RETRACTED CHAPTER: Management System for Optimizing Public Transport Networks: GPS Record

Jesús Silva[1](✉), Noel Varela[1], Erick Guerra Alemán[1], and Omar Bonerge Pineda Lezama[2]

[1] Universidad de la Costa, Barranquilla, Colombia
{aviloria7,nvarela2,eguerra4}@cuc.edu.co
[2] Universidad Tecnológica Centroamericana (UNITEC), San Pedro Sula, Honduras
omarpineda@unitec.edu

Abstract. As cities continue to grow in size and population, the design of public transport networks becomes complicated, given the wide diversity in the origins and destinations of users [1], as well as the saturation of vehicle infrastructure in large cities despite their attempts to adapt it according to population distribution. This indicates that, in order to reduce users' travel time, it is necessary to implement alternative road solutions to the use of cars, increasing investment in public transportation [2, 3] by conducting a comprehensive analysis of the state of transportation. This situation has made appear the solutions and development oriented to transportation based on Internet of Things (IoT) which allows, in a first stage, monitoring of public transport systems, in order to optimize the deployment of transport units and thus reduce the time of transfer of users through the cities [4]. These solution proposals are focused on information collected from user resources (data collected through smart phones) to create a common database [5]. The present study proposes the development of an intelligent monitoring and management system for public transportation networks using a hybrid communication architecture based on wireless node networks using IPv6 and cellular networks (LTE, LTE-M).

Keywords: Machine learning · Proactive control · Traffic · Smart cities · Public transport networks

1 Introduction

This paper presents the first part of a scalable platform that allows to connect diverse sources of monitoring and information through a hybrid network, formed by different wireless networks [6]. This platform is designed to adapt to the new needs of the city of Medellin in Colombia as it is implemented, offering a way of intercommunication with

The original version of this chapter was retracted: The retraction note to this chapter is available at https://doi.org/10.1007/978-981-15-6648-6_28

N. Chaubey et al. (Eds.): COMS2 2020, CCIS 1235, pp. 222–233, 2020.
https://doi.org/10.1007/978-981-15-6648-6_18

new and existing systems which allows to start the conversion to an intelligent city, by first facing one of the most important problems at this time: Public transportation [7].

Public transport is a determining factor in mobility. This statement offers a perspective of individuals in their socioeconomic and spatial reality (age, gender, social and labor category) broader than the term transport, which is limited to a relation of supply and demand expressed schematically, on the one hand, in the amount of infrastructures and means of transport and, on the other hand, in the number of trips per day, mode, itinerary, time [8–11].

Public transport and traffic are associated with the economic and technical factors that determine the movement of people, while mobility is focused on individuals and their environment. Although they are different dimensions, it is clear that proper transport planning has a positive impact on mobility. This new conception of public transport materializes in the recent policies, plans and projects in Medellin—at least in discourse—under the concept of comprehensiveness or integration: comprehensive or integrated transportation in which various means of transportation are articulated, according with the territorial ordering in the area of the city-region. Thus, an attempt has been made to overcome the conception of public transport as simply satisfying the conditions of the supply and demand for travel, based on the delimitation of the economically active population, to recognize its importance in transforming the socioeconomic structure and the social space based on the participation of the population [12–16].

The proposal is focused on solving the challenge of knowing the status of public transport, dividing it into three essential parts: the first part deals with the general hardware and software modules required for the proper operation of the system [17], then briefly describes the network architecture that will be used and the technologies and protocols required for the operation of the network. Finally, the third part describes the general architecture of the system and defines the way to communicate the information collected from the bus network to the information system for subsequent deployment to the users' devices.

2 Development

Based on the characteristics of the different types of transport systems analyzed (Metrobus, Transmilenio, etc.) and the different needs of the users, a modular, scalable and minimally invasive solution is proposed, which uses new generation and low-cost technologies. These characteristics allow the implementation of monitoring and communication devices in a simple way, making use of existing infrastructure. The following is a general description of the elements that make up the system at the hardware and software levels [18].

2.1 System Elements

The elements of the system are divided into: Monitoring modules, which include the bus and station modules; Web and mobile application; and Information system [19].

2.1.1 Bus Monitoring (A: Thread, and B: Thread+LTE)

With the purpose of informing the level of saturation in transport lines, modules will be implemented for obtaining the number of users in the unit at all times. In the same way to know the location of the units, a GPS module will be installed to operate in conjunction with a BLE transceiver to detect micro location devices "Beacons" to inform the user about the station in which he is through a web application of the system [20]. As it can be seen in Fig. 1, it is proposed to distribute this monitoring in two types of modules according to the type of transport in which the system will be implemented. For transport systems with marked stations, for example RTP, type B nodes will be used, on the other hand, for transport systems with stations with fixed structures, for example MB, type A or B nodes can be used indistinctly.

The design of the nodes is shaped as follows [21, 22]:

- Control unit.
- Ascent/descent counters with direction detection
- GPS Module
- Beacons reading module
- Thread communication module
- LTE communication module (Type B only).

Figure 2 shows the block diagram of the ascent/descent modules. The monitoring modules will be distributed at each of the unit's ascent and descent points [23], and will be responsible for obtaining the ascent and descent information at each point of the unit, and communicating it to the central bus module to calculate the current number of people within the unit.

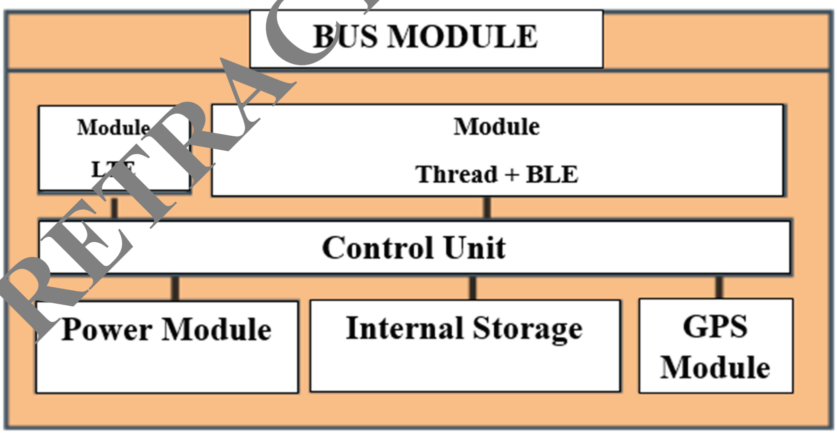

Fig. 1. Diagram of the central module of the bus.

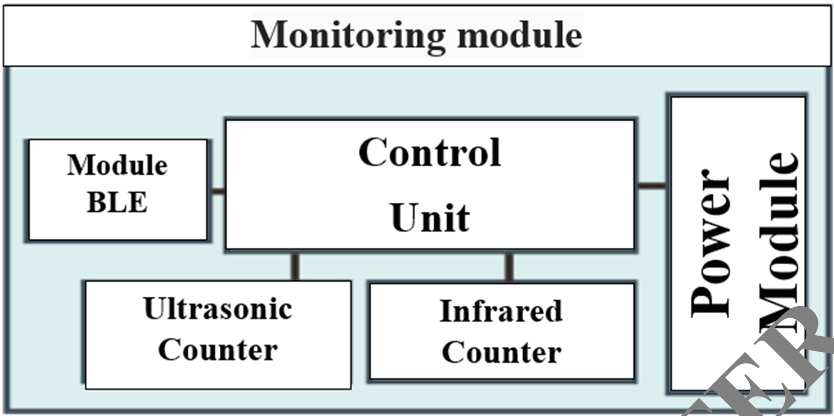

Fig. 2. Diagram of the bus ascent/descent monitoring module.

2.1.2 Station Modules

As previously mentioned, this system focuses on distributing the devices on the buses, with the aim of ensuring the versatility of the solution, in other words, that any transport system is applicable to the solution with the least possible adjustments. However, it is necessary to place identification modules in the stations for a correct synchronization and deployment of user information. These modules can be completely autonomous and with minimal impact on the current infrastructure. According to the type of transport system in which the solution will be implemented, two types of modules are proposed [24, 25]:

– Signalled stations

In the case of routes that only have signposted stations, "Beacons" will be placed at each station. This device will allow to obtain the proximity of the buses to the station based on the signal intensity, that is, whether they are arriving, departing or standing at the station. The device in conjunction with the GPS module will obtain information on the location of the unit, allowing users who have the mobile application on their devices to visualize the station they are in automatically and without consuming their data packet or GPS module, as long as they are compatible with the protocol to be used in the Beacons [26–28] (Fig. 3).

– Fixed structure stations

These modules only act as repeaters and border nodes of the Thread network deployed between stations and buses. The main feature to highlight about these nodes is their capability to adapt to the communication technology at the Internet level that is available in the place, i.e. you can implement the system communication at the Internet level from a module, LTE, 3G, Wi-Fi or Ethernet, among others [29].

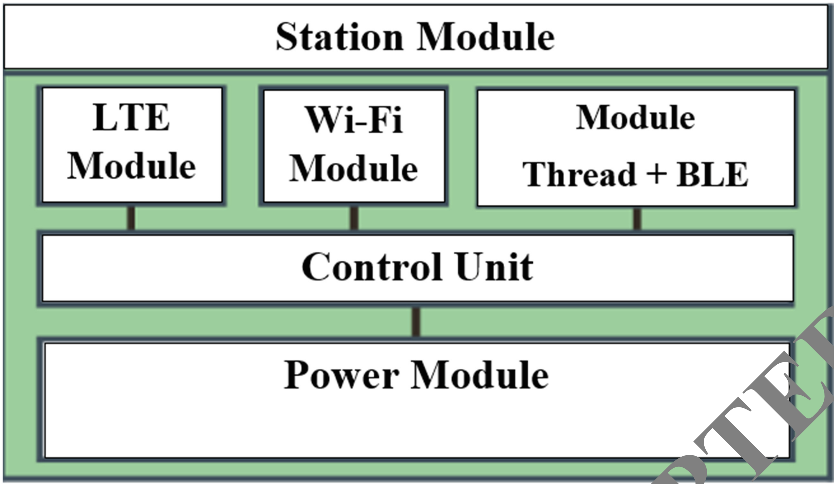

Fig. 3. Station module diagram with fixed structure.

– Web application

For the deployment of information to users, a web application will be developed for allowing access to system information from any compatible device, and adapt this web application to run on smartphones with Android and iOS operating systems.

The mobile application would allow transport users to visualize the status of the lines including: arrival time of the next bus at a specific stop, level of saturation of the bus (number of people/specified capacity), different transport routes registered in the system that stop at the same stop, as well as to automatically detect the stop it is at by detecting the "Beacon" installed in the stop [30].

2.2 Information System

The information collected from the transport systems shall be communicated through the LTE modules with the information system. This is the one in charge of processing and storing all the information of the network so that it can be displayed in an easy and understandable way by means of graphics and indicators of the different variables of the system [31].

The information system will be hosted in a private cloud platform and managed through the use of REST services. These will interconnect the different nodes of the system, as well as the mobile clients and web applications [32].

2.3 Network Architecture

For the communication of the different monitoring points, a hybrid network architecture is proposed, consisting of a network of wireless nodes that provides a first communication infrastructure between the transport units and a set of LTE links that allow all the nodes to communicate to an information system in the cloud which distributes the information to the users of the transport network (Fig. 4).

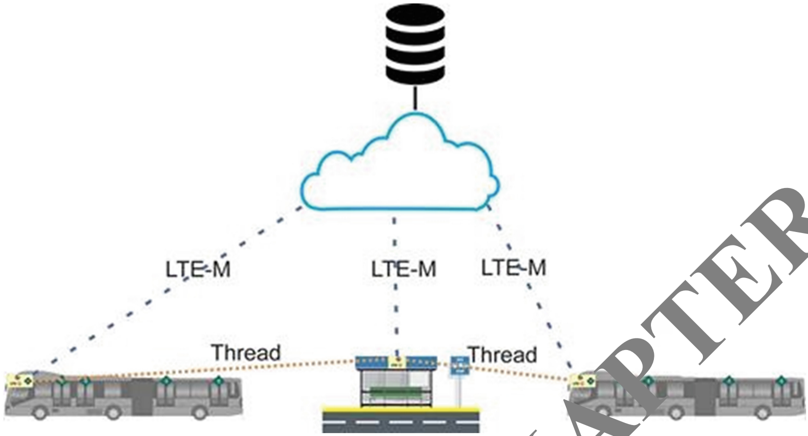

Fig. 4. Basic communication architecture.

It is necessary to place monitoring nodes at different points of the transportation unit. These points will communicate wirelessly via a Bluetooth Mesh network [2]. The information will be concentrated in the main node of the vehicle which will communicate the monitored variables with the nearby nodes using the Thread network and, in case the vehicle has a LTE modem, the information will also be sent by this means to the information system (Fig. 5).

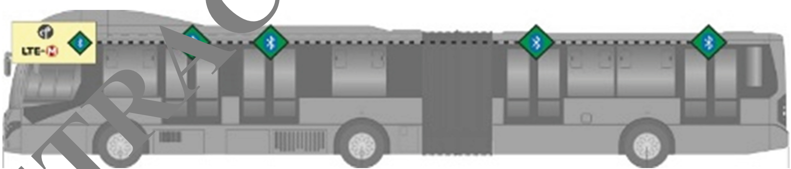

Fig. 5. Distribution of nodes in transportation units.

In order to interconnect the different transportation units with the fixed structure stations and later communicate with the information system, Thread-based nodes will be deployed in the stations, which will allow direct communication between stations and transport units, optimizing the distribution of the variables monitored at each point in an independent way, thus helping to feed the automatic learning algorithms that will be implemented in the node network (Fig. 6), in the same way that in the transport units some specific stations will be selected (based on their geographical location) to include in their node an LTE modem for allowing the communication of the nodes with the information system [33–35].

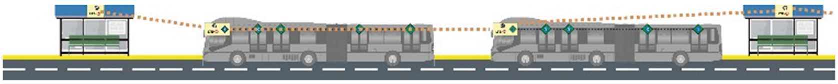

Fig. 6. Distribution of nodes in transportation stations

In the case of stations that do not have the necessary features to operate a communication node, such as those consisting only of a sign on a road, "Beacons" micro location devices will be placed to allow transport units to know and report the location of the unit through the station identifier (Fig. 7) and, in the case of users with compatible mobile devices, to obtain information on the next transport units through the mobile application developed [36–39].

Finally, the users of the system (passengers, operators and managers of the transport network) will view the information collected from the system through a web application on any device compatible with an internet connection.

2.4 System Architecture

For the communication at a logical level of all the components of the system, a modular software architecture is proposed to allow the monitoring and notification to the modules by using REST services for the first case and PUSH notifications for the second one.

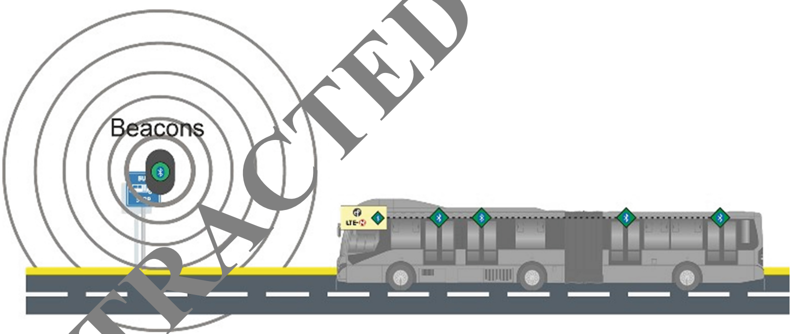

Fig. 7. Proximity detection at signaled stations.

This architecture is greatly simplified in the communication with the Thread nodes because this protocol allows redirecting the information frames directly thanks to the implementation of IPv6 within the node communication [8].

The nodes distributed in the buses communicate the information collected through the Bluetooth Mesh network deployed inside the bus, later this is communicated through the Thread network until reaching a border node from which it will communicate to the Web server using Web services [40, 41].

Once on the server, this information will be processed and stored in the information system database, and then, based on the source of the information, the nodes and users will be notified at the relevant stations through the notification channels. PUSH, which will prevent the Web application and the network nodes from constantly "pulsing" [42].

3 Implementation

Up to this moment, the analysis and design of the monitoring modules inside the bus has been carried out. These modules manage the users' account inside the transport units. Two prototypes were developed in this way, the first one using the nRF24L01+ transceiver with the objective of communicating the different nodes installed inside a unit. Due to the modularity of the system, the characteristics of the wireless sensor network can be modified, so the second prototype was chosen to use a set of different sensors and transceivers. In this second case, an infrared cut sensor was added in conjunction with the infrared distance sensors and an XBee S2C as a communication module between nodes (Fig. 8).

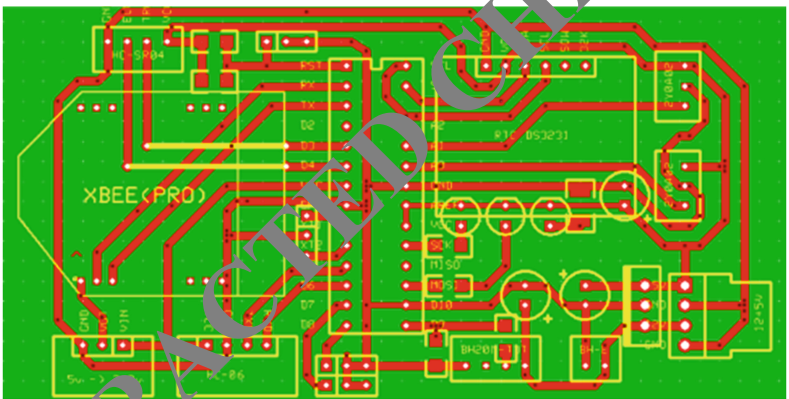

Fig. 8. Monitoring module PCB design using XBee.

Finally, an adaptable module was designed to which any of the two transceivers can be connected, as well as the different sensors analyzed. This last design was made in EAGLE and seeks to be compact and compatible with any of the transceivers tested, using ZigBee through XBee using the XB1 module or through BLE through nRF24L01+ using the JP3 connector (Fig. 9).

Likewise, the research process included the development of cards based on nRF52840 for the deployment of bus and station nodes. These modules are in charge of generating the multiprotocol Thread network with BLE for the communication of the different transport units.

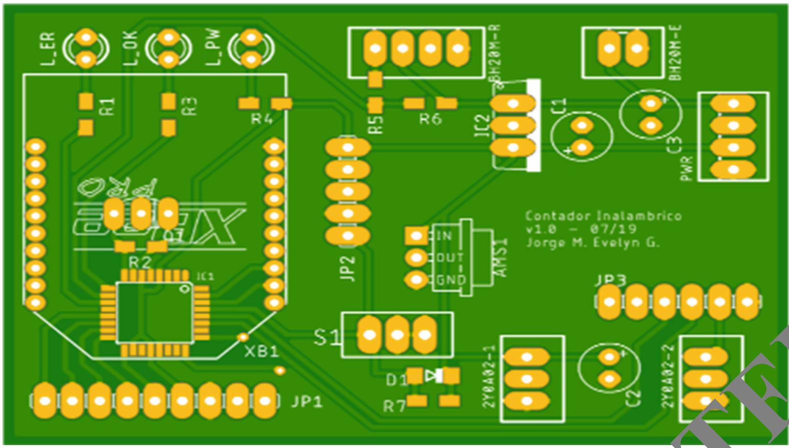

Fig. 9. Monitoring node PCB design at EAGLE.

4 Conclusions

The proposed system differs from other similar implementations in the communication architecture of transport vehicles which allows the node to know the status of other nodes besides its own.

The main advantages of the proposal are:

- Easily scalable architecture.
- Wireless nodes that allow high flexibility in the installation within the transport units.
- Communication of the transport units without internet connection
- Possibility of using different types of transport units and different routes within the same system.

As future work, the communication network between buses and stations based on the Thread protocol will be developed, the LTE-M communication modules will be developed, and the information system will be developed with the necessary communication technologies, to verify the correct operation of the system, some nodes will also be deployed in designated vehicles which will be monitored on a defined road within the city in order to carry out operational tests in a real environment and verify the functionality of the system.

In a next stage, it is considered to visualize the possibility of integrating the payment of the transport service through the platform, as well as acting as an identification credential for access to the transport route. This can be developed through the implementation of NFC or through some dynamic two-dimensional code (QR, PDF417, etc.).

Finally, we consider that it is important to develop solutions focused on IoT, including Smart Cities that allow the integration of the diverse existing infrastructure to the new trends in information systems, so that the different services offered by cities can be optimized, reducing, in the case of public transport, transfer times and improving the efficiency of fuel consumption, gradually improving the quality of life of the inhabitants.

References

1. Handte, M., Foell, S., Wagner, S., Kortuem, G., Marron, P.J.: An Internet-of-Things enabled connected navigation system for urban bus riders. IEEE Internet Things J. **3**, 735–744 (2016). https://doi.org/10.1109/JIOT.2016.2554146
2. Cats, O., Vermeulen, A., Warnier, M., van Lint, H.: Modelling growth principles of metropolitan public transport networks. J. Transp. Geogr. **82**, 102567 (2020)
3. Tomej, K., Liburd, J.J.: Sustainable accessibility in rural destinations: a public transport network approach. J. Sustain. Tour. **28**(2), 222–239 (2020)
4. Lohokare, J., Dani, R., Sontakke, S., Adhao, R.: Scalable tracking system for public buses using IoT technologies. In: 2017 International Conference on Emerging Trends & Innovation, ICT, ICEI 2017, pp. 104–109 (2017)
5. Raj, J.T., Sankar, J.: IoT based smart school bus monitoring and notification system. In: 5th IEEE Region 10 Humanitarian Technology Conference 2017, R10-HTC 2017, pp. 89–92 (2018). https://doi.org/10.1109/R10-HTC.2017.8288913
6. Spyropoulou, I.: Impact of public transport strikes on the road network: the case of Athens. Transp. Res. Part A: Policy Pract. **132**, 651–665 (2020)
7. de Regt, R., von Ferber, C., Holovatch, Y., Lebovka, M.: Public transportation in Great Britain viewed as a complex network. Transportmetrica A: Transp. Sci. **15**(2), 722–748 (2019)
8. Lusikka, T., Kinnunen, T.K., Kostiainen, J.: Public transport innovation platform boosting intelligent transport system value chains. Util. Policy **62**, 100998 (2020)
9. Munizaga, M.A., Palma, C.: Estimation of a disaggregate multimodal public transport origin-destination matrix from passive smartcard data from Santiago, Chile. Transp. Res. Part C: Emerg. Technol. **24**, 9–18 (2012)
10. Perez, R., Vásquez, C., Viloria, A.: An intelligent strategy for faults location in distribution networks with distributed generation. J. Intell. Fuzzy Syst. **36**(2), 1627–1637 (2019)
11. Liu, Y., Cheng, T.: Understanding public transit patterns with open geodemographics to facilitate public transport planning. Transportmetrica A: Transp. Sci. **16**(1), 76–103 (2020)
12. Petersen, N.C., Rodrigues, F., Pereira, F.C.: Multi-output bus travel time prediction with convolutional LSTM neural network. Expert Syst. Appl. **120**, 426–435 (2019)
13. Viloria, A., Robayo, P.V.: Virtual network level of application composed IP networks connected with systems-(NETS peer-to-peer). Indian J. Sci. Technol. **9**, 46 (2016)
14. Viloria, A., Acuña, G.C., Franco, D.J.A., Hernández-Palma, H., Fuentes, J.P., Rambal, E.P.: Integration of data mining techniques to PostgreSQL database manager system. Procedia Comput. Sci. **155**, 575–580 (2019)
15. Tomasiello, D.B., Giannotti, M., Arbex, R., Davis, C.: Multi-temporal transport network models for accessibility studies. Trans. GIS **23**(2), 203–223 (2019)
16. Muro, F.J.M.: Planificación y optimización de redes ópticas en el Internet del futuro (Doctoral dissertation, Universidad Politécnica de Cartagena) (2019)
17. Saif, M.A., Zefreh, M.M., Torok, A.: Public transport accessibility: a literature review. Period. Polytech. Transp. Eng. **47**(1), 36–43 (2019)
18. Gatta, V., Marcucci, E., Nigro, M., Serafini, S.: Sustainable urban freight transport adopting public transport-based crowdshipping for B2C deliveries. Eur. Transp. Res. Rev. **11**(1), 13 (2019)
19. Cervantes, M.E.S., García, L.D.J.M.: El uso de modelos de redes y modelos de transporte para la optimización y reducción de tiempos y costos de transporte en la Comercializadora Gonac S. A de CV/The use of network models and transport models for the optimization and reduction of transport times and costs in the Comercializadora Gonac S. A de CV. RICEA Revista Iberoamericana de Contaduría, Economía y Administración **8**(15), 29–53 (2019)

20. Allulli, L., Italiano, G.F., Santaroni, F.: Exploiting GPS data in public transport journey planners. In: Gudmundsson, J., Katajainen, J. (eds.) SEA 2014. LNCS, vol. 8504, pp. 295–306. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-07959-2_25
21. Shen, L., Stopher, P.R.: Review of GPS travel survey and GPS data-processing methods. Transp. Rev. **34**(3), 316–334 (2014)
22. Schüssler, N., Axhausen, K.W.: Identifying trips and activities and their characteristics from GPS raw data without further information. Arbeitsberichte Verkehrs-und Raumplanung **502**, 1–29 (2008)
23. Edwards, D., Griffin, T.: Understanding tourists' spatial behaviour: GPS tracking as an aid to sustainable destination management. J. Sustain. Tour. **21**(4), 580–595 (2013)
24. Schuessler, N., Axhausen, K.W.: Map-matching of GPS traces on high-resolution navigation networks using the multiple hypothesis technique (MHT). Arbeitsberichte Verkehrs-und Raumplanung **568**, 1–22 (2009)
25. Wang, Y., Ram, S., Currim, F., Dantas, E., Sabóia, L.A.: A big data approach for smart transportation management on bus network. In: 2016 IEEE International Smart Cities Conference (ISC2), pp. 1–6. IEEE (2016)
26. Gonzalez, P., et al.: Automating mode detection using neural networks and assisted GPS data collected using GPS-enabled mobile phones. In: 15th World Congress on Intelligent Transportation Systems, pp. 16–20 (2008)
27. Ma, X., Yu, H., Wang, Y., Wang, Y.: Large-scale transportation network congestion evolution prediction using deep learning theory. PLoS ONE **10**(3), e0119044 (2015)
28. Chaix, B., et al.: Active transportation and public transportation use to achieve physical activity recommendations? A combined GPS, accelerometer, and mobility survey study. Int. J. Behav. Nutr. Phys. Act. **11**(1), 124 (2014)
29. Strutu, M., Stamatescu, G., Popescu, D.: A mobile sensor network based road surface monitoring system. In: 2013 17th International Conference on System Theory, Control and Computing (ICSTCC), pp. 630–634. IEEE (2013)
30. Dabiri, S., Heaslip, K.: Inferring transportation modes from GPS trajectories using a convolutional neural network. Transp. Res. Part C: Emerg. Technol. **86**, 360–371 (2018)
31. Harrison, F., Burgoine, T., Corder, K., van Sluijs, E.M., Jones, A.: How well do modelled routes to school record the environments children are exposed to?: a cross-sectional comparison of GIS-modelled and GPS-measured routes to school. Int. J. Health Geogr. **13**(1), 5 (2014)
32. Anderson, M.K., Rasmussen, T.K.: Matching observed public route choice data to a GIS network. In: Selected Proceedings from the Annual Transport Conference at Aalborg University, vol. 5, no. 1 (2010)
33. Badland, H.M., Duncan, M.J., Oliver, M., Duncan, J.S., Mavoa, S.: Examining commute routes: applications of GIS and GPS technology. Environ. Health Prev. Med. **15**(5), 327 (2010)
34. Stopher, P., FitzGerald, C., Xu, M.: Assessing the accuracy of the Sydney household travel survey with GPS. Transportation **34**(6), 723–741 (2007)
35. Gallet, M., Massier, T., Hamacher, T.: Estimation of the energy demand of electric buses based on real-world data for large-scale public transport networks. Appl. Energy **230**, 344–356 (2018)
36. Holleczek, T., Yu, L., Lee, J.K., Senn, O., Ratti, C., Jaillet, P.: Detecting weak public transport connections from cellphone and public transport data. In: Proceedings of the 2014 International Conference on Big Data Science and Computing, pp. 1–8 (2014)
37. Wang, H., Calabrese, F., Di Lorenzo, G., Ratti, C.: Transportation mode inference from anonymized and aggregated mobile phone call detail records. In: 13th International IEEE Conference on Intelligent Transportation Systems, pp. 318–323. IEEE (2010)

38. Chaix, B., et al.: GPS tracking in neighborhood and health studies: a step forward for environmental exposure assessment, a step backward for causal inference? Health Place **21**, 46–51 (2013)
39. Buys, L., Snow, S., van Megen, K., Miller, E.: Transportation behaviours of older adults: an investigation into car dependency in urban Australia. Australas. J. Ageing **31**(3), 181–186 (2012)
40. Gonzalez, P.A., et al.: Automating mode detection for travel behaviour analysis by using global positioning systems-enabled mobile phones and neural networks. IET Intell. Transp. Syst. **4**(1), 37–49 (2010)
41. Arellana, J., de Dios Ortúzar, J., Rizzi, L.I., Zuñiga, F.: Obtaining public transport level-of-service measures using in-vehicle GPS data and freely available GIS web-based tools. In: Mobile Technologies for Activity-Travel Data Collection and Analysis, pp. 25[illegible]–2[illegible]5. IGI Global (2014)
42. Ladha, A., Bhattacharya, P., Chaubey, N., Bodkhe, U.: *IIGPTS*: IoT-based framework for intelligent green public transportation system. In: Singh, P.K., Pawłowski, W., Tanwar, S., Kumar, N., Rodrigues, J.J.P.C., Obaidat, M.S. (eds.) Proceedings of First International Conference on Computing, Communications, and Cyber-Security (IC4S 2019). LNNS, vol. 121, pp. 183–195. Springer, Singapore (2020). https://doi.org/10.1007/978-981-15-3369-3_14