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Modeling and Implementation of Bus Rapid Transit corridor based on isolated or coordinated Traffic Prioritization and Automatic Location

Ioannis Patias[1], and Vasil Georgiev[1]

[1]Faculty of Mathematics and Informatics
University of Sofia St.Kliment Ohridski"
5 James Bourchier blvd., 1164, Sofia, Bulgaria
ioannis.patias@gmail.com

Abstract. In many cities facts defining conditions for very high concentration of functions and population make transport difficult. The proposed solutions are Automated Vehicle Location (AVL) and prioritization systems for mass urban transport buses, and priority vehicles, through a Bus Rapid Transit (BRT) corridor. Two solutions presented, which consist of a detection sub-system, with a bus component, using transmitter, and a receiver placed on the traffic lights, in the case of isolated system and an additional control center, in the case of the integrated / coordinated system. The functionality is described, and it is also presented as architecture the solution of an integrated bus priority management GPS system. In both cases we aim in minimizing the waiting time on traffic lights, and thus the waste of time on traveling. Such system is a useful instrument for any mass urban transport system.

Keywords: Intelligent Transport System (ITS), Automated Vehicle Location (AVL), Traffic Prioritization, Bus Rapid Transit (BRT).

1. Introduction

The term Intelligent Transport Systems (ITS) refers to a wide range of applications. The most basic ones include simple traffic signal control and management systems, automatic number plate recognition with speed cameras, security CCTV systems. The more advanced applications can integrate real-time traffic and vehicle data and can regulate the traffic in real-time with using such historical data.

Although ITS may refer to all modes of transport, EU Directive 2010/40/EU [1] (7 July 2010) defines ITSs as systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport. ITSs are important in increasing safety and also manage Europe's growing emission and congestion problems. They make transport safer, more efficient and more sustainable [2].

On the other side in other countries, like the United States, the increased interest in the area of ITSs is rather motivated by an increasing focus on homeland security. Many of the proposed ITSs also involve surveillance of the roadways, which is a priority of homeland security [3, 4].

When talking about ITS, there is e a wide range of technologies applied [5]. Those technologies include: data processing, management and archiving, detection, communication, information dissemination, location referencing and positioning, traffic control and vehicle control, electronic payment, and surveillance and enforcement technologies.

Bus Prioritization System (BPS) or Transit Signal Priority (TSP) is an ITS aiming to reduce the time waist on traffic lights for Mass Urban Public Transport vehicles. Although are most often related with buses, they also are applied in trams, rails, etc., and any kind of priority vehicles. In terms of technologies BPS involve traffic control, and detection technologies.

There are two categories of BPS. The so-called active BPS is a system based on detecting Mass Urban Public Transport vehicles as they approach the traffic light and adjusting the traffic light's timing dynamically, and thus create "green wave", meaning uninterrupted traffic along the bus line route. It is important to mention here that implemented this way the system can also be used for the emergency vehicles, so from now on when we are talking about buses we always mean also emergency vehicles. The most advanced active BPS are based on AVL, and real-time Estimated Time of Arrival (ETA) calculation. Passive BPS called those systems, which are built with specialized hardware and try to optimize the traffic lights timing by using historical data, and this effect applies to all vehicles along a route.

2. Literature Review

The term Ubiquitous Computing [6] is used to express the idea of a post-desktop model of human-computer interaction, where we have integration of information processing into everyday objects and activities. In many cases the end-user uses more than one distributed systems and devices even simultaneously, without even being aware of their existence. The implementation of this concept is not that easy. But the overall dividend is great. Our life would be quite easier if all objects in the world surrounding us get equipped with identifying devices.

The most widely used identifying devices are the ones using Radio-Frequency Identification (RFID). RFID tags, or electronic labels are used with objects to be monitored or tracked. The technology can be applied to any object, animal, or people. We can identify and track the objects by using radio waves or sensing signals. There are tags, which can be tracked with range of tens or hundreds of meters. The syntax of RFID tags contains two major parts at least. The first is storing and processing information integrated circuit, which is also modulating and demodulating a radio-frequency (RF) signal. The second part consists of an antenna, used for receiving and transmitting the radio signals.

There are active, semi-active, and passive RFID tags. Tags can store up data and consist of microchip, and antenna, and also battery for the cases of active and semi-passive tags. All the components can be enclosed in plastic, or silicon. In general RFID tags help us in our everyday activities, since they are not expensive, and at the same time they can apply in almost any object.

The use of RFID enriches the options of systems used for giving priority to vehicles. The concrete needs determine the most appropriate measures to be used. A feasibility study should be implemented prior to the concrete measures to be used can be defined.

There are various ways of giving priority to buses, which could be broadly categorized as [7, 8]:

- physical measures,
- traffic signal priorities, and
- integrated measures.

Physical measures can include with and contra-flow lanes, bus only lanes or even streets. Traffic signal priorities method's typical example is the BPS. Integrated measures are those, which combine traffic signal measures with physical measures. The latest is applicable in cases where none of the first two systems alone is effective.

Focusing on the traffic signal priorities method, there are different systems implementations. Those differentiations usually called traffic signal control systems and strategies, and are categorized in:

Isolated systems. In isolated systems the controlled by signal traffic light is located and operates independently, this is why the term isolated traffic light is used. Traffic light's signals can also be linked to a Control Centre, but only for fault monitoring purposes, not for management. Isolated system can further be divided into fixed time or vehicle actuated (VA).

Co-ordinated systems. Co-ordinated systems are so called because they coordinate the operations at a traffic light, with the operations at one or more neighboring traffic lights. All traffic lights have to be connected to a centralized system implementing a Control Center system. Co-ordinated under Control Center systems can be further divided into traffic responsive or fixed time.

VA systems rely on detectors placed on traffic lights. When a bus approaches to the traffic light, and once it is detected the traffic light performs the appropriate timing. A bus approaching a traffic light with red light sends to the controller a demand for a green light. The demand is then served by the controller, which can apply different timing cycles. After serving any signals and with no more incoming ones, the controller will continue the preprogrammed mode/s.

The VA system can give priority both to buses, and any other special purpose and/or emergency vehicle. Also the VA systems can serve different priority levels requests. This means that special purpose vehicles can transmit a higher priority level "priority request", and thus be served with privilege.

3. System architecture

The proposed AVL and prioritization system for urban transport buses, through the BRT corridor system architecture consists of the two major sub-systems, the vehicle, and the traffic lights sub-system. The deployment diagrams of the two sub-systems are given in Fig.1: Vehicle sub-system deployment diagram, and Fig.2: Traffic lights sub-system deployment diagram.

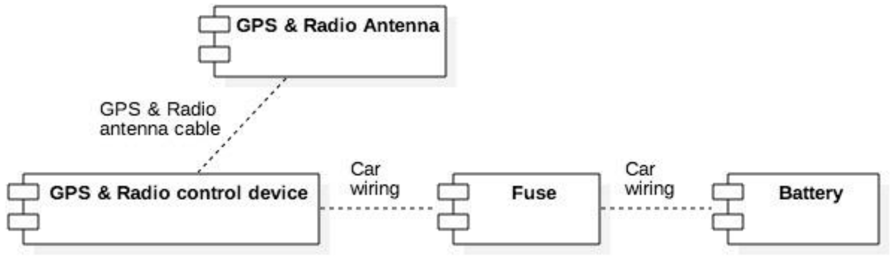

Fig. 1. Vehicle sub-system deployment diagram

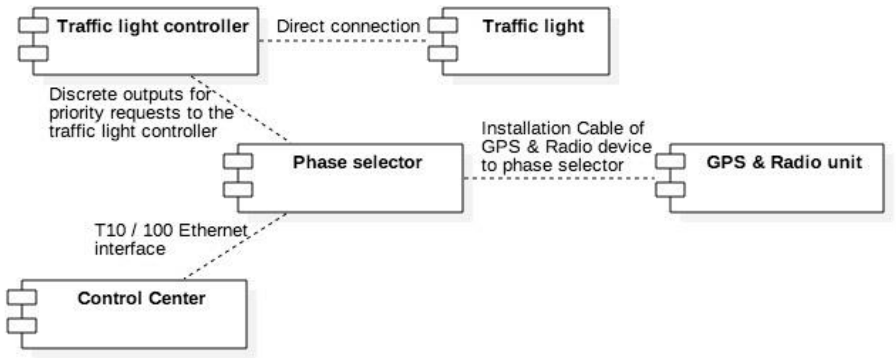

Fig. 2. Traffic lights sub-system deployment diagram

Fig.1 presents vehicle sub-system deployment diagram, models the physical deployment of the system's components on the vehicle. This describes the physical deployment in terms of hardware components, and how the different pieces are connected. No software component runs in this sub-system, including node "GPS & Radio control device".

Fig.2 presents Traffic lights sub-system deployment diagram. All nodes appear as boxes, including node "Control Center", which conceptually represents multiple physical nodes, such as a database server, user workstations etc, used for ETA calculation.

4. System functionality

At each junction the phase selector is set and configured according to respective approach points for that intersection. Meaning when the bus approaches the intersection (and assuming that a request for priority is activated by the onboard AVL system), the intersection tracks the progress of the vehicle. When the bus reaches the predefined distance to the intersection or the respective ETA time limit, the request is activated.

The respective priority signals are transmitted further, and the AVL system will activate the application to ensuring priority. The request for priority is processed only if it is made within the "virtual sensor" – a so-called area, the boundaries of which are determined by the sensors positioning, defining the location of the intersection and the approaches to them. Such geo-fencing may be of any shape or combination of shapes (e.g., square, rectangle, a series of rectangles, etc.).

Using such software setup and phase selector configuration, the system makes the approach zones corresponding to an intersection. Thus, suitable zones act based on sensors, and they are used by the system to trigger a request for priority. And finally the system allows the use of conditions, when requesting priority based on distance and / or time.

When the bus is moving towards an intersection and the request for priority by AVL, its location and ETA are calculated once per second. This additional functionality of using the ETA as a variable for the operation, allows the system to take into consideration any variations in the speed of the bus and to provide an effective extension of the green phase or early termination of the red phase.

When the bus reaches a certain point approaching the intersection, static trigger point is an optimal solution only if the buses are approaching the intersection with predefined unchanging speed. Busses, that are faster than the average buses will need to point the trigger further back from the intersection to ensure that the green phase is available and the priority request has been overlooked. But, busses slower than the average bus will have to trigger a request at a point closer to the intersection to avoid the use of more than the optimum amount of the green phase and its extension. Thus, the system allows the use of either pure distance from the intersection or a combination of distance/ETA of the priority activation. Reaching that either a certain place or at some point a priority request will be triggered. As a point of activation it can be set to a certain distance or a certain period of time - whichever comes first. Meaning it is possible to make a combination of the two activation criteria.

4.1. Converting the requests for priority in to data to the controller

The phase selector, which is located at the intersections, is associated with the controller supporting digital inputs with discrete signal wires. When a request for priority intersection is approved, a request is transferred by any of the outputs of the phase selector to the controller, by activating one of the electrical input controllers, each of which corresponds to the direction of priority. This system allows the user to activate different traffic phases like straight, left, or right, depending on the current need. The signal to the controller can be a constant low voltage to activate the highest priority, or pulsatile low voltage to activate the low priority depending on the desired system performance. The controller will recognize this signal as a priority for the phase and adjust the timing of signals as programmed.

4.2. Assuring priority

Each controller must be configured to provide priority, as follows.

Option 1. Prolongation of priority

Upon receiving the request for priority (through an external input) and the priority phase/stage is a green signal in the direction of the bus, then the green signal is extended to the set maximum time for priority (in addition to the normal green time).

Option 2. Change Priority

Upon receiving the request for priority and priority phase/stage is red, then the current phase is terminated prematurely but not suddenly with the minimum values as assured safety limits and the following phases, which are also reduced to the minimum required in order to proceed to the next cycle to reach the next green phase/stage where the green signal will be extended in the direction of the bus.

Upon receiving of a request for priority during the yellow signal and when the next phase is green, it will be the first option that will be used to proceed. And upon receiving of a request for priority during the yellow signal and the next phase is red, then it will be the second option that will be used to proceed.

5. Full integrated system

The big advantage of the described until now system is that it operates independently. Meaning it is easy and cheap to implement, since the controlled by signal traffic light is located on the traffic light is used. In such isolated systems sometimes the traffic lights can also be linked to a Control Centre, but only for fault monitoring purposes, not for management.

In case we want to get the advantages of the coordinated systems, meaning to co-ordinate the operations at a traffic light, with the operations at one or more neighboring traffic lights we need to assure connectivity between the system's components and the Control Centre. In this case the centralized system is implemented through a Control Center system, to which all traffic lights are connected. The architecture of the Local bus priority management GPS integrated system through Control Centre functionality is described in Fig.3.

Such an integrated system has the ability to create a BRT corridor serving bus lines that can attract more passengers. Since the information system in place, ensures the maximum accessibility to each bus. Of course we have to bear in mind that the proper system functioning involves also physical measures, meaning the necessary line-width for driving without entering neighboring driving lines or cross bars. But for sure it is a total solution to the problems almost all public transport authorities phase, namely low operating speeds, expensive travel fares - especially for trips with connecting routes, lack of information for passengers, and high operating costs.

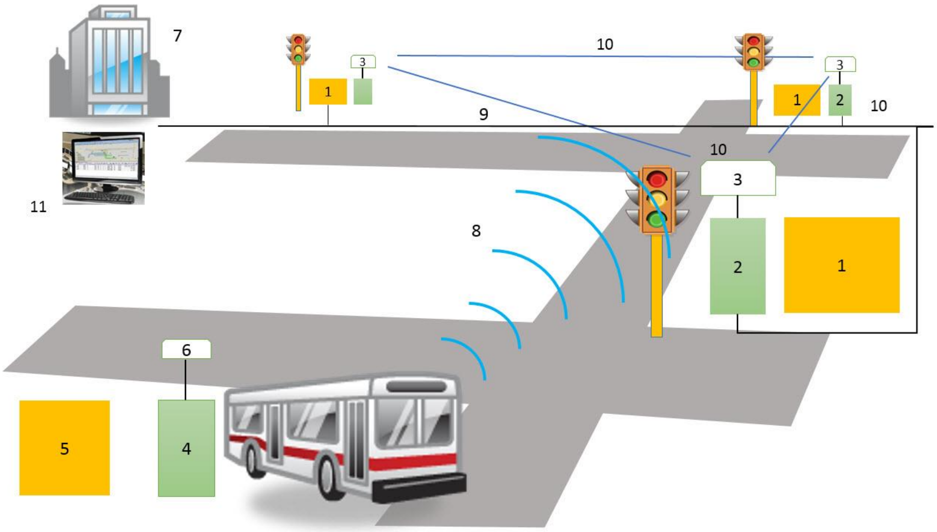

Fig. 3. Local bus priority management GPS integrated system architecture

In the above Fig.3, we have the following positions:

1 Traffic light controller junction
2 Phase selector
3 Radio / GPS device (can be implemented as two antennas in one housing)
4 Car unit
5 AVL-board automotive system
6 GPS / Radio Antenna
7 Control Center
8 Built-in radio transmission connection - Bus to junction
9 Network Internet connectivity from Center to junction
10 Radio link junction to junction
11 Software for centralized management

The above system architecture assures advantage of vehicles for Mass Urban Public Transport (MUPT) at intersections. The system provides the advantage of buses MUPT along the BRT corridor, and can be used to to save time in the corresponding direction for instance in morning rush hour, or other hours / day times.

The Control Centre for MUPT serves as a server for continuous registration of events which will receive information from vehicles in real time, will process the data to calculate the time of arrival of the stops and will transmit the information to the appropriate terminal devices (stops, online, mobile applications).

The system can be either used as only to serve the route of the BRT corridor, but also as extended to provide real-time information to bus stops, equipped with information boards. The Control Center also provides fleet management by monitoring vehicle location, identification of delays and collection operational data that can be used to regulate the operation of the system.

6. Conclusions

Both passengers and the mass urban transport authorities can get advantages of Automated Vehicle Location (AVL) and prioritization systems for mass urban transport buses, and priority vehicles, through the Bus Rapid Transit (BRT) corridor. First as they minimize the waiting time on traffic lights, and thus the waste of time on traveling, which increases the capacity of urban transport systems. But also as they increase the passengers' satisfaction, and respectively the number of passengers on public transport and the market share of public transport. Two approaches are presented for BRT corridors implementation. The isolated, and the coordinated systems, functionality and architecture are presented together with their advantages and disadvantages, in accordance with the applied standards.

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