Augmented Trolley Services for Metro Stations: An Innovative Metro Journey Experience

Mohammed Arfat Raihan Chowdhury[1], Md Rakibul Hasan[1,2,] Ashhadul Islam[1]

[1]Hamad Bin Khalifa University, Qatar
[2] Mohammad Danesh Science and Technology University, Bangladesh

Abstract

Metro service in Qatar gives a new pace of societal advancement in terms of communication and sustainability. It has become a day-to-day life need for the residents of Qatar. The customer-oriented routing and accessibility to different parts of Qatar is a blessing to its residents. However, this study identified the challenges of commuting in the metro with bulk and/or heavily weighted belongings. This issue constraints the customer's willingness to travel in the metro. It increases the carbon footprint as the potential commuters of the metro move to take motor vehicles due to their carriages. We propose an augmented RFID-based trolley service inside the metro station, which will ease the traveling with heavy baggage and children and inspire more commuters to travel by metro. The IoT-enabled proposed design of the trolley will take the idea of a smart city step ahead.

Keywords: IoT; Smart City; Society 5.0; RFID; Carbon

1. Introduction

Sharing economy-based services are common nowadays in city life, and it is seen as a crucial building block of sustainability in smart cities. From food ordering to ride-sharing, every service industry is becoming online-based rapidly. Mobile applications and online platforms are becoming a crucial part of every business. The application of IoT and sensors in designing augmented vehicular services enhances the provision of society 5.0.

In Qatar, the Doha metro is one of the common means of transportation for its residents. It's like a backbone that reaches every important corner of Doha city. Commuters need to walk around 0.5-1.5 km inside every station to take the train and tram. Carrying heavy carriage along the way to this cheaper and sustainable means of transportation is not ergonomically correct, and it creates an unwillingness to use metro services. Subscription-based trolley services inside the station reduce the stress of carrying heavier belongings. After their shopping and groceries, people can take the metro instead of motor vehicles, from which a significant amount of carbon emission can be reduced.

The Internet of Things relies heavily on radio frequency identification (RFID). RFID technology is typically used to identify objects. However, due to its characteristics of non-touch, low-cost, high precision, long-distance transmission, and compatibility with the field of interior positioning, it has become a viable alternative for obtaining object mobility location information in recent years (Zhou & Shi, 2008). This is the reason RFID technology is a very good solution for guided vehicle routing.

2. Related Works

IoT-enabled smart trolley in malls and supermarkets is nothing new in literature. Clever trolley using industry 4.0 properties to enhance the purchasing and product checking experience has already been tested in human lifestyle (Bedi et al., 2017; Das et al., 2020; Gunawan et al., 2019; Shankar et al., 2021). Wi-fi and RFID integrated networking has been proposed by Raiyani(2019), where RFID has been used in trolleys inside a superstore. In that proposed system, the trolley itself can read the purchase information shown on the LCD screen. Later, the customer can easily pay his bill at the counter without manual check out, which can save time. However, the application of IoT to enhance the commuting experience by using smart trolleys is a call for eco-friendly transportation. Shared mobility instead of having an own car became popular due to the user-friendly systems. For achieving sustainability, a sharing economy is a great breakthrough.

The most difficult part of this investigation is going to be detecting the trolleys inside the metro stations, where the GPS won't be able to pinpoint their exact location. There are some popular methods for location identification and routing in GPS-denied areas. Installation and setup of those technologies in GPS-denied areas is the main problem for the implication of those methods. Area-specific application of one or combined method may result in better and more robust performances. The popular technologies for pedestrian navigation have been analyzed below.

Method	Process	Challenges	Article
Dead reckoning principals	When GPS is available, the model with fixed parameters is used to find an object. When GPS is not available, the model with variable parameters is utilized.	GPS is still required to set the parameters and update the accuracy.	Jirawimut et al., (2003)
Visual feature-based simultaneous localization and mapping systems (VSLAM)	The visual object uses as the identification landmark to identify the location.	Useful for autonomous vehicles but not that much applicable to human objects. Difficult to model in the monotonously visual featured area.	Zhao et al., (2019)
Inertial Navigation System (INS)	Optical flow sensor and magnetometer-infested inertial navigation system to locate and navigate objects in GPS-denied areas.	The applicability of this method is limited to small-scale unmanned vehicle routing. Gyro, accelerator, and magnetometer information is required to reduce error.	Shen et al., (2016)
Magnetometer with hall sensor-based technique	Magnetometers and sensors deployed movable object location design.	Design is difficult to implement in the cave type of road.	Mitra & Sarkar (2020)
Simultaneous localization and mapping in underground mining environment	Helpful for autonomous vehicles in hazardous settings. Localization is performed by clustering observed tags.	Human factor related to the human operator is not measured.	James et al., (2012)
Localization using LiDAR sensors	Computational geometry approach using LiDAR sensors	The proposed system is limited by the range of sensors in open space.	Veronese et al., (2016)
UAV-based target finding and tracking	The system figures out a plan for how to move around and avoid barriers.	The implementation is for unmanned aerial vehicles and is useful for avoiding obstacles.	Vanegas et al., (2016)

The papers propose different techniques for locating objects in GPS-denied environments. Mitra & Sarkar (2020) proposes a technique using low-cost sensors like magnetometers, Hall sensors, gyroscopes, and accelerometers to track the movement of a wheel-based object like a bicycle. James et al., (2012) suggest using RFID tags to autonomously localize and navigate in underground mining environments. Veronese et al., (2016) propose a localization system based on the random disposition of LiDAR sensors and the use of the Hausdorff distance to estimate the position of the sensors and the pose of the vehicle. These papers suggest that there are various techniques available for locating objects in GPS-denied environments, and the choice of technique depends on the specific application and environment.

This study mainly explored trolley specification in terms of smart technology and different IoT-based ride-sharing concepts to formulate a framework for trolley service in metro stations. As those trolleys will be deployed in the metro station where GPS is less competent, the RFID and in-vehicle sensors fusion is adopted from the design proposed by Song et al.(2016). However, this technique will be applicable for GPS-denied areas, and the proposed system GPS will also be applicable for GPS-covered areas.

Least Square Support Vector Machines (LSSVMs) are a popular and cutting-edge learning technique for classification and regression that can be used to build support vector machines. In daily trainings, RFID sensors and receivers create a lot of data. Using LSSVM, Mall & Suykens (2015), demonstrate how to reduce vast amounts of data for learning. Less computational time is needed because the data set's smallest cardinality has been extracted. The best application of LSSVM prediction has been found in the combinatorial optimization problem for different network routing such as pipeline in oilfield, passenger flow and vehicle routing problem (Qiao & Jiang 2016, Wang et al., 2021, Fazaviet al.,2014).

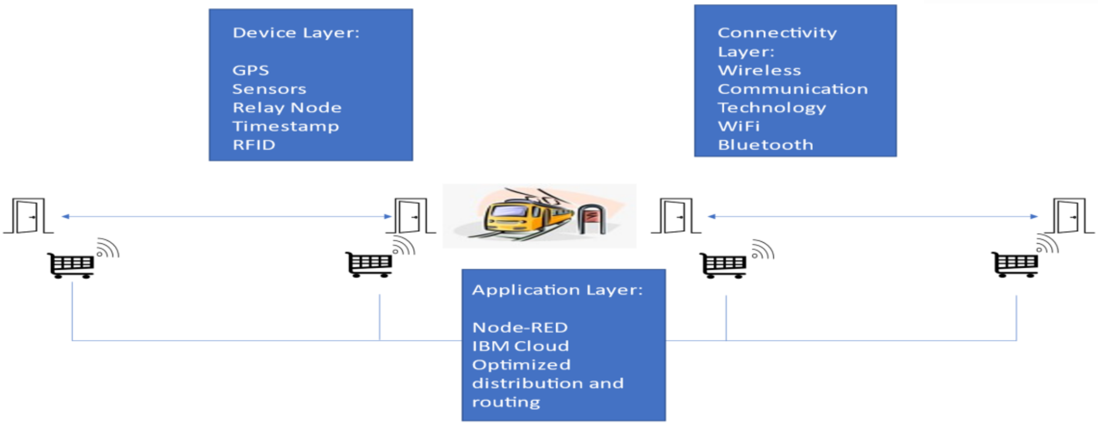
3. Proposed System

A determined number of the trolley will be available at the metro station entrance and at the entrance of the metro. Using the trolley inside the metro will be prohibited as it will create congestion inside the metro. Android application of subscribers can execute their travel plan with our trolly. A coupon (QR code) based on the travel plan will be issued to use accordingly. Customers need to scan the code with the scanner provided in the trolly to occupy. Customers can scan the QR code provided with a trolly to rent it from any point of start to any point end. It will be more convenient for the customer if he wishes to leave the trolly at any point of his journey inside the metro.

A fixed number of bags will be accepted in the trolly. Because more packages will be difficult for the customer to take in and take out from the metro as the door of the metro opens for a limited time in each station. It will also discourage customers from using the unnecessary number of packages (e.g., polybags).

The materials of the proposed system can be divided into three-layer such as the device layer, the application layer, and the connectivity layer. The modular framework of materials used in the proposed design is shown in Figure 1.

Figure 1: Modular framework of trolly



***Device layer**:* Radio frequency identification (RFID) has been used for monitoring and tracking assets, goods, and living things for a decade. The use of RFID in a trolley in a metro station is a good solution for tracking in GPS-denied areas. However, GPS is still attached to the trolley for the surface area of the metro station.

Application layer: Node-RED is used in the application layer, which is open-sourced visual editor that can easily design the interconnection of physical and digital interfaces. It will connect the cloud (Platform as a service) and optimization machine subsequently.

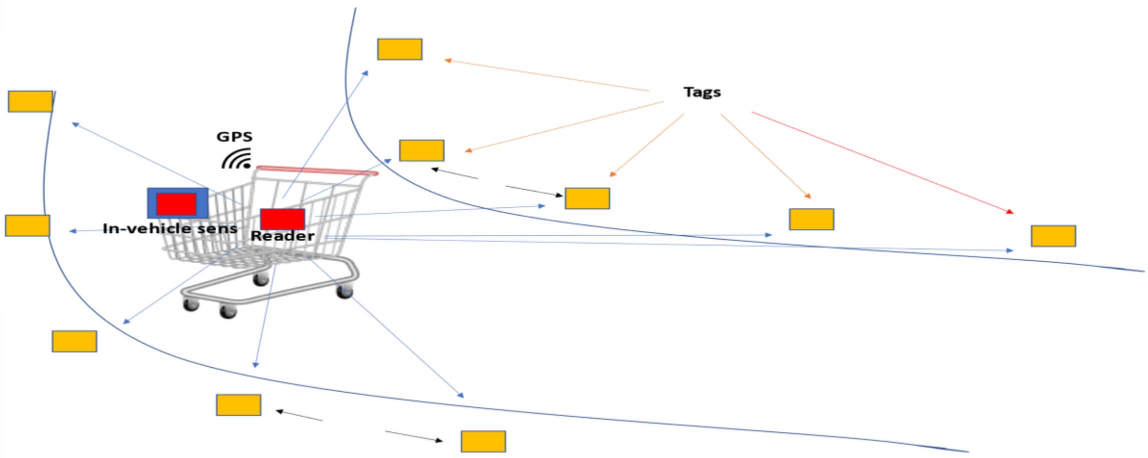
Connectivity layer: The IoT sensed data would generate the optimal distribution of trolleys around the metro network. For that purpose, wi-fi technology is used to connect RFID sensed data from RFID reader to monitoring main head.

3.1. Smart Trolley Design

The active RFID reader is placed on the top of the cart, and RFID tags are placed on both sides of the walkway inside the metro station. Those tags are installed at the regular interval as the exact position of those tags determines the accurate position of the trolley. The GPS system is also installed with the trolley with an appropriate power supply.

For enhancing the positioning performance, in-vehicle sensors are introduced with RFID obtained data. That sensor is also important for an optimized allocation of trolleys in every dock (entrance/exit) using GPS data. The features of the proposed smart trolley are shown in Figure 2.

Figure 2: The layout of RFID tags, RFID reader, sensor, and GPS installation



The Least square support vector machine (LSSVM) algorithm is developed to estimate the distance between RFID reader and tags. By that indoor positioning technology, total travel time, time of arrival, and the time differences of arrival can be used to obtain the calculation of the traveling distances of the trolley.

The powerful model of LSSVM is a nonlinear function and can be trained offline utilizing the experiment data collected in a specific environment. This model has more generalization ability than other methods such as Artificial Neural Network (ANN). The location information of distributed trolleys can be analyzed and optimized for the appropriate allocation time to time at every entrance and exit of metro stations.

If the training sets $\{x_n, y_n\}_{n=1}^{N}$; $x_n, y_n \in R^1$, where x_n is input received signal strength (RSS) vector and y_n is output distance-vector, R^1 is the one-dimensional vector space. According to Xu and Chen (2013), in the feature space, the LSSVM model takes the following equation,

$$f(x) = \gamma^T \theta(x) + b$$

Where, $\gamma \in R^{m_h}$ is the adjustable weight vector

$\theta(.) : R^1 \rightarrow R^{m_h}$ is the nonlinear mapping and $R^1 \rightarrow R^{m_h}$ Maps the input data into higher dimensional feature space.

b is the scaler threshold.

4. Conclusions

Although RFID technology appears to be a viable method for object localization, compared to the other localization technique, RFID localization is still in its early stage. Deploying this technology in metro stations is only useful because of the localization of trolleys in GPS denied areas. On the other hand, proper optimization of trolley distribution as per customer traffic is required at every point of entrance and exit in metro stations.

Traveling by metro train with the trolley is not applicable in the proposed design as it will create an unnecessary crowd inside the train, and customer is going to travel a long distance, which will incur more expense. As the proposed design is user-friendly, the extra charge for traveling long distances by train should not be collected. However, by getting the velocity and position of the trolley, the implication of free-of-cost off-pick hour traveling by train can be designed. For RFID in the LSSVM model, velocity can be measured from the deviation of position frequency.

References

Bedi, H. S., Goyal, N., Kumar, S., & Gupta, A. (2017). Smart Trolley using Smart Phone and Arduino. *J Electr Electron Syst*, *6*, 223. https://doi.org/10.4172/2332-0796.1000223

Das, T. K., Tripathy, A. K., & Srinivasan, K. (2020). A Smart Trolley for Smart Shopping. *2020 International Conference on System, Computation, Automation and Networking, ICSCAN 2020*. https://doi.org/10.1109/ICSCAN49426.2020.9262350

Fazavi, M., Hosseini, S. M., Arabloo, M., Shokrollahi, A., Nouri-Taleghani, M., & Amani, M. (2014). Applying a smart technique for accurate determination of flowing oil-water pressure gradient in horizontal pipelines. *Journal of dispersion science and technology*, *35*(6), 882-888.

Gunawan, A. A. S., Stevanus, V., Farley, A., Ngarianto, H., Budiharto, W., Tolle, H., & Attamimi, M. (2019). Development of Smart Trolley System Based on Android Smartphone Sensors. *Procedia Computer Science*, *157*, 629–637. https://doi.org/10.1016/J.PROCS.2019.08.225

James, S., Verrinder, R. A., Sabatta, D., & Shahdi, A. (2012, November). Localisation and mapping in GPS-denied environments using RFID tags. In 2012 *5th Robotics and Mechatronics Conference of South Africa* (pp. 1-4). IEEE.

Jirawimut, R., Ptasinski, P., Garaj, V., Cecelja, F., & Balachandran, W. (2003). A method for dead reckoning parameter correction in pedestrian navigation system. *IEEE Transactions on Instrumentation and Measurement*, 52(1), 209-215.

Mall, R., & Suykens, J. A. (2015). Very sparse LSSVM reductions for large-scale data. *IEEE* *transactions on neural networks and learning systems*, *26*(5), 1086-1097.

Mitra, S., & Sarkar, S. (2020, February). Location sensing of wheel based movable object with low cost sensors in GPS denied environment. In 2020 *IEEE Calcutta Conference (CALCON)* (pp. 482-485). IEEE.

Qiao, L., & Jiang, H. L. (2016). Energy-aware Routing Algorithm Based on Combinatorial Optimization Theory. *International Journal of Simulation--Systems, Science & Technology*, *17*(5).

Raiyani, R. (2019). Iot Based Intelligent Trolley for Shopping Malls. *International Journal of Scientific Research & Engineering Trends*, *5*(6), 2026-2033.

Shankar, S. K., Balasubramani, S., Basha, S. A., Ariz Ahamed, S., & Kumar Reddy, N. S. (2021). Smart Trolley for Smart Shopping with an Advance Billing System using IoT. *Proceedings - 5th International Conference on Computing Methodologies and Communication, ICCMC 2021*, 390–394. https://doi.org/10.1109/ICCMC51019.2021.9418348

Shen, C., Bai, Z., Cao, H., Xu, K., Wang, C., Zhang, H., ... & Liu, J. (2016). Optical flow sensor/INS/magnetometer integrated navigation system for MAV in GPS-denied environment. *Journal of Sensors, 2016.*

Song, X., Li, X., Tang, W., & Zhang, W. (2016). A fusion strategy for reliable vehicle positioning utilizing RFID and in-vehicle sensors. *Information Fusion*, *31*, 76–86. https://doi.org/10.1016/J.INFFUS.2016.01.003

Vanegas, F., Campbell, D., Eich, M., & Gonzalez, F. (2016, October). UAV based target finding and tracking in GPS-denied and cluttered environments. In *2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 2307-2313). IEEE.

Veronese, L. D. P., Auat Cheein, F., Bastos-Filho, T., Ferreira De Souza, A., & de Aguiar, E. (2016). A computational geometry approach for localization and tracking in GPS-denied environments. *Journal of Field Robotics*, 33(7), 946-966.

Wang, X., Liu, S., & Zhang, L. (2021). Highway Cost Prediction Based on LSSVM Optimized by Intial Parameters. *Comput. Syst. Sci. Eng.*, *36*(1), 259-269.

Xu, H., & Chen, G. (2013). An intelligent fault identification method of rolling bearings based on LSSVM optimized by improved PSO. *Mechanical Systems and Signal Processing*, *35*(1–2), 167–175. https://doi.org/10.1016/J.YMSSP.2012.09.005

Zhao, J., Huang, Y., He, X., Zhang, S., Ye, C., Feng, T., & Xiong, L. (2019). Visual semantic landmark-based robust mapping and localization for autonomous indoor parking. *Sensors*, 19(1), 161.

Zhou, J., & Shi, J. (2008). RFID localization algorithms and applications—a review. *Journal of Intelligent Manufacturing 2008 20:6*, *20*(6), 695–707. https://doi.org/10.1007/S10845-008-0158-5