# INTELLEGENT TRAFFIC MANAGEMENT SYSTEM USING SOFTWARE DEFINED RADIO (SDR) TECHNIQUE

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## ABSTRACT

This paper presents an approach supplemented to manage the traffic system using the FPGA based (Radio Frequency Identification) RFID readers, stating the requirements, the problem solving approach and the best practice design to fulfill those requirements.

This system is related to intelligent traffic management system with Smart Auto Driven Vehicle (SADV). More specifically, it present a new method to execute a smart auto-driven vehicle for physically challenged personnel and senior citizen (or an emergency use purpose ) to reach the desired destination with minimum traveling time and fuel consumption. The auto-driven car is also equipped with vehicle collision avoidance system so as to reach destination safely. As a whole, this system is able to bring significant benefit to the community and country in terms of traveling safety, security and independency.

Key words: traffic management system, SDR, active RFID, tag, FPGA, digital modulation.

## 1. INTRODUCTION

During the last decade the importance of information technology has become more important than ever. To travel from one place to another the use of modern technology is increasingly in demand.

Traffic congestions is considered as the serious problem on the modern society, and this increases the needs to design an intelligent traffic management system, so the scientists introduce some detectors and sensors to overcome all these problems. Presently, the modern cities are facing the problem of congestion, since the increasing of the number of cars every year makes the road very congested and this can gives many disadvantages such as fuel & time consumption to reach the desired destination.

Many researches have been done on the traffic management system area. A smart traffic control device transmits information to approaching vehicles regarding its current and future state enabling vehicles to control their speed to avoid arriving at the traffic light until it permits the passage of traffic, thus avoiding stopping, idling and reaccelerating when reaching the traffic control device [1].

Some recent researches were done in these fields; to monitor the road and the traffic status and detect the jam or congestion, but none of them imply how to control the vehicles to avoid the jam or congestion area [2].

In this paper an intelligent traffic management system have been designed to provide best route guidance in terms of time or traveling distance from starting point to destination which is able to minimize the fuel and time consumptions for users. Here road and traffic monitoring devices are used to measure road conditions, and control the traffic system [1]. These devices are installed in the vehicles and along the road in order to monitor the situation accurately in the road and then direct the driver to the best way to avoid the congestion. These devices are the RFID readers beside the RFID tags, FPGA, microcontroller, sensors, etc.

This system mainly works by the pre-determination of instant location parameters: location and average velocity of a car. Then, an active RFID network is used to detect the location of the car (including auto-driven car).

Soft Defined Radio (SDR) based active RFID (FPGA based RFID) tag is mounted on top of the cars and auto-driven cars whereas the FPGA based active RFID readers are attached at the lamp posts along the road and junction. Once the active RFID reader scans the ID of a car, the ID is extracted by reader and sent to server using ISM frequency band in MHz.

The server is able to detect the location and the speed of the car, the server then sends wireless signal to control the car direction of movement and route immediately using ISM band. The decision of car route determined by shortest path guidance algorithm, which is presented in the next section. The route guidance information will be automatically updated and transmitted by the server periodically. The processes of automatic control and update will be presented in details later.

For safety reason, a sonar sensor is mounted in front of the auto-driven car. Once the sonar sensor senses a car in front, the auto-driven car will be slowed down and stopped eventually, if needed maintain a 3 sec. distance

The reason to apply the SDR concept in the RFID tag is to make the system seamless to support different modulation schemes in different traffic management system. The SDR concept has been demonstrated by tuning between different modulations scheme such as amplitude shift keying (ASK), frequency shift keying (FSK), and binary phase shift keying (BPSK) that are used to communication between the RFID readers and tags. With SDR developed a system can be built that can give a car the ability to move across many devices or detector without any problems, besides giving a very accurate and stable performance. In addition to that the system have to calculate the velocity of each car to determine whether there is a congestion in the road or not, and store this records in a server to use when needed

This paper proposes the use of wavelet transform for the detection of ASK, FSK and BPSK digital modulations based on the principle that the ASK modulation depend on the amplitude changes, where as the FSK and BPSK depends on the frequency and phase changes respectively, all of them can be distinguished using the continuous wavelet transform with the Haar family, to compute the variance of the Haar Wavelet Transform (HWT).

This paper is organized as follows. Section II present the materials and methods focusing on basic concept of software defined radio, followed by the techniques and the strategic used to implement the SDR, description and discussion, simulation results and finally conclusions.

## 2. MATERIAL AND METHODS

SDR system is a radio communication system which can tune to any frequency band and any modulation across a large frequency spectrum by means of programmable hardware which is controlled by software [3]. An SDR performs significant amounts of signal processing in a general purpose computer, or a reconfigurable piece of digital electronics. The goal of this design is to produce a radio that can receive and transmit a new form of radio protocol in term of software only.

A software defined radio is a radio in which the receive signal digitization is performed at some stage downstream from the antenna. This is typically after wideband filtering, low noise amplification, and down conversion to a lower frequency in subsequent stages, with a reverse process occurring for the transmit digitization [4]. SDR effectively integrates wireless applications to operate over any interface (air and mode) by allowing both software and hardware to be adapted on-the-fly most effectively to handle any given task [4].

The basic concept is based on the use of the simple hardware platform built using SDR to enable customers to modify both the network and the end-user device to perform different functions at different times [5].

To design the SDR, usually needs to use the FPGA because the FPGA is powerful and able to do the most complex functions during its implementation phase. Figure1 shows a simple SDR architecture designed with an integration of FPGA.

The main idea of this block is to provide a simple term for the SDR based on: DAC & ADC and the processing operation in terms of digital signal processing.

The materials we intend to use are the RFID readers and tags, the FPGA device to implement the SDR and the server to operate and control the whole system (shown in Figure1).

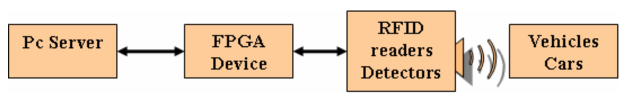



Figure 1. General block diagram of the system

Figure 1 describes the general model of the system. The RFID readers that detect the cars and establish a two way communication to send the car (ID) to the server through the FPGA either by cable or wirelessly. During the communication between the RFID readers (mounted on the lamp post) and the tags (mounted on the car), different modulation schemes are used adaptively represent the SDR concept, which is implemented through the FPGA device.

The FPGA contain the DSP device that make all the digital signal processing operations and functions and it has the ability to change the modulation scheme for the reader and tag, the ASK, FSK and BPSK modulation. However, the car that holds the tag can moves across all the readers and still can be detected even with the different of modulation scheme during the communication session between the tag and the readers.

### 2.1. Modulation Detection

The most important point here is when the RFID reader can detect the tag that might be with different modulation; hence the method to detect the modulation and adapt it accordingly is very necessary. The active reader comes with frequency range 315 MHz and the SDR tag can support either 315 MHz or 433 MHz using either OOK (on-off key) modulation scheme or FSK modulation scheme. OOK is a type of modulation under the amplitude shift key (ASK) modulation.

In order to change the modulation in both sides (readers and tags) and give the car the ability to move across all lamp posts with different modulations without problems or system failure and still can be detected by the different readers, we put the FPGA in both sides to be able to change the modulation, which give the ability to tune among different digital modulation signals ASK, FSK and BPSK.

There are many techniques for modulation detection such as maximum likelihood approach and pattern recognition approach.

Digital modulation waveform is a cyclostationary signal that contains transit in amplitude, frequency and phase. The Wavelet Transform (WT) is quite suitable for extracting transient information beside that it's capable to be computed using fast algorithm and hence allowing identification in real time [6].

To extract the features of the signal there are two ways. The first one called multi resolution analysis, decompose the signal at different level, and the other way is to look for the local maximum of the magnitude by Continuous Wavelet Transform (CWT) [7].

Many researches have been done using wavelet transform techniques. Lin and Kuo [8] applied morlet wavelet to detect the phase change, and used the likehood function based on the total number of detected phase change as a feature to classify M-ary PSK signal. Ho and Chan [9] on the other hand proposed a method to identify PSK and FSK signal using the Haar WT (HWT) without the need of any communication parameter of a modulated signal. LiedtKe [10] applied amplitude and frequency variances to differentiate ASK and FSK signal.

To differentiate ASK, FSK and BPSK signals, it is needed find a common feature and select a criterion based on the differences. Hence in this paper, the identification system is designed based on multi-steps analysis and variance that finally implies the statistical approach to differentiate between the ASK, FSK and BPSK signal.

The WT magnitude of BPSK has one DC level and many levels of peaks, whereas that of FSK has several levels for DC and peaks. After filtering, the FSK WT magnitude still contains different DC levels; whereas there is only one in BPSK. Thus the median filter output for FSK will have a higher variance, and the variance test is a simple method to separate the two [3].

Where as for ASK it has many DC level with constant and same level of peaks since it is changes according to amplitude.

The detection in the reader or in the tag done by the FPGA device attached to each one of them , the FPGA perform the signal processing to the transmitted and received signal, apply the characteristics to classify the type of the modulation. The pattern recognition approach is used to tune between the modulations techniques (it is upgradeable to many modulation techniques), so it is suitable to meet our requirements. Pattern recognition approach comprises of three parts; i.e. sensing, feature extraction, and procedures. In each measurement, (or observation), pattern vector x = (x[1],x[2],….,x[n]) describes a characteristic of the pattern or object. The block diagram of general pattern recognition system is illustrated in Figure 2 [5].

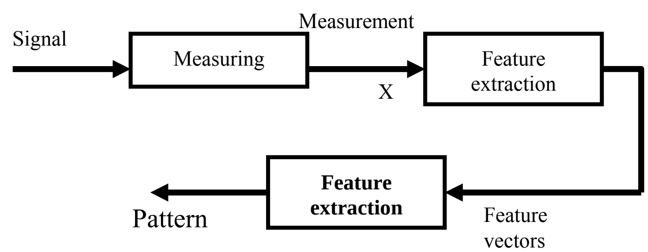



Figure 2. General pattern recognition system

In this paper, the concept for detection of digital modulations depends on the wavelet transform that has widely been used because of its advantages of extracting the transient information and thereby allowing simple method to perform modulation detection and identification.

## 2.2. The Location Detection and Speed Calculation

One of the main functions of the server is to monitor the road and collect the data coming from the readers paced along the road, analyze those, calculate the car location, velocity and then determine whether there is a congestion or not. The location and speed of a car are detected by using the RFID system. Each RFID reader has an omni-directional antenna which transmits 315 MHZ signal to server when it detects the active RFID tag while the car passes near the lamp post.

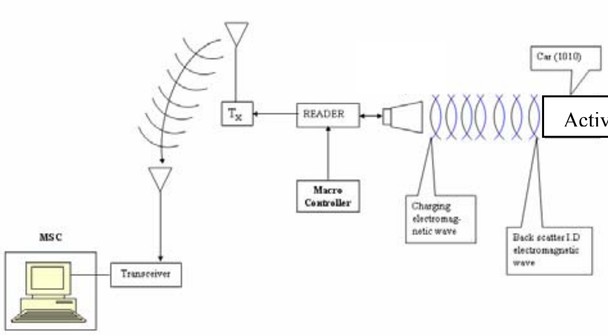



Figure 3. Block diagram of the car location detection with single RFID reader system

To determine the velocity, the readers are placed in positions separated by distance D between each other. Hence if car (a) passes readers placed in lamp post A and B at time ***Ta*** and ***Tb*** respectively, then the velocity of that car can be calculated as follows.

$$v = \frac{D}{Ta - Tb} \tag{1}$$

The server has its own Data Base (DB) to store and record all the incoming data from the active readers. It then calculates the velocities and stores those in terms of tables in DB. Each car differentiated by its tag (car ID) so it's easy to detect each car and record their particulars separately in data base DB.

To determine the condition of the traffic on the road, the average speed $v$ of $n$ cars that pass this road can be determined by Equation (2):

$$\bar{v} = \frac{\sum_{i=1}^{n} v_i}{n} \tag{2}$$

After that, the server is able to send the road congestion status to all car users and the shortest path route guidance to the auto-driven car. Here, we have modeled and tested this scenario by considering six cars only. The six cars are identified as C1, C2, C3, C4, C5 and C6. C6 is considered as auto-driven car, which is controlled by server. The server communicates wirelessly with C6 for possible route guidance. Assuming cars C1 - C5 are manual and receiving all sorts road congestion notification signal from the server in the road as shown in Figure 4 while C6 is guided by server to drive according to the shortest routes. Hence, after C6 has reached the T-junction, the location of C6 is identified at reader attach on lamp post D. Then, server will send an instruction to guide C6 to follow the intended road automatically. Once C6 senses a car in front, C6 will slow down automatically and finally stop.

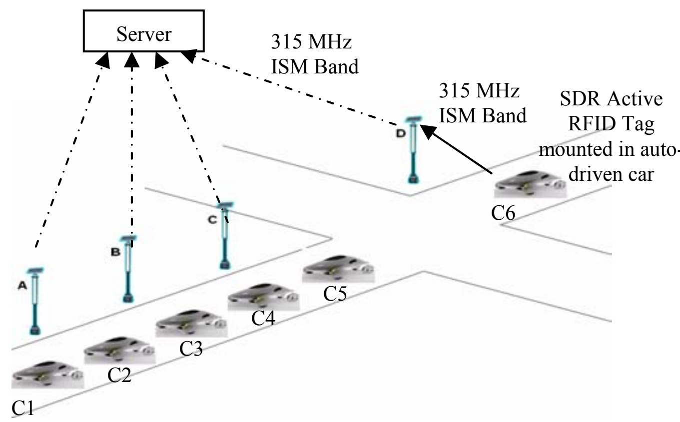



Figure 4. Block diagram of the car location detection network with multiple RFID reader system

### 2.3. Auto-Driven Vehicle Collision Avoidance System

A sonar sensor is attached in front of the auto-driven car. Once the sonar sensor detects a car or an object in front, the micro-controller will calculate the distance between the object and the auto-driven car based on the duration between transmitted and reflected sonar waves. If the distance is below safety margin (3sec), the micro-controller will automatically decelerate and finally stop the car (if needed). The 3sec distance is adjustable depending on the velocity of the cars. Figure 5 shows the auto-driven vehicle collision avoidance system.

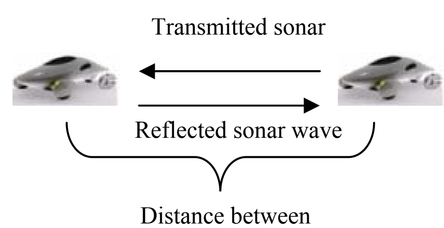



Figure 5. Auto-driven vehicle collision avoidance system

### 2.4. Shortest Path Guidance Algorithm

The proposed route guidance algorithm finds the shortest distance route from the car's current position to the destination. The shortest distance route is considered in term of minimum fuel consumption and optimum traveling time.

Step 1:
The distance of destination location and average velocity of cars are known and pre-defined (in terms of server DB).

Step 2:

An automobile driver inputs his current position and destination with the input device equipped in the vehicle.

Step 3:
The possible routes from his current position to the destination are sorted according to the shortest traveling distance in the server DB.

Step 4:
The optimum shortest travel distance of the route is calculated using the Dijkstra's algorithm mentioned in the next section, and transmitted back to the vehicle.

### 2.5. Dijkstra's Algorithm

In the server the Dijkstra's Algorithm is used to find the shortest mean travel distance of the route.

Considering the road map as showing in Figure6, which have nodes A, B, C, D, E and F. Suppose an auto-driven car wants to travel from node A to node F. The travel distance from A to B and A to C are 4 km, and 2 km respectively. Hence initially A – C will be chosen. The same procedure will be repeated to obtain the shortest path ABCDEF as shown in Table 1.

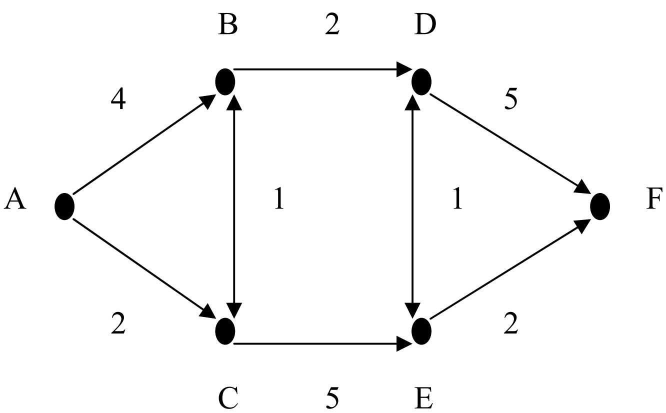



Figure 6: Road map with 6 nodes.

Dijkstra's Algorithm finds the minimum mean travel distance as follows:

| Iteration | i | AA | AB | AC | AD | AE | AF | Path added |
|---|---|---|---|---|---|---|---|---|
| Initial | | 0 | 4 | 2 | ∞ | ∞ | ∞ | (A,C) |
| 1 | C | - | 3 | - | ∞ | 7 | ∞ | (C,B) |
| 2 | B | - | - | - | 5 | 7 | ∞ | (B,D) |
| 3 | D | - | - | - | - | 6 | 10 | (D.E) |
| 4 | E | - | - | - | - | - | 8 | (E.F) |

Table 1: The path with shortest mean travel distance is (A, C, B, D, E, F)

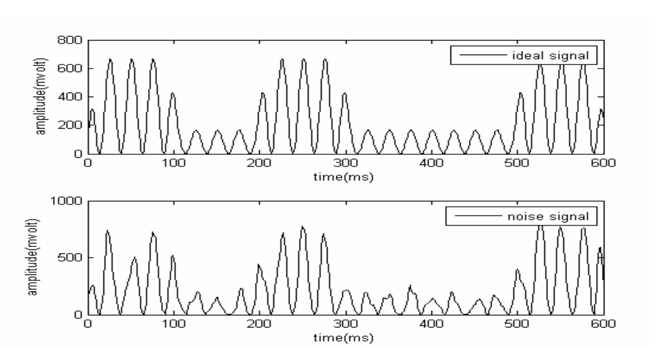
## 3. MODULATION DETECTION EFFICIENCY USING MATLAB

The main point in this system is to design the FPGA to maintain the SDR concept to tune between different modulation schemes. The ASK, FSK and BPSK modulation require a tool and technique to distinguish each of them uniquely, and regenerate the signal again with the new modulation to send over.

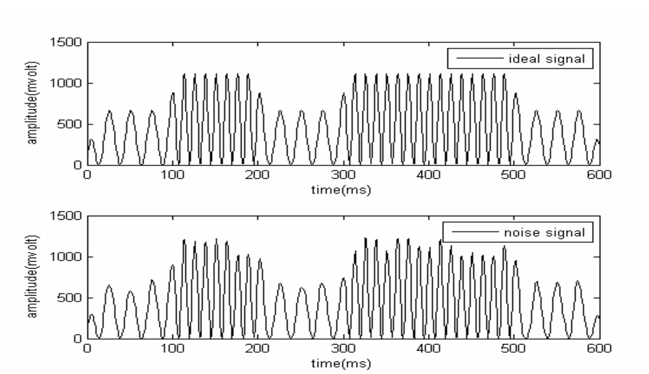
The design of the detection and identification procedure for the modulated signal, based on five steps. First step is to analysis the signal by the CWT using Haar family technique, then applying the digital filter for the coefficient result to remove the peaks of the signal, then compute the first step variance of the digitally filtered signal, then compute the second step variance and finally threshold matching with the unknown modulated signal.

This is done using MATLAB programming tools. Ideal signal and noise signal were generated with different noise to ratio (SNR) levels.

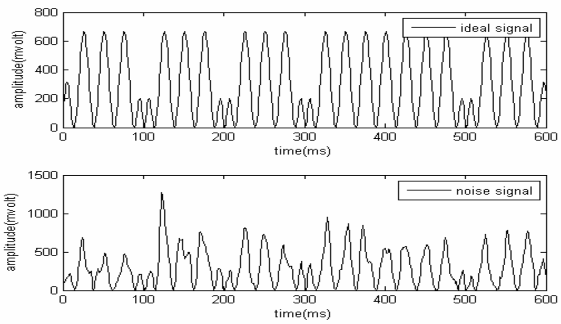
The first step variance calculation implies the signal graph for the ideal signal it was used as a reference to compare with the unknown modulated signal.




(a) ASK signal




(b) FSK signal




(c) BPSK signal

Figure 7 a, b and c. Comparison of ASK, FSK and BPSK signal with unknown modulated signal after processing by wavelet transform respectively

Figure 7a shows the comparison between the variance of both ASK ideal signal and the unknown modulated signal, the first graph is the ideal signal that was generated by the system as a reference, and the second one is the unknown modulated signal after it has been identified by the system as ASK signal.

Figure7b and 7c shows the same concept of the comparison between the FSK and BPSK respectively with the unknown modulated signal and this comparison mainly depends on the threshold value of the ideal signal calculated by the second variance step, and this threshold has been used to identify the unknown modulated signal.

The different SNR values included in the unknown modulated signal gives some alteration to the variance than the variance of the ideal signal, which finally after calculating the second variance for both ideal and unknown modulated signals; resulting in a fixed threshold value for the ideal signal, whereas show different values for the unknown modulated signal depending on the noise level in the signal.

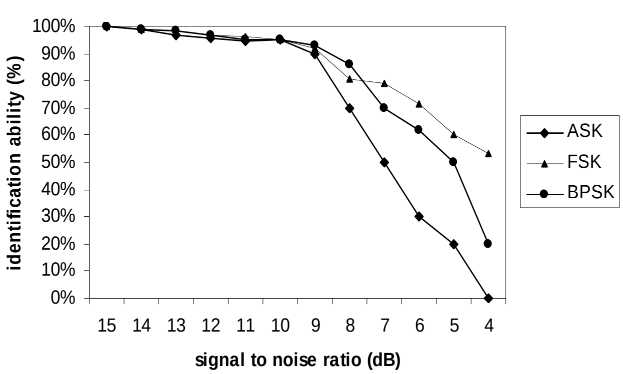



Figure 8. Percentage of correct identification performance for ASK, FSK and BPSK modulated signal using WT

In general, the system's identification ability is approximately 95% and above for SNR > 9dB (shown in Figure 8).

## 4. SERVER PROTOTYPE WITH DIJKSTRA'S ALGORITHM

Three nodes (SK, SS and KL) have been created. The distance among SK-SS, SS-KL and SK-KL are 700 km, 100 km and 500 km respectively as shown in Figure 9.

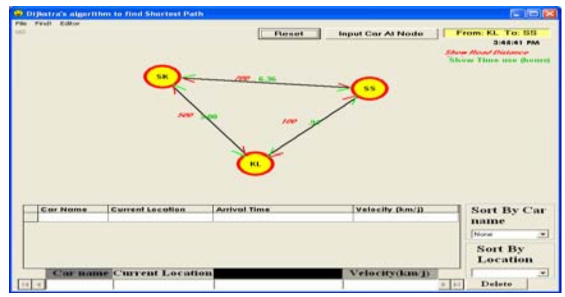



Figure 9. Server prototype with three nodes

Applying shortest path Dijkstra's algorithm to select the fastest way from SS to SK, server output was: (SS -> KL -> SK, 600 km) as shown in Figure 10. After that, we inserted some cars in the map with different traveling velocity. Then, we applied the shortest time Dijkstra's algorithm again on the same map. It was found that, the result of shortest time Dijkstra's algorithm is different from shortest path Dijkstra's algorithm as the car traveling time varies from time to time as shown in Figure 10.

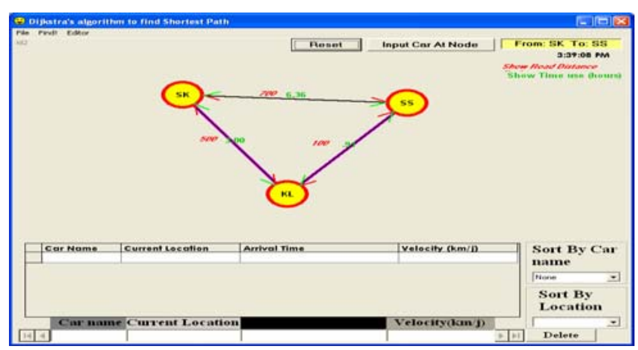



Figure 10a. Server prototype with three nodes

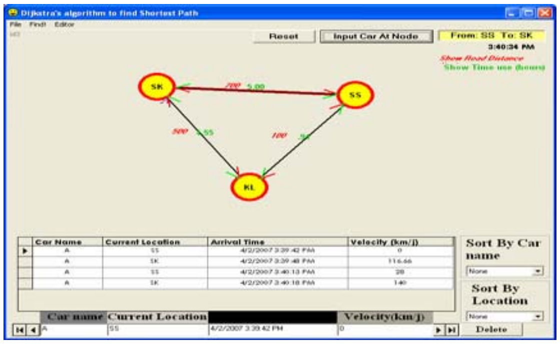



Figure 10 b. Shortest Time Dijkstra's algorithm

## 5. OVERALL SYSTEM PROTOTYPE

The system distribute the RFID readers among the streets and highways beside assigning one RFID tag to each vehicles, hereby allowing the vehicles to be detected when crossing the RFID reader while moving on the roads,, thereby enabling the readers to send the ID of the vehicles wirelessly to the central station to dynamically calculate best route guidance for that vehicles putting in the consideration the fuel and time consumption.

The integrated design consists of three stages: network (RFID) reader, server with software platform and the car control and safety with tag.

- Network Part: The active wireless RFID reader will detect the location of vehicle and inform the server periodically.
- Serve Part: The serve detects the location of auto-driven vehicle; it will send a wireless signal to control the direction of vehicle immediately. The decision of direction is determined by optimum shortest path and shortest time Dijkstra's algorithm.
- Vehicle Control Part: The targeted vehicle will follow the instructions of server to go to the desired destination to avoid the traffic congestion.

### 5.1 Smart Auto Driven Vehicle

The smart auto-driven vehicle (SADV) system designed to provide best route guidance in terms of time or traveling distance from starting point to destination which is able to minimize the fuel and time consumptions for users.
The SADV car as described in Figure 11 which attached with the tag on the top, it consist of two parts, the vehicle control part that allows the auto-driven vehicle to follow the instruction of server to go to the desired destination safely, and safety control part which is mounted in front of the auto-driven car to avoid collision with other vehicles.

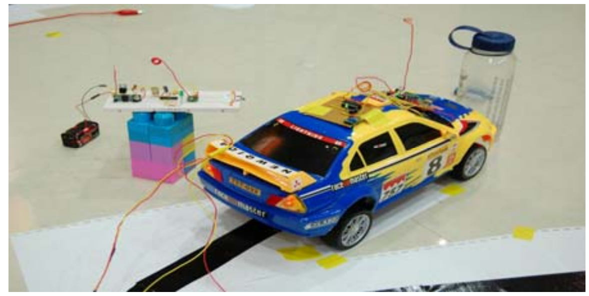


Figure 11 shows the (SADV) model prototype consist of the vehicle attached with the tag on the top

### 5.2 The over all system with network

The overall system done in four stages:

- The first stage was building up the basic prototype of the RFID reader and tag, which consist of transmitter and receiver module that works on ISM band in MHz and programmable microcontroller IC for transmission control.
- the second stage was designing the smart vehicle attached with the RFID tag on the top of the vehicle, the second stage include designing of the first model and RFID readers to establish the traffic detection concept between the car and the readers.
- The third stage finalizes the final layout of the prototype model as shown in figure 11 and testing the detection procedure and movement of the vehicle. In addition to that setting up the obstacles avoidance system of the vehicles.
- The last stage establishing the connection between the RFID readers and the server via wireless communication band.

## 6. CONCLUSION

With this system many problems on the road can be solved such as decreasing the congestion and minimizing the fuel consumption. The current researches on the traffic management system focus on how they can monitor the car and inform the deriver (all registered car derivers, automatic and or manual) to avoid the jam (if it exists) beside control the auto driven cars.

This paper presents a brief view of an intelligent traffic management system in terms of software defined radio (SDR) for a smart auto driven vehicles system. This system is able to monitor and control the cars movement on the road to avoid any collision or jam.

However, building an intelligent traffic management system is a tuff job as it needs to control some cars with all safety precautions while those are moving along the road without drivers besides other traffic management jobs.

Finally, this system may bring benefits and convenience to all car users in terms of multi-use of a car, low times & fuel consumption, and collision traffic jam avoidance.

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