A Low-Power Self-service Bus Arrival Reminding Algorithm on Smart Phone

Xuefeng Liu, Jingjing Fan, Jianhua Mao, and Fenxiao Ye
School of Communication and Information Engineering, Shanghai University, China

Abstract: *In this paper, a low-power self-service bus arrival reminding algorithm on smart phone is proposed and implemented. The algorithm first determines the current position of the bus by Global Positioning System (GPS) module in smart phone and calculates the linear distance from the bus current position to the destination station, then sets a buffer distance for reminding passengers of getting off the bus, estimates the bus maximum speed and calculates the minimum time of approaching the buffer. In terms of the time, the frequency of the GPS location and the distance calculation between the bus and the destination station is intelligently adjusted. Once the distance to destination station is within the buffer distance, smart phone will immediately remind passengers to get off. The test result shows that the algorithm can timely provide personalized arrival reminding service, efficiently meet the requirements of different passengers and greatly reduce the power consumption of smart phone.*

Keywords: *Bus arrival reminding algorithm, power consumption, buffer distance, GPS location.*

Received June 21, 2015; accepted July 4, 2016

1. Introduction

With the increase of urban motor vehicles and population, the urban traffic jam, road congestion, and air pollution are becoming increasingly prominent. Comfortable inexpensive, time controlled and intelligent reminding bus system can attract more people choose to take the bus during their trip, which can help to solve problems mentioned above [7]. So issues based on public traffic system like road traffic congestion detection [1], intelligent dispatching of transportation system [2], prediction of arrival time [6, 11], information management [3, 5] and arrival reminding [4, 8] have become hot research area in the world.

Arrival reminding function is very common in the bus system. Nowadays, there are two kinds of automatic arrival reminding methods that are becoming more and more mature. One is based on the mode of wireless signal transmission and receiving. This method takes advantage of the signal receiver installed on the bus to receive the specific signal transmitted by the signal generator near the bus stop [10]. Its signal in this mode is easily affected by the environment, the signal transmitter deployment cost is high, and the system maintenance is troublesome. The other one is based on Global Positioning System (GPS) positioning. This method uses the GPS module embedded on bus to obtain real-time location and calculates the linear distance between current position and the next station [9]. The method is easy to implement and maintain. Its accuracy depends on the accuracy of GPS module positioning.

Nowadays, the functions of smart phone are increasingly powerful and its power consumption is correspondingly growing too. In addition to using large capacity battery, optimizing mobile phone application software algorithm to reduce the power consumption of the mobile phone also is one of the ways to extend the phone standby time. If we don’t take the power consumption into account, a simple and effective arrival reminding scheme can be implemented by the built-in GPS module. The scheme uses the smart phone’s real-time longitude and latitude to locate the bus and calculates the linear distance between current position and destination at a certain time interval (e.g., 5 seconds). Likewise, once the distance is less than a pre-specified buffer distance (e.g., 300 m), smart phone will start alarming. This paper names it as Continuous Positioning bus arrival reminding Algorithm (CPA). Because continual positioning and frequent distance calculation of GPS, this scheme works at the expense of enormous power consumption of smart phone. Although it can enlarge the GPS positioning and distance calculating time interval to reduce the power consumption, it's very easy to lead to the possibility that the bus has already passed the destination station when the passengers are reminded to get off. This paper proposes and implements a Low-power Self-service bus arrival reminding Algorithm (LSA) on smart phone. The algorithm sets a buffer distance, estimates the maximum speed of the bus in advance and calculates the shortest time to enter into the buffer distance. Based on the time, the algorithm controls the GPS module to be activated or deactivated and changes the frequency of calculating the distance between current position and destination station. In this way, the reminder can work timely and greatly reduce the power consumption.

2. Algorithm Design

Suppose one passenger gets on the bus at station A and get off at station E. The maximum speed is estimated to be V_{max}. The d' is the Arrival Reminding Buffer Distance (ARBD) to the destination station. When the distance between the bus and station E is less than d', the smart phone begin to alarm. The position A is got by the GPS embedded in passengers' smart phone. The position of station E is provided by the electronic map applied in the smart phone. The linear distance (d_{AE}) between A and E is calculated and the distance (d) between the passenger and E equals d_{AE}. If d isn't more than d', it indicates that the bus is in the reminding buffer and the smart phone alerts immediately by the way of vibrating or popping-up a notification. Conversely, the shortest time to enter the buffer can be calculated by Equation (1).

$$t_{\min} = \left(d - d^{'}\right) / v_{\max} \qquad (1)$$

If t_{min} is no less than a Preset Time Interval (PTI, e.g., 10 seconds), it shows that the bus is about to enter the buffer and we select the CPA as the location way to reduce the GPS power consumption produced by frequently activating and deactivating the GPS in a short time. And d is calculated at every time-interval (e.g., 5 seconds) until the bus enters the buffer. Only if the average speed of the bus is no less than the maximum speed we estimate, there is no possibility for the bus to enter the buffer in tmin. If t_{min} is more than PTI, we deactivate the GPS in t_{min}. Otherwise we starts again the location service, repeats the previous steps and calculates the linear distance between the current location and destination station to compare with the buffer distance until the bus enters the buffer and then this system will remind the passenger to get off.

Figure 1 shows an example of LSA. One passenger gets on the bus at A and off at E station. Suppose the linear distance d between A and E station is 6000m. The bus's maximum travel speed V_{max} we estimated is 20m/s. PTI and ARBD are set to 10 seconds and 300m, respectively, and when the bus is about to enter the ARBD, the distance from station E is calculated every 5 seconds. Figure 1-a shows that the bus's position in the bus route at four different times is A, B, C, D, respectively. Figure 1-b, 1-c, 1-d, and 1-e demonstrate the linear distance away from station E at four different times, respectively. When passenger starts the reminding service, the bus's position is located in station A. The linear distance away from the destination station is 6000m (Figure 1-b) and is greater than 300m. There is no need to begin to remind. Meanwhile, t_{min}=(6000-300)/20=285s. The positioning strategy doesn't have to be changed yet, because t_{min} is greater than PTI, which means it is not possible that the bus enters into the buffer in 285s. Therefore, the GPS module will be deactivated. After 285 seconds, the bus arrives at B (Figure 1c) and the smart phone activates the GPS automatically. The distance to the station E is 1500m and its action is similar to A. After 60 seconds, the bus is located at C and the GPS is activated once again. At point C, the distance is 400m and t_{min}=(400-300)/20=5s. The t_{min} is less than PTI, which shows that it will enter the buffer soon and we should change the positioning strategy to select CPA as the positioning method. CPA keeps working 10 seconds and the bus arrives at point D. The linear distance is updated to be 280m and the bus is in the buffer. So the smart phone alarms the passenger to get off immediately. From starting the reminding service to ending it, the total working times of the GPS module are no more than 15 seconds and the number s of positioning are 4. However, if we only use CPA, the GPS module works throughout the service. The total working times of the GPS module are more than 355 seconds. And the numbers of calculating the distance and comparing it with d' is more than 71. Obviously, LSA reduces greatly power consumption and can be implemented easily.

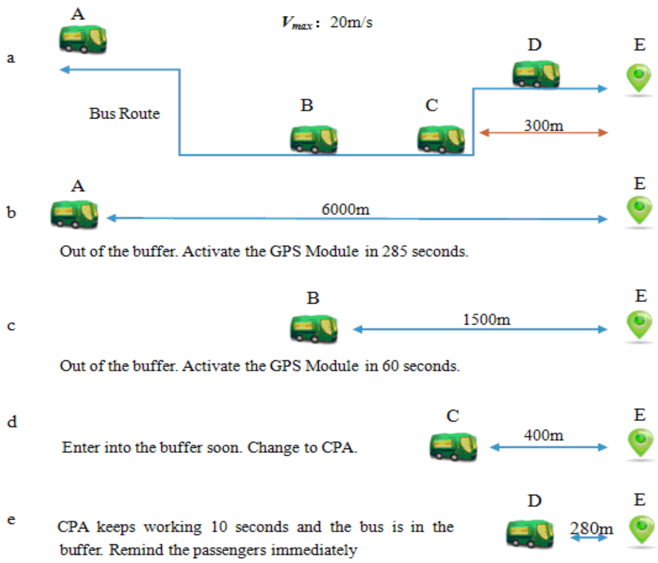


Figure 1. An Example for Low-power self-service bus arrival reminding algorithm (LSA).

3. Algorithm Implementation

Figure 2 is the flow chart of LSA based on the low-power self-service bus arrival reminding algorithm mentioned above. With Java as the development language and Android Development Tools (ADT) Eclipse as the development environment, Android Package (APk) in Android smart phone terminal is developed and deployed with the help of the electronic map on Android platform to get the information about the bus stations. In order to compare LSA with CPA, we also implement CPA on Android smartphone and the Figure 3 shows its working flow.

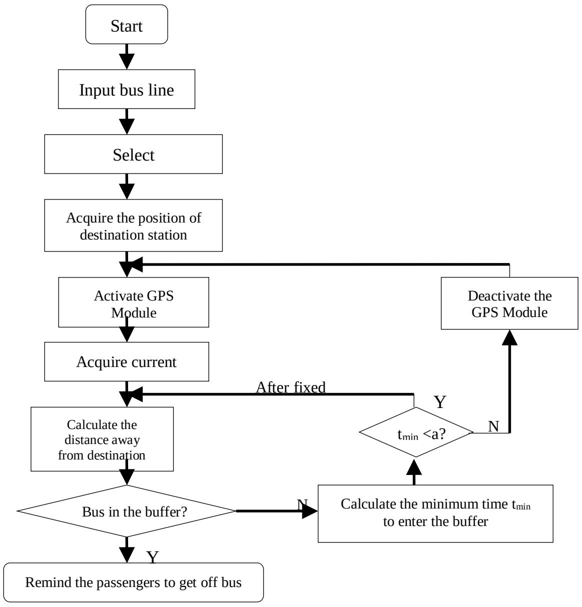


Figure 2. The overall architecture Figure 2 Flow Chart of LSA.

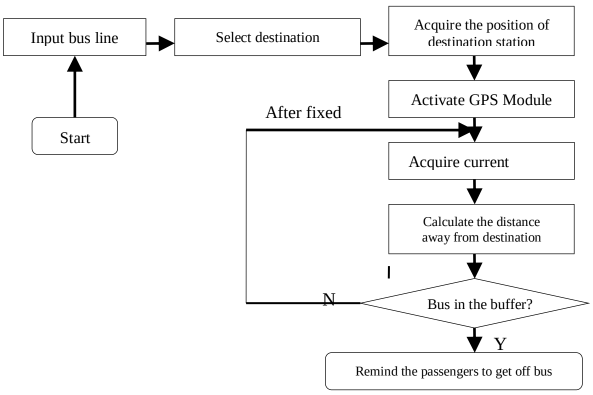


Figure 3. Flow chart of CPA.

4. Experiments and Analyses

We deploy APK of LSA in LG Nexus5 whose system is Android 4.4.4. With the experiments in the real bus line, the effectiveness of LSA will be verified and its performance will be compared with CPA.

We tested the bus line in Shanghai. The maximum speed of the bus is estimated as 15m/s. The buffer distance is set to be 300m. An Android application named PowerTutor is used to monitor CPU power consumption of different applications. Figure 4 is the results monitored by PowerTutor and it displays the running time, power consumption and power consumption percentage of the applications in the smart phone. In these experiments, we wrote down CPU power consumption consumed by LSA and CPA in every bus line. From start the time the reminding service is started to it is ended, the number to check the distance away from the buffer and the distance away from the destination station is counted(Table 1). Figure 5 displays the prompt information when the bus is in the buffer. The notification bar with Android icon represents the prompt information of LSA. And the bar with clock icon represents CPA.

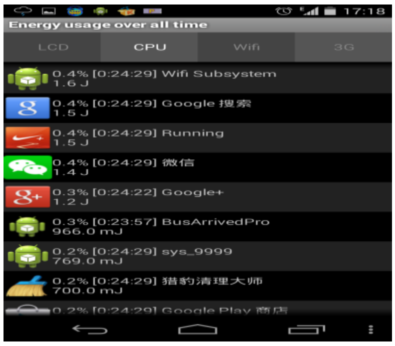


Figure 4. Power tutor monitoring window.

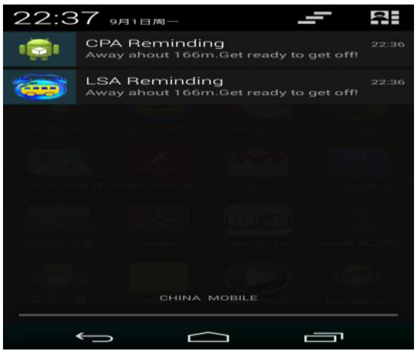


Figure 5. Reminding information.

As seen from the Table 1, both LSA and CPA can remind the passenger timely when the bus enters the buffer. However, the number of GPS positioning and distance calculating using LSA is just 5.6%, 5.1%, 3.1% of that using CPA with 4.6% on average in the three different bus lines. Accordingly, the power consumption consumed by LSA is 23.5%, 12.7%, 4.6% of that using CPA, 13.6% on average. Obviously, both LSA and CPA reminds timely. But power consumption of LSA is much lower than that of CPA and the longer the travel distance is, the greater the difference becomes. The results prove that LSA can remind the passenger timely and minimize power consumption of smart phone without great increase of algorithm complexity.

Table 1. Performance of LSA and CPA.

Bus Line	Algorithm	Distance from the start point to destination station (m)	Numbers to calculate the distance from the current position to destination station	Power Consumption (J)	Distance to destination station when passenger is reminded to get off(m)
58	CPA	3177	89	3.4	252
	LSA	3177	5	0.8	266
767	CPA	6416	311	7.1	262
	LSA	6430	16	0.9	262
876	CPA	8456	671	26	270
	LSA	8459	21	1.2	267

5. Conclusions and Discussion

This paper proposes a low-power self-service bus arrival reminding algorithm for smart phone. This algorithm combines web geographic information with GPS real-time location service. It makes use of web electronic map to get location information about bus stations and utilizes smart phone with built-in GPS location module to obtain real-time position. The distance between the current position and destination station is calculated and compared with the buffer distance to confirm whether the bus is in the buffer or not. In order to reduce power consumption, LSA gets the minimum time of entering the buffer by estimating a maximum speed in advance. According to the minimum time, we control the GPS module to be activated or deactivated and change the positioning strategy. Without additional cost, LSA timely and effectively provides the personalized reminding service to different users. Furthermore, it saves power consumption and is good for environment protection.

The key of LSA is to estimate the maximum speed, which is hard to estimate accurately. In fact, there is no need of accurate speed estimation. LSA can work effectively as long as the estimation is not less than the average speed of the bus. Usually, the closer the estimated maximum speed to the average, the fewer time the distance calculated from the current position to destination station, and the less the power consumption. On the other hand, the buffer distance can also significantly influence the results. If the buffer is too short, the user has to get off the bus hastily. If the buffer is too long, it results in wrong reminding when the bus is at one of previous stations. Typically, the buffer is set to be slightly less than the distance between the adjacent stations; therefore, it ensures smart phone to remind its user after the bus pulls out from the previous station.

Acknowledgement

This study greatly benefited from the research funding support provided by the National Natural Science Foundation of China (61271061). We thank three anonymous reviewers whose valuable comments helped in improving the paper.

References

[1] Al-Najdawi N., Abu-Roman A., Tedmori S., and Al-Najdawi M., "An Adaptive Approach for Real-Time Road Traffic Congestion Detection Using Adaptive Background Extraction," *The International Arab Journal of Information Technology*, vol. 13, no. 3, pp. 327-335, 2016.

[2] Coffey C., Pozdnoukhov A., and Calabrese F., "Time of Arrival Predictability Horizons for Public Bus Routes," *in Proceedings of 4th ACM SIGSPATIAL International Workshop on Computational Transportation Science*, Chicago, pp. 1-5, 2011.

[3] Farooq U., Haq T., Amar M., and Iqbal A., "GPS-GSM Integration for Enhancing Public Transportation Management Services," *in Proceedings of 2nd International Conference on Computer Engineering and Applications*, Bali Island, pp. 142-147, 2010.

[4] Liu B., "Algorithm and System for Arrival Reminding," *Chinese Patent*, 2014.

[5] Liu J., Gong C., Li J., and Cui X., "Social Sensing Enhanced Time Ruler for Real-Time Bus Service," *in Proceedings of 9th International Conference on Semantics, Knowledge and Grids*, Beijing, pp. 165-172, 2013.

[6] Padmannaban R., Divakar K., Vanajakshi L., and Subramanian S., "Development of a Real-Time Bus Arrival Prediction System for Indian Traffic Conditions," *IET Intelligent Transport Systems*, vol. 4, no. 3, pp. 189-200, 2010.

[7] Redman L., Friman M., Garling T., and Hartig T., "Quality Attributes of Public Transport that Attract Car Users: a Research Review," *Transport Policy*, vol. 25, pp. 119-127, 2013.

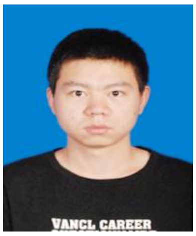
[8] Tang J., "Algorithm and Terminal for Arrival Reminding," *Chinese patent*, 2013.

[9] Yu R. and Zhao G., "Algorithm Research on GPS-based Bus-stop Auto-announcement System," *in Proceedings of 2nd International Conference on Mechanic Automation and Control Engineering*, Hohhot, pp. 57-59, 2011.

[10] Zhou B., Feng W., Hu J., and Luo H., "Design of the Intelligent Stop-reporting System in the Bus" *Journal of Sichuan University of Science and Engineering*, vol. 21, no. 3, pp.79-81, 2008.

[11] Zhou P., Zheng Y., and Li B., "How Long to Wait? Predicting Bus Arrival Time with Mobile Phone Based Participatory Sensing," *IEEE Transactions on Mobile Computing*, vol. 13, no. 6, pp. 1228-1241, 2014.

Xuefeng Liu received his BS degree in geology science from China University of Geosciences in 1991 and his PhD degree in Photogrammetry and remote sensing from Wuhan University in 2004. From 2001 to 2004, he has been an Associate Professor in Department of Geographical Information at Yangtze University. From 2005 to 2007, he has been a postdoctoral researcher at Shanghai University. He is presently working as Professor in the school of Communication and Information Engineering, Shanghai University, Shanghai city. His research interests include sensor Web data service, spatial data processing and analysis, remote sensing application, and geological 3D modeling and visualization.



Jingjing Fan received his BS degree in communication and information engineering from Tianjin University of Commerce in 2014 and pursuing his MS degree in communication engineering from Shanghai University. His main research filed is sensor communication and event service.

Jianhua Mao received his BS in geography science degree from Jiangxi normal University in 1994 and MS in natural geography science degree from Lanzhou University in 1997. He received his PhD degree at Wuhan University in 2002. He is presently working as Associate Professor in the school of Communication and Information Engineering, Shanghai University, Shanghai city. He is having a total of 17 years of teaching experience in various engineering colleges. His research interests include GIS, Data Analysis, and Sensor Event Service. He has published 30 papers in International and National Journals, 12 papers in International conferences and National Conferences.

Fenxiao Ye received his BS degree in communication system engineering from Jiangxi University of Science and Technology in 2013 and his MS degree in communication and information engineering from Shanghai University in 2017. He has published two papers in International journals and conference.