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(54) Abstract Title: **Bus arrival time estimation system and method**

(57) A standalone bus arrival time estimation system for providing a proximate arrival time of a bus that travels along a route comprises a transponder mounted on a bus, a transceiver, a processing unit and a display device disposed at a bus stop along the route. The processing unit is in communication with both the transceiver and the display device. The transponder is capable of communicating with the transceiver when the bus arrives at the bus stop. A method for estimating the arrival time of a bus comprising the steps of monitoring a bus's arrival at a bus stop, recording time stamp of arrival, determining the time deviation and calculating the next arrival time independently without any input from any other systems, and displaying and counting down the estimated arrival time.

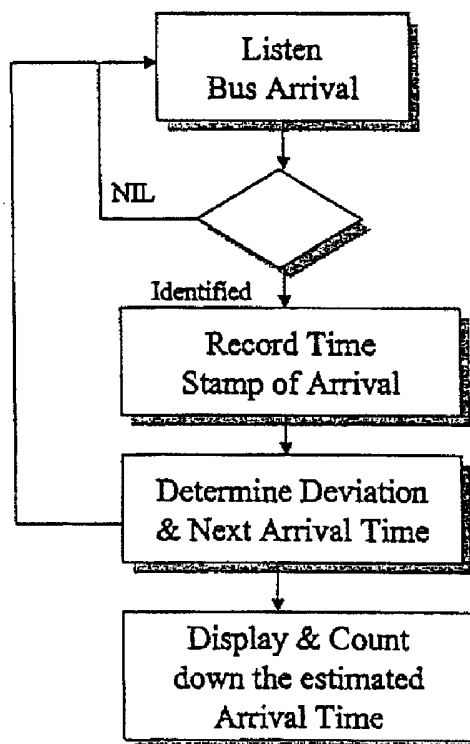


FIG. 2

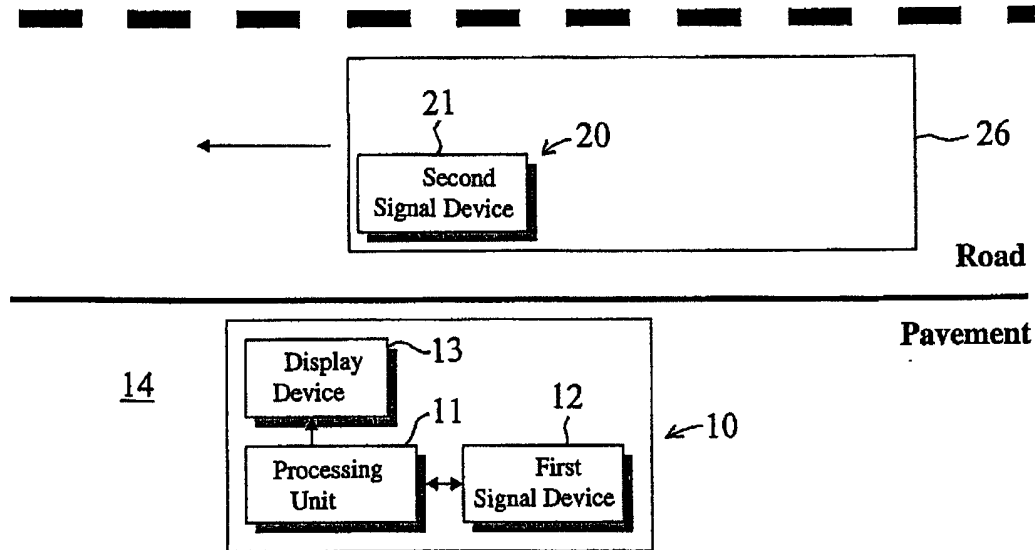


FIG. 1

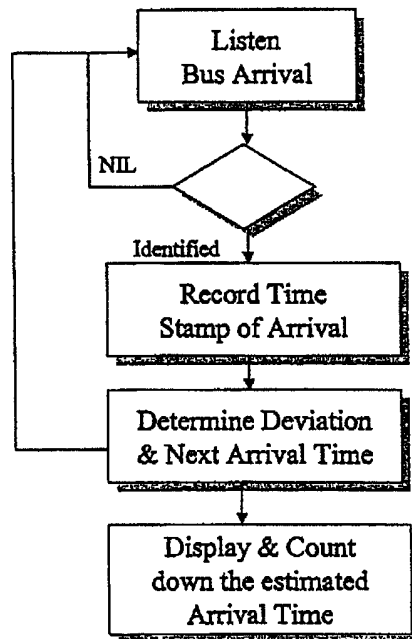


FIG. 2

BUS ARRIVAL TIME ESTIMATION SYSTEM AND METHOD

FIELD OF THE INVENTION

The present invention relates to a bus arrival time estimation system and a method for estimating arrival time of a bus at a bus stop along a bus route.

BACKGROUND OF THE INVENTION

Nowadays, people go to upper floors of a high-rise building by taking a lift. The lift lobby shows the position and the direction of the lifts. People could estimate how long they will wait for a lift to take them to their destination floor. Similarly, for riding trains, people in the platform are also informed with an estimated time the next train will arrive. Therefore, people could manage their time more effectively.

It would be desirable if such an arrival estimation system is available for people riding bus, who could similarly be informed with an estimated arrival time while waiting at the bus stop. People usually spend long time waiting for a bus to their destination and they know nothing about when the bus could arrive. If they could know the estimated time of bus arrival, they could adjust their itinerary, re-arrange their jobs, or choose other alternatives to reach their destinations. If most of the people manage their travel and get, say, one more minute efficiency, the economy of the society could also benefit from this one-minute gain and productivity.

There are available a number of systems for keeping track of vehicles traveling in the field, to provide an estimate of the whereabouts of them at a given time and/or provide an estimated arrival time to a destination. For example, the systems and methods disclosed in the following patents are directed to such uses: JP 7320198 A, JP 8305996 A, JP 9305895 A, US 6191708 B1. Most, if not all, of those systems require long-distance radio transmission and measurement of electric field strengths of consecutive transmissions at different vehicle's locations. Because a long-distance radio communication is by nature volatile and fragile due to fluctuated communication delay, varied signal-to-noise ratio, uncertain availability, etc, the arrival time estimated dependent thereon is also volatile and not robust. In addition,

those systems require facilities or equipment installed all the way along the route in order to report arrival time at as minimum as one stop or station. Those systems are considerably expensive to implement, a contributing factor for the scarcity of such systems being used in urban public bus transportation.

JP 2002203299 published on July 19, 2002 discloses a system and method for providing bus navigation schedule. A navigation managing center collects information showing arrival/departure in respective bus stops, which are supplied from a bus system installed in the bus, or previously stores a bus diagram. The navigation managing center calculates waiting time based on the delay of a navigation with respect to the previous diagram on the first bus stop and calculates waiting time based on information that the bus leaves the previous bus stop on the other bus stop about the respective bus navigation systems. The navigation managing center informs the respective bus stop systems of the calculated waiting time. The bus stop system displays the informed waiting time and informs the waiting passenger about it.

This system requires a GPS system and a navigation managing center. However, radio coverage of GPS might not fully cover all the road where the concerned bus travels. For example, it is difficult to get signal inside tunnels or high-rise buildings.

JP 8305996 discloses a method for transmitting a bus recognition information for every predetermined transmitting cycle through a specific low power transmitter for communication between a bus and a stop. The stop receives the transmitted recognition information. The distance between the stop and the bus is calculated from the field strength of the received information. Then, the arrival time to the stop is computed based on the calculated distance and a guidance display is performed at the stop.

When the bus Ax is the object to be communicated with, the intensity of the electric field at the time of the reception is detected and its time T1 is detected. The detected intensity of the electric field is converted into the distance L1 from the bus stop B1 to the bus A1. Similarly, the distance L2 between the bus stop B2 and bus A1 at the point of time T2 as next transmission timing is obtained. A CPU 15 computes the speed of the bus A1 to calculate the time when the bus arrives at the bus stop B1, and

displays the arrival time on a display unit 16 and outputs it as a voice through a speech unit 17.

This system requires a long-distance radio communication between the bus stop and the bus vehicles. The electric field strength of the radio communication is taken to determine the distance between the bus stop and the bus as well the estimated arrival time. The estimation of arrival time heavily depends on the radio communication between the bus stop and the bus. A long-distance radio communication is by nature volatile and fragile (long delay, varied random noise, uncertain availability). Thus, the arrival time estimation is also volatile and not robust.

This system also requires the determination of electric field strengths of two consecutive transmissions. However, the field strengths can be easily affected by the movement of other vehicles on the road, rainy weather, blocking by buildings or mountains, and blocking if the bus travels inside a tunnel. The estimation of arrival time will be fluctuated and not reliable.

Furthermore, the system requires the determination of electric field strengths of two consecutive transmissions. With the field strengths of two consecutive samples, the system determines the distance (L1, L2) from the bus stop B1 and the bus A1, and then calculates distance the bus A1 travels. However, this distance is the radio distance or a straight-line distance between the bus stop B1 and bus A1. It does not match the exact distance (route) the bus A1 travels on the road. It is even worst if the road runs radially with the centre at the bus stop (ie, the road is a circumference of the bus stop). The estimation is strongly affected by the physical orientation of the roads of the bus route.

JP 9305895 discloses a system that includes a first controller that is arranged in a bus. A first transceiver of the first controller carries out data communication with a second controller. The second controller is arranged on the bus stops on the route through which the bus travels. The identification code of the bus stop is received through the first transceiver and stored in a first memory. A measurement unit measures the distance of the bus from the previous bus stop. The transit data consists of the bus stop identification code, and the measured distance value is transmitted to the next bus

stop through the first transceiver. A second transceiver is provided in the second controller. The second transceiver carries out data communication with the bus.

This system requires a long-distance radio communication between the bus stop and the bus vehicle for reporting the remaining distance between the bus vehicle and next bus stop. The estimation of arrival time depends on the transit data sent over the radio communication between the bus stop and the bus. A long-distance radio communication is by nature volatile and fragile (fluctuated communication delay, varied signal-to-noise ratio, uncertain availability). Thus, the arrival time estimation is also volatile and not robust.

This system also requires a least two sets of equipment - "second controller and transceiver", installed separately in two consecutive bus stops along the bus route, to report the estimated arrival time for a single bus stop for a single bus route. The first set provides the bus with the identification code of the bus stop as a reference to determine the distance the bus travels. The second set at the next bus stop receives the "transit data", measures the distance of the bus from the previous bus stop and displays the estimated time. For a minimum configuration, this system requires more than two sets if it supports more than one bus route. Therefore, the system disclosed in this patent is not flexible for gradual deployment and for deployment at random (or non-consecutive) bus stops along a bus route.

Furthermore, the system requires a long-distance radio communication between the bus stop and the bus vehicles. The long-distance radio communication is easily affected by the movement of other vehicles on the road, rainy weather, blocking by buildings or mountains, and blocking if the bus travels inside a tunnel. To ensure a more reliable radio communication, the system requires radio repeaters installed along the bus route. It is very complicated to design a good quality radio communication network over the areas of the bus route, and it is not flexible to cater for the change of bus routes.

JP 7320198 discloses a system which requires long-distance radio communication between two consecutive bus stops. The previous bus stop sends the actual departure time of the bus to the next bus stop. The next bus stop then determines the estimated

departure (arrival) time of the bus based on actual departure time C of the bus, as follows:

$E = B + C - A$, where

A = scheduled departure time for the previous bus stop,

B = scheduled departure time for the next bus stop,

C = actual departure time from previous bus stop, and

E = estimated departure time for the next bus stop.

To provide estimation of departure (arrival) time of the bus, the system requires at least two sets of control units: one installed in previous bus stop; and another installed in the next bus stop.

This system requires a long-distance radio communication between the previous and next bus stop for reporting the actual departure time of the bus from previous bus stop for the estimation of departure (arrival) of next bus stop. The estimation depends heavily on data sent over the radio communication among the bus stops. A long-distance radio communication is by nature volatile and fragile (fluctuated communication delay, varied signal-to-noise ratio, uncertain availability). Thus, the departure (arrival) time estimation is also volatile and not robust. Even though the data communication between bus stops are provided by leased circuits, it is not feasible to provide a mesh data network to connect all bus stops if the system supports more bus routes.

The system also requires at least two sets of equipment - “control unit”, installed separately in two consecutive bus stops along the bus route, to estimate and report the estimated departure (arrival) time for a single bus stop for a single bus route. The previous set provides the actual departure time of the bus to the next set, which takes the actual departure time for estimation. For a minimum configuration, the system requires more than two sets if it supports more than one bus route. Therefore, the system disclosed in the patent is not flexible for gradual deployment and for deployment at random (non-consecutive) bus stops along a bus route

Furthermore, the system estimates the departure time only based on the deviation (C-

A) of the departure time from previous bus stop. It is not accurate because it does not consider the change of traffic flow between previous and next bus stop along the bus route.

U.S. Patent No. 6,191,708 discloses an invention comprising two systems: (i) bus system installed in a bus vehicle to collect and store bus information including identity, speed, door position, time to next stop, number of stops, current segment of route or position; and (ii) home system carried by passengers at home near the bus stop to enquire the estimated arrival time of desired bus route by entering bus & stop number.

With UHF radio communication, the bus system regularly sends data packets of bus information to all home systems in the vicinity. If the bus information corresponds to the desired bus route, the home system will determine and display the estimated arrival time.

This system requires a long-distance radio communication between the bus vehicle and the passengers for reporting the bus information and estimated arrival time. The estimation of arrival time depends on the data packets transferred over the UHF radio communication. A long-distance radio communication is by nature volatile and fragile (fluctuated delay, varied signal-to-noise ratio, uncertain availability). Thus, the arrival time estimation is also volatile and not robust. If one or two data packets are dropped, the home system will at once incorrectly or cannot determine the arrival time.

The system also requires every commuter who needs the estimated bus arrival times to have a home system to receive the bus information via UHF radio communication from the bus vehicles. In case the commuters are located far away from the bus route or blocked by buildings, walls or mountains, or in case of road diversion, the commuters cannot receive the bus information. To ensure a more reliable radio communication, the system requires radio repeaters installed along the bus route. It is very complicated to design a good quality radio communication network over the areas or vicinity of the bus route, and it is not flexible to cater for the change of bus routes.

The home system requires a continuous reception of current bus information from bus systems to determine the bus arrival time. In case the home system cannot receive any data packets for a long time, for example, because of road diversion or traffic congestion, the commuters do not have any idea whether it is really traffic congestion, failure of home system or transmitter sub-system, or a case that there is no bus passing the area.

Furthermore, it is cumbersome for every commuter to carry a home system to know the arrival time. On the other hand, the commuters are required to enter a bus stop number before they could enquire the estimated arrival time. If the commuters go to some places they do not usually take bus, it is difficult for them to enter an accurate bus stop number.

In view of those factors, a more robust and less expensive system is needed for providing public bus arrival-time estimation.

SUMMARY OF THE INVENTION

With the recent emerge of advanced computer and radio technologies (e.g. Bluetooth, IEEE802.11 Wireless LAN or Radio Frequency Identification (RFID) technology), the present invention provides a Bus Arrival Time Estimation (BATE) System that is simple, low cost, scalable and adaptive. The BATE system of the present invention is implemented as an independent system and could be installed in preferred locations of bus stops for selected bus routes. By way of example, not limitation, the BATE system consists of a Computer System (or a simpler system with a Central Processing Unit) with a RF Transceiver (preferably RFID), a Display Device to show the commuters the arrival time information, and a passive or active RFID Transponder (tag) to be installed in the bus vehicles of selected routes.

Continue with the above example, the Computer System (or a simpler process unit) installed in a bus stop will continuously listen if there is any bus vehicle with a RFID tag arriving the bus stop. The RFID tag contains a unique bus identifier (including bus route, vehicle license number or other code) to distinguish a bus vehicle. If there is a bus coming, the Computer System will read the RFID tag and its bus identifier.

The Computer System stores the time stamp of each bus arrival. With a sufficient number of time stamps and pre-input scheduled bus frequency, the Computer System could estimate the arrival time of the next bus with an predetermined acceptable level of confidence, by the use of an appropriate Probability Model (Normal Distribution). The estimation information is shown in the Display Device in the bus stop.

For a particular embodiment of the estimation system, the main features of the present invention are described in the following:

1. The accuracy of the estimated time of bus arrival is adjustable according specific situation where and when the system is used by simply choosing a suitable level of confidence as an input in the calculation performed by the computer system.
2. The estimated time is adaptive to the current conditions (e.g. road traffic condition) that are reflected by the latest set of arrival times.
3. The BATE System displays “DELAY” message to the commuters if the estimated arrival time is over. Commuters could keep waiting or choose other alternative routes.
4. The BATE System could provide recommended bus route as an alternative in case a particular bus route is delayed.
5. Only one BATE System is required to be installed in a chosen bus stop.
6. A single BATE System in a bus stop could estimate the arrival time of multiple bus routes.
7. The BATE System is a standalone system and requires no network connection (no matter wireless or data circuit connection) to any computer system or any BATE System in other locations.
8. The BATE System is highly scalable, starting from one bus stop and one bus route to all bus stops and bus routes.

9. The BATE System could identify a passing-through bus vehicle, though the bus does not park at the bus stop to provide service.
10. The BATE System could identify a bus vehicle inside a bus stop without line of sight.
11. The bus identifiers are encrypted for security purpose.

Of course, the above features do not have to be all implemented in a particular embodiment to provide satisfactory results. One or more of the features can be omitted without affecting the practice of the present invention.

According to one aspect of the present invention, there is provided a method for estimating the arrival time of a vehicle that travels along a predetermined route, comprising the steps of (a) monitoring a vehicle's arrival at a stop or a station; (b) recording time stamp of the arrival; (c) determining time deviation of the arrival and calculating arrival time of a next vehicle; and (d) displaying and counting down the arrival time. As used in this disclosure and claims, a vehicle's arrival means either the vehicle's entering and stopping at a stop or station or passing through without stopping.

According to another aspect of the present invention, there is provided a bus arrival time estimation system, comprising a first signal device adapted to communicate with a second signal device when both come within a predetermined short distance; the second signal device being installed aboard in a bus vehicle with bus identifier; a central processing system, installed in a stop, which is in communication with the first signal device via wired or wireless communication means and which contains algorithms, either hardware or software implementation, to calculate the next bus arrival time with input of several predetermined factors according to a number of statistical principles; and a display device connected, wired or wireless, to the central processing system and capable of showing the arrival time and/or counting down based on the information fed from the center processing system.

The arrival time estimation is calculated statistically and independently by a single standalone system without any input of real-time data from other systems or other standalone systems of the present invention at other stops or stations along the route.

As used in this disclosure, a standalone system comprises:

- (a) a second signal device mountable on a vehicle;
- (b) a processing unit adapted to be placed in or near a stop or station;
- (c) a first signal device adapted to be placed in or near a stop or station; and optionally
- (d) a display device; said processing unit being adapted to communicate with said first signal device and with said display device, and said second signal device being adapted to communicate with said first signal device only when said vehicle arrives at said stop or station.

The step of determining time deviation comprises calculating the sample mean $\bar{D}$ and sample variance S^2 of the deviations $D_p, D_{p+1}, D_{p+2}, \dots, D_q$ of previous estimated arrival times against previous actual arrival times, from a sufficient number n ($n=q-p+1$) of past observations of the deviations, where D_i is assumed to be taken from a normal distribution of measurement with unknown mean μ and unknown variance σ^2 .

The step of determining time deviation further comprises determining a $(1-\alpha)$ 100% prediction interval, with the level of confidence $(1-\alpha)$ 100%, of a future observation of the deviation D_{q+1} as follows:

$$\bar{D} - t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} < D_{q+1} < \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}}$$

where $t_{\alpha/2}$ is the t-value (t distribution) with $v = n-1$ degrees of freedom, leaving an area of $\alpha/2$ to the right.

The step of determining time deviation further comprises determining the Estimated Deviation DE_{q+1} of next Estimated Arrival Time against next Actual Arrival Time as follows:

$$DE_{q+1} = \begin{cases} \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} & \text{if } \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} < D_{\max} \\ D_{\max} & \text{otherwise} \end{cases}$$

where $D_{\max}$ is the maximum tolerable and reasonable deviation of arrival time.

The step of calculating arrival time of a next vehicle comprises determining an estimated arrival time to be $f + DE_{q+1}$, with the $(1-\alpha)$ 100% level of confidence, where f is the frequency, in time, of the schedule of the vehicle along the route, wherein the level of confidence for the estimated arrival time can be chosen and adjusted by selecting the value of α , preferably before the start of the system, or during the time of maintenance.

BRIEF DESCRIPTION OF THE DRAWINGS

Specific embodiments of the invention will now be described by way of example with reference to the accompanying drawings wherein:

FIG. 1 is a block diagram of the bus arrival time estimation system in accordance with a particular embodiment of the present invention; and

FIG. 2 is a flow diagram of the method for estimating the arrival time of bus vehicles in accordance with a particular embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a specific embodiment of the Bus Arrival Time Estimation (BATE) system of the present invention. The BATE system consists of two sub-systems, namely a First Sub-system 10 and Second Sub-system 20.

The First Sub-system 10 comprises three components, namely a Processing Unit 11, a First Signal Device 12, and a Display Device 13. The Second Sub-system 20 comprises a Second Signal Device 21.

The Processing Unit 11 is preferably a computer or micro-controller that implements the arrival time estimation method of the present invention. The Processing Unit 11 stores a set of arrival time stamps and service time table, real-time calculates the estimated arrival time, and real-time counts down the estimated arrival time.

The First Signal Device 12 is a radio communication device that transmits and receives information to and from one or a plurality of Second Signal Devices 21 or Second Sub-systems 20 that have already entered in the area of a bus stop 14. The First Signal Device 12 is preferably a RFID (Radio Frequency Identification) transceiver, WiFi transceiver or Bluetooth transceiver. The First Signal Device 12 is either embedded inside the Processing Unit 11 or connected to the Processing Unit 11 with a standard interface, such as RS232 serial interface, via a cable. The First Signal Device 12 real-time monitors and senses the presence of any Second Signal Devices 21 entering the area of the bus stop 14. Once the First Signal Device 12 identifies one or a plurality of Second Signal Devices 21, the First Signal Device 12 informs the Processing Unit 11. The Processing Unit 11 then starts the communication with those Second Signal Devices 21.

The Display Device 13 is preferably a LED (Light Emitting Diode) display board or LCD (Liquid Crystal Display) system that is installed at a place inside the bus stop 14. The Display Device 13 can be easily seen by passengers who are waiting for buses at the bus stop 14. The Display Device 13 is connected to the Processing Unit 11 with either fixed wire or wireless media, such as WiFi or Bluetooth. The Display Device 13 displays the information of estimated arrival time, count down information of the estimated arrival time, route delay message or alternative route message, provided by the Processing Unit 11.

The First Sub-system 10 can comprise only one Processing Units 11, but one or a plurality of First Signal Devices 12 to increase the radio coverage within the bus stop 14, and one or a plurality of Display Devices 13 to increase the visibility of displayed information. The Processing Unit 11 is preferably housed inside a cabinet (preferably water-proof and good ventilation) at the bus stop 14. The First Signal Device 12 is preferably installed in a pole or cover of the bus stop two to three meters above the ground level to avoid any interference of pedestrian or passengers. The Display

Device 13 is preferably installed in a pole or cover of the bus stop two to three meters above the ground level to increase the level of visibility.

The Second Signal Device 21 is a radio communication device that transmits and receives information to and from the First Signal Device 12 in the area of the bus stop 14. The Second Signal Device 21 is preferably a RFID (Radio Frequency Identification) transponder (tag), WiFi transceiver or Bluetooth^(an) transceiver. Preferably, the Second Signal Device 21 is hard-coded with identification information of license number, vehicle number and route number. Some of the information may be omitted and additional information may be added. The Second Signal Device 21, inside the bus stop 14, transmits the identification information to be received by the First Signal Device 12, either constantly or upon an instruction from the First Signal Device 12. The Second Signal Device 21 can be active or passive. If the area of the bus stop 14 is large, the Second Signal Device 21 must be active so that its radio signal becomes stronger to reach the First Signal Device 12 fixed at the bus stop 14.

The Second Sub-system 20 is installed on-board in a bus vehicle 26. The Second Sub-system 20 is mounted in a place adjacent to the windscreen of the vehicle 26 or a place where the radio signal of the Second Sub-system 20 is not reduced or shielded. The Second Sub-system 20 can comprise one or a plurality of identical Second Signal Devices 21 that are installed in different appropriate places inside the vehicle 26, in order to ensure that the First Signal Device 12 at the bus stop can easily identify the presence of the Second Sub-system 20 when the vehicle 26 is entering into the bus stop 14.

The BATE System is deployed per bus stop basis. For example, for a chosen bus route A where there are, say, a total of thirty bus stops along the route and a total of five bus vehicles providing the service of that route, one First Sub-system 10 is installed in only one bus stop (out of thirty bus stops) if only one bus stop is required for estimated arrival time information, or a number of the First Sub-system 10 are installed in that number of bus stops (out of thirty bus stops) respectively if that number of bus stops are required for estimated arrival time information, or thirty First Sub-systems 10 are installed in all thirty bus stops if all thirty bus stops are required for estimated arrival time information. However, the Second Sub-system 20 with

appropriate bus identifiers should be installed in all of the five bus vehicles providing the bus service of that route.

The BATE System can provide estimated arrival time information for multiple bus routes simultaneously. For example, in case more than one route (A and B) provides bus service at one bus stop, only one First Sub-system 10 is required at the bus stop to provide arrival time information for both routes A and B, instead of two independent First Sub-systems 10 for estimated arrival time of routes A and B respectively. All bus vehicles serving route A and all bus vehicles serving route B should be installed with different Second Sub-systems 20, one Second Sub-system 20 against each bus vehicle. The Second Sub-systems 20 for both routes A and B are similar except for the hard-coded information inside the Second Sub-systems 20.

At another bus stop where routes A and C provide bus service, similarly, only one First Sub-system 10 is required at that bus stop to provide arrival time information for both route A and route C. The First Sub-system 10 serving routes A and B at one bus stop is independent of that serving routes A and C at another bus stop.

The BATE system of the present invention collects a series of samples of actual arrival times and then estimates or predicts the next bus arrival time with the adoption of Normal and Student t distribution. With the use of the First Signal Device or RFID Transceiver 12, the BATE System continuously listens to the RF media if there is any arrival or passing through event of a bus vehicle of the concerned bus route. If a bus vehicle with RFID transponder on-board is entering into the bus stop 14, the First Signal Device or the RFID Transceiver 12 will detect the presence of the Second Signal Device or RFID Transponder 21, read its bus identifier hard-coded in the RFID Transponder 21, and transfer the bus identity and the arrival event to the Processing Unit or Computer System 11. Then the Computer System 11 records the time stamp of each bus arrival. The Computer System 11 implementing a process of the BATE Method calculates the deviations of the previously estimated arrival times against the actual arrival times collected at the bus stop 14. Gradually, a set of samples or observations (say, size n) of the deviations is built up and stored in the Computer System 11.

With a sufficient number of deviations of previous estimations (being collected and built-up at the bus stop 14), and with pre-input scheduled bus frequency, the BATE System with the implementation of the BATE Method estimates the arrival time of the next bus at an acceptable accuracy defined by a preferred level of confidence.

Upon the completion of bus arrival time estimation, the BATE System displays the arrival time information in the Display Device 13 at the bus stop 14, for example,

“The next bus 98D will arrive in about 10 minutes.”

At the same time, the BATE System continuously updates and counts down the estimated arrival time. For example, after three minutes, the BATE System has already counted down the estimated arrival time from 10 to 7 minutes, and displays the latest update of arrival time information, for example,

“The next bus 98D will arrive in about 7 minutes.”

During a time interval when the estimated arrival time is being counted down, if a bus of the bus route arrives or passes through the bus stop 14, the BATE System will immediately stop the count down and display an arrival message, for example,

“The bus 98D has just arrived at the bus stop”

The BATE System records the time stamp of the actual arrival and conducts next iteration of bus arrival time estimation. With the use of the BATE Method, the BATE System calculates the next arrival time from a total of n samples or observations (including the one just captured) being most lately collected at the bus stop 14. Then the BATE System displays and counts down the estimated next bus arrival time as it did previously.

Back to the previous estimation or iteration, in case the count down of the estimated arrival time is over before there is any bus arriving or passing through, the BATE System will display a delay message, for example

“We are sorry that the next bus 98D is possibly delayed”

Subsequently, the BATE System looks up a table of alternative or similar routes, checks if each possible alternative route at the same time is also delayed or not, and short-lists those possible alternative routes that are still normal and not delayed. Then the BATE System displays a message of recommendation for alternative routes, for example,

“Please take alternative route 93K to reach your destination”

The present invention provides a benefit of real-time and validated information of alternative bus routes for the passengers at a bus stop. This advantage allows passengers to make alternative choices.

On the other hand, if there is no alternative route, or if all possible alternative routes are also delayed, the BATE System will not display any message of alternative routes. The BATE System will not conduct any estimation of next arrival time for that route, say 98D, until there is an arrival or passing through of the bus of the concerned route. The long period of time during which there is no bus arriving or passing through will increase the value of deviation of next or subsequent observations, which also increases the next estimated bus arrival times. The estimations for other routes that are not delayed remain normal and determine independently.

For an extreme case, just after the time when the BATE System has just displayed a delay and alternative route message at the bus stop 14, the next bus vehicle of the route immediately enters the bus stop 14. The BATE System can immediately identify the arrival of the next bus vehicle, stop displaying the delay and alternative route messages, and instantaneously display the arrival message of the bus route, such as “The bus 98D has just arrived at the bus stop”. Even though the BATE System quickly changes reporting from delay to arrival message, it is a fact that the next arriving bus is actually late (nonetheless 30 seconds or 5 minutes) for the bus stop 14 and arrives at the bus stop 14 after the end of the estimated arrival time count down.

In a normal case after the BATE System produces and displays an arrival time estimation but before the count down of estimated arrival time is over, when a bus of the route arrives at the bus stop, the BATE System immediately stops the current count down and displays an arrival message, no matter at the middle or at the end of the count down of the estimated arrival time.

Afterwards, the BATE System will start the next estimation or iteration after a reasonable Parking Time, no matter the bus really leaves the bus stop or actually parks in the bus stop for a longer time, say, because it is out of order. The reasonable Parking Time is a period of time a bus normally stays at a bus stop for passengers alighting and embarking. Even though there are more than one bus vehicles of the same route staying at the bus stop, the BATE System can still perform its next estimation or iteration normally, and record the time stamps of next arrival, because each bus vehicle has a unique bus identifier. Though the bus vehicles of the same route remain at the bus stop 14, the passengers at the bus stop 14 really encounters the next bus arriving, in accordance to the information of next estimated arrival time.

The BATE Method

The BATE Method statistically estimates the bus arrival times with the following four assumptions:

- i. A time table of scheduled frequency for a bus route concerned should be well defined.
- ii. The route of a bus in question is preferably fixed for each scheduled bus frequency.
- iii. The road traffic condition changes slightly in the time interval between two successive bus arrivals.
- iv. Assume the population (P) of deviations of estimated arrival times against actual arrival times is approximately normally distributed.

The BATE Method provides an estimation of the arrival times of next buses by determining the sample mean and the sample variance of a series of deviations of the previously estimated arrival times against the actual arrival times at an acceptable

level of confidence by the use of normal and t-distribution probabilistic models. The flow diagram of the BATE Method is shown in FIG. 2

For a particular bus stop S_j and for a particular bus route R , let's define the followings:

Variables	Description
f	Scheduled frequency of bus route R (mins).
i	The i th observation or iteration
TE_i	Estimated arrival time of next bus (route R) at bus stop S_j for the i th estimation (hh:mm:ss).
TA_i	Actual Arrival Time of next bus (route R) at bus stop S_j for the i th observations (hh:mm:ss).
Di	Deviation (error) of estimated arrival time against actual arrival time for the i th observation (hh:mm:ss).
n	Number of observations (Actual Arrival Time) taken from the population P , or the size of moving window.

The deviation Di of the previous estimated arrival time against the previous actual arrival time for the i th observations can be determined in equation (1):

$$(1) \quad Di = TA_i - TE_i, \text{ where } i \in [p, q] \text{ and } q > p$$

where p and q are the p th and q th observations of arrival time for route R respectively.

A set of random samples or a moving window of observations from p th to q th observations or samples are established, and the sample size is $(q - p + 1)$. Let $n = q - p + 1$ and $n > 0$.

Thus, $[D_p, D_{p+1}, D_{p+2}, \dots, D_q]$ represents a set of random samples of size n taken from the population P . The sample mean $\bar{D}$ and the sample variance S are defined by the following statistics (2) and (3):

$$(2) \quad \bar{D} = \sum_{i=p}^q \frac{1}{n} D_i$$

$$(3) \quad S^2 = \frac{\sum_{i=p}^q (D_i - \bar{D})^2}{n-1} \quad \text{OR} \quad S^2 = \frac{n \sum_{i=p}^q D_i^2 - \left(\sum_{i=p}^q D_i \right)^2}{n(n-1)}$$

Since D_i is taken from a Normal Distribution of population P with unknown mean μ and unknown variance σ^2 , a $(1-\alpha)$ 100% prediction interval of a future observation D_{q+1} can be determined by an inequality (4):

$$(4) \quad \bar{D} - t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} < D_{q+1} < \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}}$$

where $t_{\alpha/2}$ is the t-value in the Student t distribution with $v = n-1$ degrees of freedom, leaving an area of $\alpha/2$ to the right, and $(1-\alpha)$ 100% is the level of confidence or probability that D_{q+1} likely falls in the prediction (confidence) interval defined by (4).

Let DE_{q+1} be the Estimated Deviation of next Estimated Arrival Time against next Actual Arrival Time, then the estimated deviation for next bus arrival is determined by equation (5):

$$(5) \quad DE_{q+1} = \begin{cases} \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} & \text{if } \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} < D_{\max} \\ D_{\max} & \text{otherwise} \end{cases}$$

where $D_{\max}$ represents the maximum tolerable and reasonable deviation of an estimated bus arrival time against the actual arrival time. For example, $D_{\max}$ can be set to a value of $3f$ or three times of schedule bus frequency f .

Therefore, the estimated arrival time for next bus (TE_{q+1}) at an accuracy of $(1-\alpha)$ 100% level of confidence is calculated by equation (6):

$$(6) \quad TE_{q+1} = f + DE_{q+1}$$

The BATE System displays a message of estimated arrival time in the display device 13, for example,

“The next Bus 98D will arrive in about $[TE_{q+1}]$ minutes”

with the level of confidence $(1-\alpha)$ 100%.

At the same time, the BATE System continuously updates and counts down the estimated arrival time $[TE_{q+1}]$. If a bus of the bus route arrives or passes through the bus stop, the BATE System will immediately stop the count down and displays an arrival message, for example,

“The bus 98D has just arrived the bus stop”

The BATE System records the time stamp of the actual arrival and conducts next iteration of bus arrival time estimation. The BATE System calculates the next arrival time from a new set of n samples or observations, namely, $[D_{p+1}, D_{p+2}, \dots, D_q, D_{q+1}]$. The moving window of n samples or observations advances one step.

In case the count down of the estimated arrival time is over before there is any bus arriving or passing through, the BATE System will display a delay message for commuters to decide, for example,

“We are sorry that the next Bus 98D is possibly delayed.”

The BATE System can recommend other alternative routes, if any, if the alternative routes are not delayed at the same time and the count down of the alternative routes are normal. The message might be:

“Please take alternative route 93K to reach your destination.”

Since the BATE Method estimates the next bus arrival time from the latest built-up samples of actual arrival times and their deviations, which automatically increase or decrease due to the change of traffic condition or ad hoc change of bus routing paths, the BATE Method can be automatically adaptive to any change of road traffic conditions or any ad hoc change of bus routing path, without any manual input or adjustment, or any information about the change of traffic condition and routing paths.

Since the BATE Method estimates the next bus arrival time from the latest built-up samples of actual arrival times and their deviations, which automatically increase or decrease due to the change of current speed, direction, travelling distance or position of bus vehicles, the BATE Method can independently produce an estimation of next bus arrival time at an acceptable level of confidence, without the need of information or tracking about current speed, direction, travelling distance or position of bus vehicles of concerned bus routes. As a result, the present invention provides a benefit of simplicity without collecting, tracking or processing the information of current speed, direction, travelling distance or position of bus vehicles of concerned bus routes, yet at an acceptable accuracy defined by the level of confidence.

The BATE System

For data security and integrity purpose, the bus route, bus license number and/or other codes are encrypted and hard-coded in the RF Transponder 21. In case someone taps the information over the RF media, he or she cannot read or modify the contents so that the operation of bus arrival time estimation is not affected. The Computer System 11 should decrypt the information of bus identity collected from the RF Transceiver 12.

Usually, a bus stop is set up for a plurality of bus routes for picking up or embarking passengers. The BATE Method can provide the estimation of bus arrival times for a plurality of bus routes at the same time by operating multiple processes of the BATE Method, but employing different sets of built-up samples or observations (i.e. actual arrival times and deviations) for different bus routes. The Computer System 11 operates multiple and independent processes of the BATE Method: one process against one bus route.

After power interruption or reset of the BATE System, the BATE System once being power-on automatically collects and builds up a series of actual arrival times and deviations, and resumes the estimation and display of estimated arrival time until a sufficient number of observations (or arrival times) are accumulated. Since it takes time to build up a sufficient number of observations before the BATE System can produce an estimation of next arrival time, the BATE System can reduce the time of building up samples or observations by employing previous samples or observations that were collected in previous days of similar conditions within the same period of time. For example, if today is Sunday, the BATE System should recall a series of samples or observations that was collected last or in the preceding Sundays within the same period of time. The BATE System employs historic data of similar pattern for a quick response of providing arrival time estimation after interruption or reset. The BATE System should immediately switch to process current samples or observations once a sufficient number of samples or observations are attained.

The accuracy of bus arrival time estimation is defined by the level of confidence $(1-\alpha)$ 100%, which may be adjusted to match different acceptable accuracy standards. For example, if the value of α is set to 5%, then the level of confidence becomes 95%. The accuracy of the estimation shall be 95%. In other words, the next bus has 95% likelihood to arrive at the bus stop in $[TE_{q+1}]$ minutes. Once the level of confidence is configured and set up in the BATE System, the BATE System estimates the bus arrival times with such accuracy all the time until the time of next re-configuration.

With the use of Normal and Student t probability distribution, and with the use of short-range RF communication inside the area of the concerned bus stop for detecting the arrival of bus vehicles, the BATE System and Method estimate the next bus arrival times solely from the latest built-up samples of actual arrival times and deviations, and from pre-input scheduled bus frequencies. Thus, the BATE System is an independent and standalone system solely installed at a bus stop, without any requirement for real-time or non real-time, wired or wireless communication with any central offices, any other bus stops, or any bus vehicles outside the area of the bus stop, and also without any requirements for an establishment of facilities or systems

outside the concerned bus stops or along the path of bus routes. As a result, the present invention provides a benefit of zero cost or zero service charge of communication facilities.

In addition, the independent and standalone BATE System is highly flexible for deployment at any bus stops in different orientations, including but not limited to, as minimum as only one bus stop along a bus route, a few of non-consecutive bus stops along a bus route, or all bus stops along a bus route, or a few scattered bus stops of different bus routes and paths, with the justification of the importance to the passengers or commuters at the bus stops. As a result, the present invention provides a benefit of high scalability of deployment.

Optionally, the BATE System could display entertainment or advertising messages between those information about Bus Arrive Time Information.

Optionally, the BATE System could be fed with any other information or heuristics from other traffic information systems to enhance the accuracy of the estimation or the level of confidence.

While the present invention has been shown and described with particular references to a number of preferred embodiments thereof, it should be noted that various other changes or modifications may be made without departing from the scope of the present invention.

What is claimed is:

1. A method for estimating the arrival time at a stop or a station of vehicles that travel along one or more predetermined routes, comprising the steps of:
 - (a) monitoring the arrival of each of said vehicles at said stop or station;
 - (b) recording time stamp of said arrival;
 - (c) determining time deviation of next arrival and calculating arrival time of a next vehicle;
2. The method of claim 1, further comprising the steps of:
 - (d) displaying and counting down said arrival time.
3. A method as claimed in claim 2 wherein said steps (a)-(d) are accomplished using a standalone system which comprises:
 - (a) a second signal device mountable on a vehicle;
 - (b) a processing unit adapted to be placed in or near a stop or station;
 - (c) a first signal device adapted to be placed in or near a stop or station; and optionally
 - (d) a display device; said processing unit being adapted to communicate with said first signal device and with said display device, and said second signal device being adapted to communicate with said first signal device only when said vehicle arrives at said stop or station.
4. A method as claimed in claim 1 wherein step (c) is performed statistically and independently by a single standalone system without any input of real-time data from other sources.
5. A method as claimed in claim 1 wherein said step of determining time deviation comprises calculating the sample mean $\bar{D}$ and sample variance S^2 of the deviations $D_p, D_{p+1}, D_{p+2}, \dots, D_q$ of previous estimated arrival times against previous actual arrival times, from a sufficient number n ($n=q-p+1$) of past the deviations, where D_i is assumed to be taken from a normal distribution of measurement with unknown mean μ and unknown variance σ^2 .

6. A method as claimed in claim 5 wherein said step of determining time deviation further comprises determining a $(1-\alpha)$ 100% prediction interval, with the level of confidence $(1-\alpha)$ 100%, of a future observation of the deviation D_{q+1} as follows:

$$\bar{D} - t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} < D_{q+1} < \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}}$$

where $t_{\alpha/2}$ is the t-value (t distribution) with $v = n-1$ degrees of freedom, leaving an area of $\alpha/2$ to the right.

7. A method as claimed in claim 6 wherein said step of determining time deviation further comprises determining the Estimated Deviation DE_{q+1} of next Estimated Arrival Time against next Actual Arrival Time as follows:

$$DE_{q+1} = \begin{cases} \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} & \text{if } \bar{D} + t_{\alpha/2} \cdot S \cdot \sqrt{1 + \frac{1}{n}} < D_{\max} \\ D_{\max} & \text{otherwise} \end{cases}$$

where $D_{\max}$ is the maximum tolerable and reasonable deviation of arrival time.

8. A method as claimed in claim 7 wherein said step of calculating arrival time of a next vehicle comprises determining an estimated arrival time to be $f + DE_{q+1}$, with the $(1-\alpha)$ 100% level of confidence, where f is the frequency, in time, of the schedule of said vehicle along said route, wherein the level of confidence for the estimated arrival time can be chosen and adjusted by selecting the value of α .

9. A method as claimed in claim 1 wherein said displaying step comprises providing a display device at said stop or station, said displaying device being in communication with said processing unit.

10. A method as claimed in claim 1 further comprising the step of displaying a “delay” message if the counting down of said arrival time is over.

11. A method as claimed in claim 1 further comprising the step of displaying an “alternate route” message if the counting down of said arrival time is over.
12. A method as claimed in claim 2 wherein said second signal device is a transponder.
13. A method as claimed in claim 12 wherein said transponder is hard-coded and encrypted with route number and license number of said vehicle.
14. A method as claimed in claim 2 wherein said first signal device is a transceiver.
15. A method as claimed in claim 2 wherein said processing unit is a computer or micro-controller.
16. A method as claimed in claim 9 wherein said display device is a LCD panel.
17. A method as claimed in claim 1 wherein said vehicle is a bus.
18. A method of claim 2, wherein said vehicles travel along at least two predetermined routes.

Application No: GB0521849.0

Examiner: Nigel Hanley

Claims searched: 1-18

Date of search: 22 February 2006

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-18	US 5739774 A OLANDESI - See whole document. Note exchange of information between bus and bus stop. Note also display of information based on exchange of information.
X	1 at least	EP 0923061 A1 PRECIMATION - See whole document. Note calculation of delay against a timetable. Note also transmission of information from bus to the stop.
X	1 at least	JP 09167298 A SUMITOMO - See abstract and figures. Note transmission of information between bus and a bus stop. Note calculation at bus stop of delay and forward transmission to the next stop.
X	1 at least	FR 2648938 A1 SOCAVEL - See whole document. Note transmission of information between bus and bus stop. Note also subsequent calculation of delays and display of information to passengers.
X	1 at least	JP 07320198 A KOKUSAI - See Abstract and Figures. Note the calculation and display of an arrival time for the next bus based upon a communication between the bus and a bus stop.
X	1 at least	US 4799162 A SHINKAWA - See whole document. Note algorithm for calculating the delay time in a bus route and display of information to passengers.
X	1 at least	US 5493295 A LEWINER - See whole document. Note display of delay times to bus users at bus stops.
X	1 at least	JP 11339190 A CASIO - See Abstract and Figures. Note the monitoring of a bus arrival time and calculation of delays for display at information towers at bus stops.

Categories:

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
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Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^x :

G4Q; H4L

Worldwide search of patent documents classified in the following areas of the IPC

G08G

The following online and other databases have been used in the preparation of this search report

ONLINE: WPI, EPODOC, JAPIO, TXTE