There are various image sensor models such as the cameras, video cameras, infrared and ultraviolet devices, sensors ranges etc, which aims to get a good image to be used as an information source.
b) Pre-processing: before any computer vision method can be applied in order to extract some specific information, it is generally necessary to process the data to ensure that it meets certain assumptions imposed by the method:
   a. Re-sampling, to ensure that the coordinate system is correct.
   b. Reduction noise, to ensure that the noise of the sensor does not register false information.
   c. Increase Contrast, to ensure that relevant information is detected.
c) Segmentation: an important point for the detection of an object is to know the regions of the image, punctuating them with levels of interest or relevance.
d) Validation: in this stage typically uses a small set of information, assuming that contains the specific object of research:
   a. Checks whether the data satisfies the basic type or a specific assumption of the information as well the observation parameters such as the object's size or the position where it is located, in this step there are two check:
      i. The Image recognition, classifying it as an object.
      ii. The Registration information, comparing or combining two views of the same scene.

e) Decision making: At this level, the system makes the final decision:
    a. Found or not the object of study.
    b. If, pass or drop the reading, the automatic quality inspection.
    c. Signalize the situation indicating whether there are reported features such as the detection of an automobile license plate.

After these steps the image are recognized as characters and populate the data base of the tracking system and can be used as any other kind of tracking.

The main problems of surveillance cameras are four [9]

a) Determine the exact size of the field of view in order to understand the size and surface characteristics of the area you want to illuminate and cover.
b) Determine the type of light source suitable to the application (tungsten, fluorescent, halogen, LED, laser), choosing an appropriate frequency range of the light spectrum as the surface characteristics of the object under study seen in the previous step.
c) Determine the geometry (position of the source to the object and sensor, direction of light beams), the power, efficiency and temporal characteristics of the light source, necessary to enhance the desirable parts of the object in a homogeneous and steadily over time.
d) Obstructions of other vehicles must be considered to choose a redundant reader system.

2.4.1 Advantages of surveillance camera system

There are four main advantages:

a) The technology is independent of cell phone carriers or the US government satellite constellation.
b) It has an independent communication network without capacity sharing problems.
c) Immunity to radio frequency interference.
a) It does not need embedded devices.

2.4.2 Disadvantages of surveillance camera system

There are five main disadvantages:

a) It needs to implement and maintain an own network.
b) Obstructions of other vehicles.
c) Coverage area limited to a few meters.
d) Illumination.
e) There is no possibility of a two-way information exchange.

2.5 Vehicle network

The technology *V2X, Vehicle to vehicle and Vehicle to Infrastructure* is based on multiple technical cooperation, the mainly standards are developed by the IEEE – Institute of Electrical and Electronic Engineering. It is part of Dedicated Short-Range Communications (DSRC) standards and more specific the Wireless Access in Vehicular Environment (WAVE). Figure 17 ilustrates an useful situation of vehicle networks.

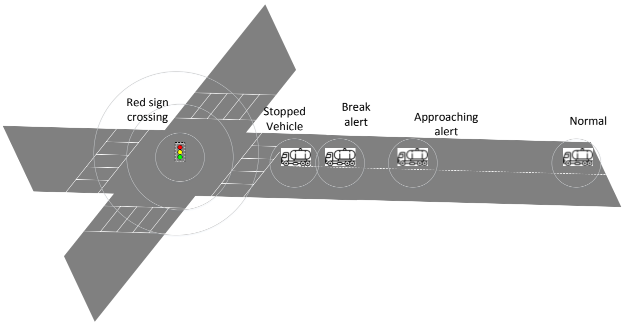


Figure 17: Vehicle network useful situation

The IEEE 802.11 protocol family is widely used on ISM (Instrumental Scientific and Medical). Figure 18 illustrates the ISM frequencies, from 900 MHz to 5850 MHz, named WiFi or high fidelity wireless communication, uses the protocols IEEE 802.11 a/b/g/n/ac/ah. These frequency ranges have the problem of multi-use application and no coordination. It affects the pollution frequency use and high maintenance to relocate the frequency.

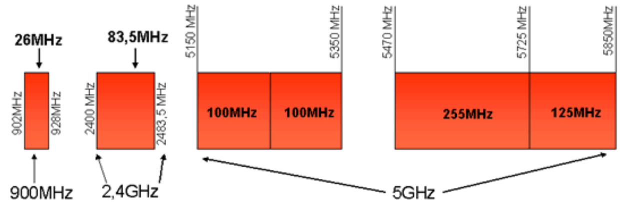


Figure 18: ISM frequency range.

The DSRC standard is in compliance to IEEE 802.11p, a seven dedicated channels in licensed band frequency with transmission rate between 6 and 27 Mbps as shown in figure 19

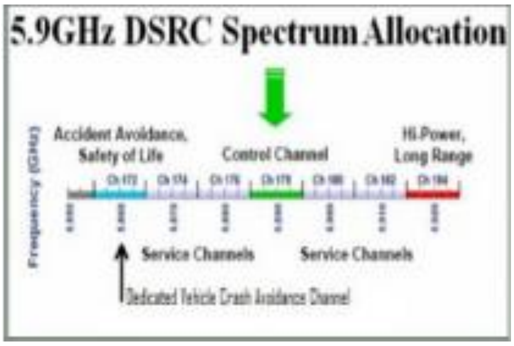
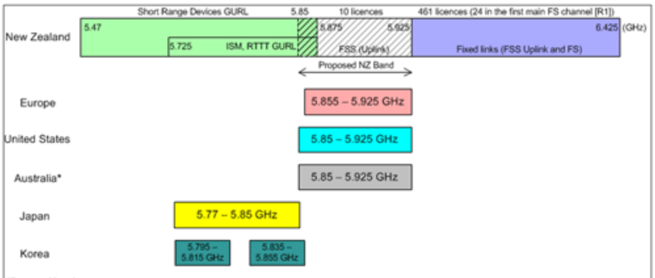


Figure 19: DSRC 7 channels [10]

The figure 20 represents the spectrum allocation of DSRC in the world:

a) Europe, USA and Australia have adopted the band 5855-5925 MHz;
b) Japan and Korea have adopted the band 5770-5850 MHz;
c) Brazil has not yet released the standard to adopt but it seems to be adopted the band 5855-5925 MHz, due to:
   a. The band below 5850 MHz is used by Internet service providers (ISM-Instrumental scientific and Medical)
   b. The upper band 5927 MHz is allocated to satellite transmissions towards earth - TV, upward link and Point to Point – PTP- radio communication.



Brazil	ISM band	5855-5925 MHz	Satellite and PTP radio

Figure 20: IEEE 802.11p standard band allocation

2.5.1 Advantages of Vehicle networks system

There are seven main advantages:

a) Technology is independent from cell phone carriers or US government satellite constellation.
b) Independent communication network does not have to share the system capacity with other users.
c) Dedicated frequency band.
d) Vehicles manufactures trend to produce all vehicles with this technology embedded devices.
e) Very low latency.
f) Dedicated channels for crisis situations.
g) 500 m radius cover.

2.5.2 Disadvantages of Vehicle networks system

There are two main disadvantages:

a) It needs to structure and maintain own network
b) It has not been adopted as the standard for all vehicle manufacturers yet.
c) There are studies to use 24 or 78 GHz frequency bands.

3 Technologies analysis – advantages and disadvantages

Figure 21 compares the latency among different technologies, the main four are:

a) GPS: 60 seconds
b) Cell phone carriers: 3,5 seconds
c) RFID : 1,5 ms
d) DSRC: 2 μs

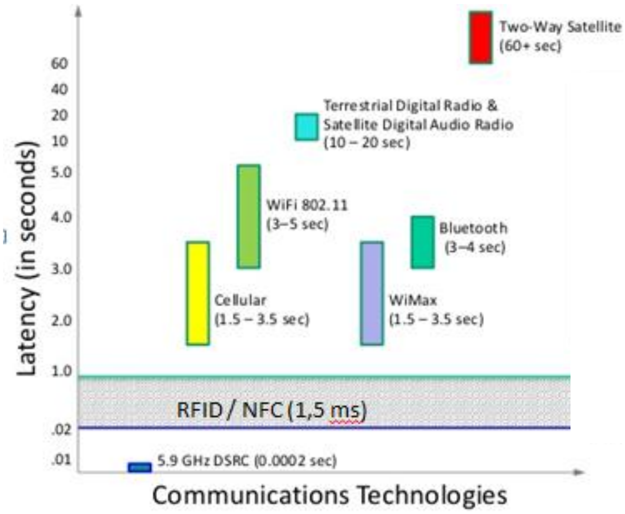


Figure 21: Comparative graphic of latency tracking technologies [11]

Table 1 compares protocol, latency, frequency band, coverage area, capacity, and security among the five different technologies:

a) GPS
b) Cell phone carriers
c) RFID
d) Vehicle network

e) Surveillance Cameras

Table 1: Comparative table

Technology	GPS	RFID	DSRC	Cell phone Carriers	Cameras
Protocol	DVBS -2X and HEVC	IEEE 802.11 ah	IEEE 802.11p	LTE	OCR
Frequency	1.5 GHz	900 MHz	5.9 GHz	700, 850, 900, 1800, 2100 and 2600 MHz	THz
Latency	2 s	1,5 ms	0,2 ms	100 ms	>> 2 s
Capacity	60 Mbps	640 Kbps	5 Mbps	100 Mbps	Image
Coverage area	Global	8 m	500 m	5 km	8 m
Security	-	Short distance	PKI Authentication	SIM card K Authentication	-

The Vehicular networks, IEEE 802.11 p standard has the smallest latency, is very secure and has more interference immunity. It is a trend to be built-in on new vehicles that does not affect additional installation costs, but it is still in the study phase, and impractical to immediate use.

The RFID technology works on the same frequency band as the tolls, it is an advantage because requires less infrastructure to be built, but has the disadvantages of interference, security and the TAG costs.

The GPS has the best coverage but it needs another system to inform the location and it does not have security protocol. It is too easy to be defrauded.

The cell phone carriers are a good two-way communication, have the advantage of offering wide coverage area, including tunnels, underground and other places not reached by GPS. The main disadvantage is that it needs cooperation among carriers, government and other stakeholders with high costs.

The cameras has the problem of one-way communication, It is feasible to track, but with this technology is very difficult to alert the drivers of a supposed route optimization.

4 Conclusion

This paper addresses the possibility to apply several resources technologies of communication to track vehicles, alert population and active responsible authorities during crisis deal to prevent huge damages.

The main idea is to use existing tools with high efficiency, low costs and short roadmap implementation.

On the factual scenario, the best option is to merge technologies were one complements the weakness of the other. The GPS navigation with radio communication is a good option while V2X or RFID do not have enough coverage.

The surveillance camera becomes a good option whereas the computational power increases and the data base storage costs decreases. Day by day it is easier to track all vehicles using this technology.

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