GSM Positioning-Based Taxi Booking And Dispatch System

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Abstract: - Taxi booking and dispatching methods had advanced from the radio-paging systems used in the past to the current satellite-based dispatch systems. This change had greatly reduced the miscommunication between the call operators and taxi drivers. However, miscommunication can still exist between the customers and call operators. This paper proposed a solution that achieves an even higher accuracy picking up the passenger. GSM Cell ID positioning will be used to locate a customer, and he can identify his desired pickup location on a map that is given based on his current position. In addition, the solution also strived to increase the income of the taxi drivers and also to boost the revenue of the taxi companies with the ease of use of the new solution.

Key-Words: - GSM positioning, Taxi Booking and Dispatching, Scheduling algorithm

1 Introduction

Getting around the city state of Singapore can be considerably easy. Almost all parts of Singapore can be reached by the three main modes of public transportation, namely bus, Mass Rapid Transit (MRT) and taxi, with taxi being the most convenient and personalised means to travel in. There is a total fleet of 23,860 taxis operated by eight taxi companies, and independent drivers in September 2009.

In order to hire a taxi, one can do it via various ways, they are, hailing one along the road, queuing for one at a designated taxi stand, or booking one. Most passengers hail for a taxi or wait for one at any specific taxi stand. However, there may be times during the morning and evening peak periods (7 am to 9 am and 5 pm to 9 pm), whereby long queues are a common sight at popular or high-demand locations. Thus, the need of calling for a taxi comes in for people who need one urgently, especially in less densely populated areas. Taxis may be booked via telephone, Short Message Service (SMS) or through the internet for a fee. These booking jobs will then be broadcasted based on the location of taxis given by Global Positioning System (GPS) to the nearby taxis within 10 kilometers of a customer. By doing so, one can request for a taxi driver to pick him up at a specific location, e.g. a taxi stand, an entrance of a building, a nearby car park or side roads.

This paper surveys the general landscape of taxi booking and dispatching methods in Singapore with the aim of understanding the present state-of-the-art technologies and with that understanding, seeks to detail a general plan to implement a more reliable and efficient solution free from issues, limitations and shortcomings of existing implementations. The ultimate objective of the implemented system aims not only to increase revenue for the taxi drivers and companies but also convenience and ease of use to the passengers.

The rest of the paper is organized as follows. Section 2 describes the current taxi booking and dispatch system in Singapore and some other countries. Section 3 discuss about the issues that the current system is facing. Section 4 talks about the architecture and system flow of the proposed solution. Section 5 presents the experiments conducted and finally, Section 6 concludes this paper.

2 Current Taxi Booking and Dispatch Systems

The satellite-based dispatch system currently implemented in Singapore is known as Automatic Vehicle Location and Dispatch Systems (AVLDS). The AVLDS comprises differential GPS, wireless data communication, interactive voice responses and computerized dispatch systems [1], [2]. Each taxi vehicle is equipped with a receiver and transmitter so as to communicate to the control centre via the stations that are set up at various locations

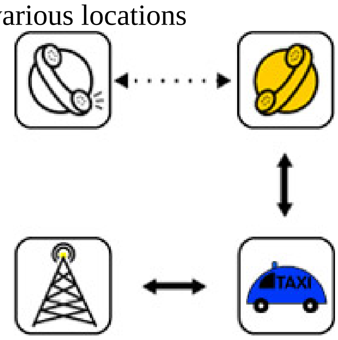

Fig. 1 How satellite-based dispatch system works.

With a centralized taxi dispatch system, all customers' taxi booking requests are being queued on a first come first serve basis at the dispatch centre. For each request, the system is able to detect the nearest taxi to the customer based on the latitude and longitude (provided by the GPS) and the taxi's current route. All taxis within 10 kilometres radius to the customer are able to receive the job via wireless transmission. Upon the human driver accepting the job via the in-vehicle terminal, the taxi number and its estimated time to reach the customer will be convey to him through his means of booking. In cases whereby no drivers accepted the job, the system continues to search for the next nearest taxis and the job is dispatched again, till successful matching.

Over the years, three such similar systems had been implemented in Singapore, namely TIBS-SkyTrek (SMRT Taxi), Comfort CabLink (Comfort Taxi) and CityNet (CityCab, further enhanced into CityNet II by ComfortDelgro, which allows different taxi fleet companies to share a common system while maintaining their business independence and identity [3], utilizes the General Packet Radio Service (GPRS) technology to wirelessly connect the entire fleet of taxis), and are owned by different taxi companies. The main difference among all these three systems are their booking methods. In other words, the way a pickup location is to be conveyed in different manner, after which, the backend dispatch system will be similar. All of them can be booked via telephone and SMS, but SkyTrek can be done via web and CabLink via FastCall. FastCall is available in major commercial buildings, hotels and tourist attractions. All a customer has to do is to simply dial a hotline and enter the designated location PIN and a taxi will be dispatched to that particular location.

3 Issues with the Current System

The major drawbacks of these existing taxi booking and dispatching systems are as follows:

- **Customers Unable to Get Through the Line** While booking a taxi via the telephone may be the most conventional means, there may be times when the demand for taxi bookings is also exceedingly high, such as during a heavy downpour or festive seasons. This might cause the phone lines to be jammed with customers (trying to book a taxi) not being able to get through the line to reach the call operators despite numerous attempts
- **Taxi Drivers Unable to Locate the Passenger** The pickup point of a passenger is always conveyed to a telephone operator or pre-set / entered by the passenger himself and stored into his account. Hence, if merely the street name (of a street that stretched for a few hundred metres) is being told, a taxi driver might not be able to locate the customer exactly. In addition, there may be situations whereby a customer is waiting at the other side or exit of a building, as to where the taxi driver thought him to be. This may result in unhappiness in both the customers and taxi drivers after a period of waiting.
- **Call Centre Having High Operational Cost** A typical call centre operates 24 hours a day, 7 days a week; hence in order to maintain a high-quality service call centre, the staffing cost will be as high as about 70 per cent of the operational budgets of the call centre. Table 1 shows the annual salary range for a call centre agent across various regions (from the eighth annual *Merchants Global Contact Centre Benchmarking Report* by Dimension Data), with Asia Pacific being the highest among all.

Table 1. Annual salary range for call centre agent across regions

Region	Annual Salary Range for a Call Centre Agent
Africa / Middle East	\$8,900 - \$22,100
North America	\$17,600 - \$26,400
UK / Europe	\$24,500 - \$33,100
Asia Pacific	\$22,000 - \$36,200

4 Proposed Taxi Booking and Dispatch System

The GSM Positioning Taxi Booking and Dispatch System should reduce the waiting time for passengers trying to book a taxi and also the miscommunication issues between them and the Call Centre Operators. The proposed system comprises of three main tiers, the mobile application (used by the passengers), the taxi terminal and the server. Figure 2 shows the overall system architecture.

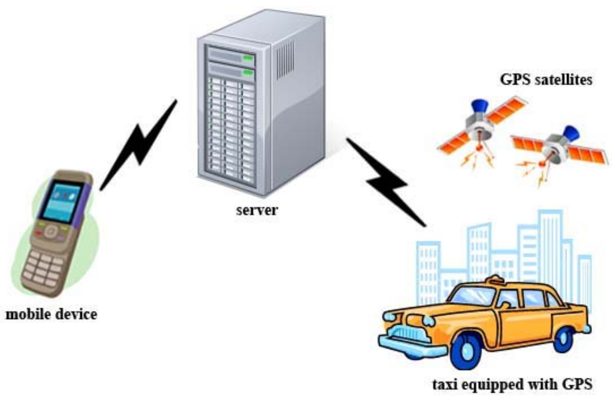

Fig. 2. Overall system architecture for proposed system.

Instead of making a call to the Call Centre Operators, customers can now "call" for a cab by using a mobile application that resides on his mobile phone. As soon as the mobile application is started, it will retrieve the Id of the cell that the mobile phone is connected to at that particular point of time. With the Id, the mobile application will query the server for the description and location of that particular cell. After which, the mobile application will know which of the map images (residing on the mobile device), should be displayed to the user. The initial map image shown will be the approximate location where the user is. The user will then be able to determine where he wants to be picked up from, by selecting a point on the map image. Once he has decided, he can send his selection, together with his mobile phone number, to the server.

With all the selected pickup points being transmitted to the taxi terminal (through the server), the taxi drivers are able to view all of them on them mobile device terminal which resides in his taxi. Despite being able to see all the selected pickup points, a taxi driver is only allowed to select a passenger that is within a certain radius from him, based on his current location provided by the GPS. This is to prevent a passenger from having to wait for too long if the taxi is too far away from him.

After a pickup point had been chosen by the taxi driver, the phone number tied to that pickup point will be displayed on the console of the terminal. At the same time, the phone number and the taxi plate number will also be transmitted back to the server, indicating that the pickup point denoted by the phone number had been accepted by the taxi driver of that plate number. The server will then broadcast to all the taxi terminals that the job have been accepted and that the pickup point associated to the mobile phone number is no longer valid, therefore, cannot be seen on other taxi's terminal. Simultaneously, the taxi plate number will be sent to the mobile application, to indicate that this particular taxi will be picking the user up at the indicated pickup point.

4.1 Locating the User

Three positioning techniques had been considered, namely, WLAN, GPS and Cellular positioning.

- **WLAN Positioning** A WLAN-based positioning system is an economical solution as WLAN network can be found almost everywhere in this present environment [4]. To get the location of a device, the signal distribution of access points is collected to train a position-determination model. The propagation delays of the signals are being monitored to triangulate and calculate relative position [5].
- **GPS Positioning** GPS, a satellite-based positioning system for identifying position (X, Y, and Z) on the earth's surface, is one of the more accurate positioning methods, with an accuracy of about 10 metres [6]. The accuracy of the position determined by GPS depends on the type of receiver used. Differential GPS (DGPS), on the other hand, is able to produce a position of even higher accuracy of about 1 metre. DGPS requires an additional reference station fixed at a known location nearby ([7], [8], [9]) to correct positions recorded by the satellites. However, GPS is typically inefficient for indoor use or in urban areas where high buildings shield the satellite signals.
- **Cellular Positioning** Cellular positioning, also known as Global System for Mobile communication (GSM) positioning, is based on the cellular network system of mobile phones [10]. Its accuracy can be as low as 100 - 1000 metres, depending on the signal strength of a base station. The signal strength of the base station also determines the size of the cell, which is the coverage of that particular cell. As this technique depends solely on the cellular infrastructure, it is usually used when the exact location is not needed.

Out of the three positioning techniques mentioned, GPS positioning being the most accurate but also the most expensive. In addition, its accuracy is only at its best when being used in an outdoor environment under the 'clear sky'. How often does one call for a taxi only when he is standing under the hot sun? In fact, most do so in the comfort of their house or office, and go out only when they know that their cab is arriving, from the estimated arrival time of the cab given.

So long as a mobile phone is connected to the Telco and able to make a phone call, Cellular positioning is able to work on the mobile phone. The purpose of the application is to display a map of the area where the user is currently at, so that he can indicate his desired pickup location on the map, which would not be too far from his location at that point of time. As such, an exact location of where the user is will not be necessary since that location will most probably not be the place where he wished to be picked up.

Table 2. Comparison of positioning methods

Location Method	Calculation	Device / Network Modification	Cost	Location Area	Accuracy (meters)
GPS	Assisted-GPS: both the network and the mobile device are needed to do the calculation	Both the network and the mobile device need to be modified	Medium	Limited in canyon environments	5-40
	Autonomous GPS: the mobile device does the calculation	Only the mobile device needs to be modified			
Cellular	Network	Cell-ID: no changes needed	Low	Limited to within the cell	100-30000

Table 2 shows the comparison between GPS and Cellular positioning. As much as we want to know the most accurate location of our users, not only does GPS positioning not being able to provide us the comfort while doing so, it is also not required. In addition, not all mobile devices are GPS-enabled.

For this reason, despite the low accuracy of Cellular positioning, as it depends on the size of the cell, it might be a better choice as compared to precise location tracking systems like GPS, which is might not satisfy the requirement in our case.

4.2 Select and Confirm Passenger

Only points within the range of the taxi's location can be selected. The selection of the points is done by looping around the entire list of pickup points that is within the (selectable) range as shown in equation (1):

$$\sqrt{(p.x - taxiLoc.x)^2 + (p.y - taxiLoc.y)^2} \leq (PICKUP\_RANGE \div 2) \qquad (1)$$

where p is the coordinate of a pickup point, *taxiLoc* is the coordinate of the taxi location and *PICKUP_RANGE* is the diameter of the selectable range.

When the taxi driver has decided which passenger pickup point that he wishes to accept, he will have to click on the 'Confirm' button and his taxi number will be sent to the server with the mobile phone number that is associated with that particular pickup point

5 Evaluation

A prototype of the system had been developed. The server and taxi terminal simulation of all tests will be run on a desktop machine with the following specifications:

- AMD Athlon 64 X2 Dual Core Processor 4400+ 2.29 GHz, with 896 MB RAM
- Microsoft Windows XP Professional SP 2

5.1 Mobile Application

Listed below are the types of emulators that the mobile application had been tested, based on Sony Ericsson Java ME SDK 2.5.0 for CLDC and Sun Java Wireless Toolkit 2.5.1 for CLDC:

- Sony Ericsson JP8 240x320
- Sony Ericsson JP7 240x320, 176x220, 128x160, 128x128
- Sony Ericsson K600
- Sony Ericsson P990
- Sony Ericsson W800
- Sony Ericsson Z558
- Sun Default Color and Grey Phone
- Sun Media Control Skin
- Sun Qwerty Device

The functions being tested are its ability to display the map images, pan and zoom map, and sending of pickup points, which all returned success. Table 3 illustrates the usage of API to retrieve Cell-ID on some Java-enabled mobile phones

Table 3. Comparison of retrieving Cell-ID on different Java phones and platforms

Phone Manufacturer	Cell-ID API	Java Security – Signing *
Nokia	For Series 40 3rd Edition, FP1 (or newer) and S60 3rd Edition, FP2 (or newer)	Yes
Sony Ericsson (SE)	Java Platform 7.3, phone may need firmware update (7.1 - 7.3) Not on SE Symbian (UIQ) phones	No
Motorola	Yes	Yes

NOTE:* some APIs are protected such that only applications signed by the manufacturer or carrier can use them

5.2 System Performance

The mobile application is being tested on the Sony Ericsson W880i, over the GPRS network. Time Interval value of midlet probing server if its pickup point had been accepted by a taxi driver is 10 seconds.

Figure 3 shows the test results for the average time taken for the specific components of the system and Figure 4 shows the total time taken, over 5 tests each, for the various time hour of a weekday where the network traffic load is different, e.g. time period having low traffic load can be at 2 AM, where most people are sleeping.

The description and assumptions of each component are as follows:

- **Application Start-up** Includes time taken to retrieve the Cell Id and get description and location of cell from the server, till the map images are being displayed.
- **Decide Pickup Location** This component includes panning and zooming of the map till a pickup location had been selected. Here, we assume that the user is familiar with the location but need to spend sometime looking at the map.
- **From Midlet to Taxi Terminal** This describes the data transmission from the midlet to the server, followed by the taxi terminal. It takes into

consideration the time taken for a pickup point to be transmitted to the taxi terminal, via the server

- **From Taxi Terminal to Midlet** This is the time taken for a taxi terminal to send its taxi number to the midlet, via the server. The time interval of the midlet probing the server is taken into consideration.
- **Total Time Taken** Total time taken from the moment the mobile application is start-up till a taxi number is received. We assume that an available taxi driver accept the pickup location immediately after it appears on his taxi terminal.

The total time taken includes the time taken to decide a pickup location, which is 16.10 seconds. This is done locally on the mobile phone and hence has no influence over the load of the traffic network

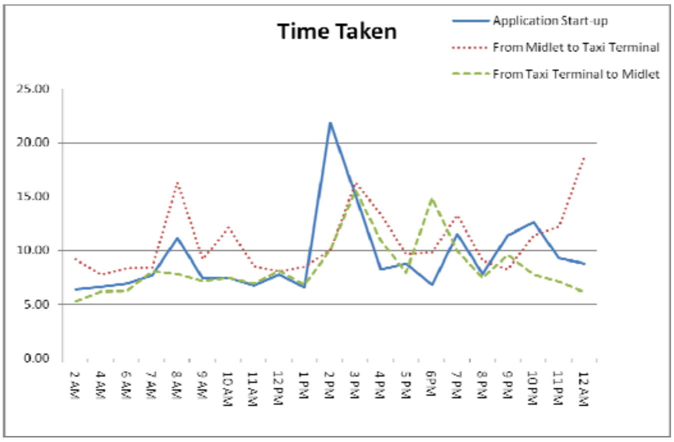

Fig. 3. Time taken for different component of the system

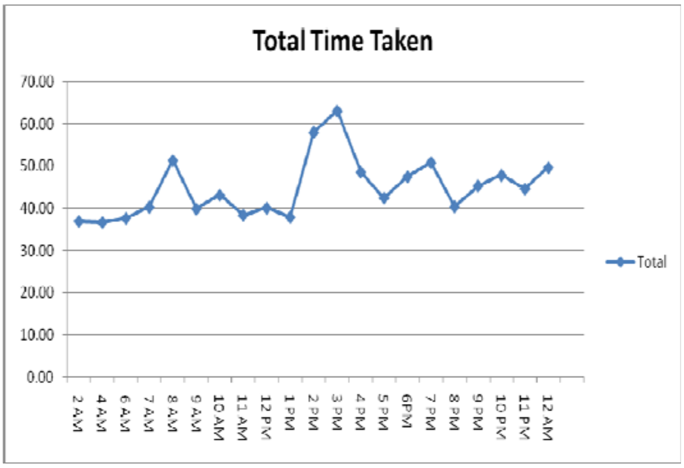

Figure 4. Total time taken

The average total time taken, throughout the day is 44.67 seconds.

During hours of the day where the network traffic load is low, the demand of taxi might be high, an example of such scenario would be at about 7 AM (where most people are setting off for work and school) or 5 PM (time when people knock off from work), and vice versa. Hence, the performance of the system will be at its best when the demand of taxi is high. Moreover, the speed of the GPRS network (2.5G) is about 80 Kbps, whereas 3G and 3.5G is at 3.1 Mbps and 3.5G at 14 Mbps respectively. Nowadays, most of the mobile phones out in the market have 3G capability, and more to be 3.5G. Therefore, the performance of the proposed system will definitely be faster and better when transmitting over 3G and 3.5G

5.3 Performance Comparison with Existing Systems

The more common ways to book a taxi currently will be via phone, SMS and internet booking. Therefore, we wish to compare the time taken of these booking methods with our proposed system.

Table 4 gives the breakdown of the time taken to make a taxi booking via the most common phone booking system.

Table 4. Time breakdown to book a taxi via phone booking.

	Time Taken
Dial number till an operator answer	54.10 sec
Convey desired pickup location to operator	36.30 sec
Waiting time to get taxi number	20.20 sec
Total	1 min 50.6 sec

To make a taxi booking via SMS, one has to provide the exact location in term of

- Postal code (e.g. 560024),
- Building Name, Block Number, Street Name (e.g. Blk 23 Ang Mo Kio Street 3), or
- Taxi stand number

Table 5 shows the breakdown of the time taken to make a taxi booking via the SMS system. This does not include the time taken to figure out the information mention above

Table 5. Time breakdown to book a taxi via SMS booking

	Time Taken
Type the SMS	38.63 sec
Waiting time to get taxi number	25.98 sec
Total	1 min 4.61 sec

To make a taxi booking via the Internet, one has to first register for an account; whereby you have to enter a few common locations that you wish to be picked up from. Each account must specify at least one and at most five pickup points, based on the SKYTREK system by SMRT Taxis. And based on the selected pickup location, the system can then allocate the nearest taxi to the customer. A confirmation together with the taxi number will be displayed on the computer screen within an average of 1 minute.

Table 6 summarises the estimated time taken for each of the booking means based on what had been mentioned above. We can see that the proposed system allows a customer to get a taxi confirmation within the shortest period of time as compared to the current common booking services:

Table 6. Comparison of booking time

Time Taken			
Telephone	**SMS**	**Internet**	**Proposed System**
1 min 50.6 sec	1 min 4.61 sec	1 min	44. 67 sec

6 Conclusion

The migration from the previous radio-paging system to the current satellite-based dispatch system eliminates the miscommunication between the call operators and taxi drivers since the customers' pickup locations are all transmitted to the drivers through wireless transmission to the in-vehicle terminal in each of the taxis. This system further enhances the existing booking and dispatch system by abolishing call centre operators, in such a way that location transmitted are all in terms of coordinates. In addition, the all locations are being selected and shown on a graphical map, minimizes all sorts of communication errors.

The proposed system is able to help the taxi companies save cost on maintaining a call centre, which will help them to cut cost where taxi booking is concern. This in turn allows them to adjust the booking charges. When the booking charge is lower, more people will then wish to call for a cab. Having more customers will in turn increase the profit of a taxi driver, and subsequently increase the revenue of the taxi companies.

With this system, passenger can also save the hassle of communicating with operators at the call centre and may or not may convey his location well enough to the taxi driver. And no more failures of attempting to get through to call centre, or holding on to the line waiting either for an operator to answer the call or for the system to tell him the taxi number (which may not be clear if the passenger is around some noisy environment), especially during peak periods. The taxi driver on the other hand, not only benefits from the increased source of income, but also a clearer idea as to where to pick up his next passenger from! No more miscommunication as to which exit the passenger wish to be picked up from.

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