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Document Version
Peer reviewed version

Citation for published version (Harvard):
Thomas, RJ, Easton, J, Preece, J, Samra, M & Nonyelu, F 2022, Developing a 5G-enabled crowd management and passenger navigation solution for post-COVID-19 multi-modal travel. in *World Congress on Railway Research.* World Congress on Railway Research 2022, Birmingham, United Kingdom, 6/06/22.

Link to publication on Research at Birmingham portal

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Developing a 5G-enabled Crowd Management and Passenger Navigation Solution for Post-COVID-19 Multi-Modal Travel

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Abstract

The COVID-19 pandemic has driven a modal shift from public transport means to single-occupancy modes of travel. As national restrictions are lifted, the travelling public returns to using public transport, there is an inherent hesitancy to maintain social distancing. This is a key factor that can dissuade travellers from using more economic modes of transport, as they do not know how crowded the station environments are at the time they wish to travel. Operators deploy crowd management solutions in a reactive fashion, as current data insights only highlight passenger volumes through ticket barriers and not within the wider station complexes. As passengers return to using the rail network, they are looking to travel with confidence, knowing that they can navigate the station environment and make connections without encountering crowds or environments where passenger density may be perceived as too high. This is achieved through real-time routing for passengers, taking into consideration their needs, requirements and accessibility constraints to ensure that all passengers are catered for and that they can travel with confidence. For transportation operators, the provision of passenger flow modelling throughout station complexes supports decision-making to implement appropriate crowd control measures, improving flows through station environments and resolving potential bottlenecks. This paper presents the results of the Travel XR project, leveraging 5G technologies to enable passengers and operators understand crowding in real-time, facilitate seamless connections and support passengers throughout their journey.

Keywords: crowd forecasting; 5G sensing; passenger flow; station navigation.

1. Introduction

Digital technologies have transformed how we navigate spaces, with services such as Google Maps, Waze, and Here now capable of providing seamless door-to-door navigation across multi-modal transportation systems. However, existing platforms fail to work in internal spaces, rendering a portion of the journey down to user decisions. For many users, this decision making becomes a burden, especially to those unfamiliar to the interior space. This includes passengers with accessibility issues, and for those concerned of social distancing regulations, common in the COVID-19 era [1].

Furthermore, then issue of passenger accessibility remains at the forefront of challenges to overcome in the field of passenger experience. The UK government have pledged to has pledged to make "rail more accessible and inclusive for all who want to travel" , with accompanying programs such as the National Strategy to Boost Accessibility for Disabled Passengers [2] and Access for All [3] paving the way towards accessible stations.

TravelXR seeks to become the first project to tackle these issues of routing users through interior spaces. To accomplish this, we look towards sensing devices backed 5G technologies, utilising the higher bandwidth to achieve greater data throughput. By utilising this data, we can build an algorithm to route the passengers due to personal requirements and crowd densities, whilst using the data to build a crowd forecasting model.

2. Managing Crowds and Navigation at Rail Stations

This section presents an overview of the TravelXR solution. Specifically, we describe how it resolves challenges with existing solutions, and address critical gaps that affect passenger confidence to travel. We developed the framework such that it can scale to the transport network in different cities and countries. From collecting passenger density data at one location, the TravelXR framework brings together real-time transit data, real-time and forecasted passenger density counts, and station and interchange navigation to the passenger, putting the passenger in control of their journeys.

2.1 Limitations with Existing Solutions

As previously identified, solutions such as Google Maps, Apple Maps and Here provide point-to-point navigation solutions to passengers, and, depending on the level of integration and partnership with local transport authorities, may be able to support the door-to-door navigation experience using the public transport network.

Where automotive solutions now can forecast and show real-time congestion on routes, there is no such equivalent for the public transport network, where crowding of services and the station environment are not presented to the passenger. Where services attempt to show crowding of particular services, this is, at best limited, as it predicts service loading by the number of queries of that service, and prompting a user to confirm whether they are on that service. Further, many of these navigation solutions lack the ability to account for the accessibility needs of the passenger (e.g., reduced mobility or unfamiliarity with the local language), which, coupled with a lack of navigation capability within stations (i.e., from the street to the train doors), this can make for a distressing environment to travel. Whilst the latter issues have not changed due to the COVID-19 pandemic, the former concern of crowding in static environments has become a critical concern for many passengers. Passengers look for ways to maintain social distancing, where operators are reactive to crowding, often when it is too late. A proactive solution, therefore, is needed, to manage crowd density, deploy interventions, and improve the passenger experience in these environments.

2.2 The TravelXR Framework

The TravelXR framework addresses these key challenges that influence passenger experience, accessibility and modal choices when travelling. By taking a data-driven approach, we achieve two key outcomes:

- Putting the passenger at the heart of their journey, empowering them to make their own choices, and promoting multi-modal journeys through a connected data platform.
- Enabling transport operators to gain insights into how they can improve the passenger experience, passenger flows through stations, and manage emergent risks (e.g., sporting events).

Figure 1 shows the generic architecture of the TravelXR framework. A key enabler to monitoring passenger density in station environments is through the use of 5G. Video sensors deployed across the static station environment (e.g., in corridors, platforms and waiting areas) capture raw video data which is streamed to a cloud service, which processes this video data, determines the density across a pre-defined station grid, and updates the current density in a time-series database. Previously, the video sensors would be required to carry out processing at the edge, increasing deployment cost, maintenance complexity and limits the opportunity to continuously improve the service. With the deployment of commercial 5G solutions, the processing can be offloaded to the cloud with no performance impact, meaning that one system is updated, compared to a full estate of assets deployed in the field.

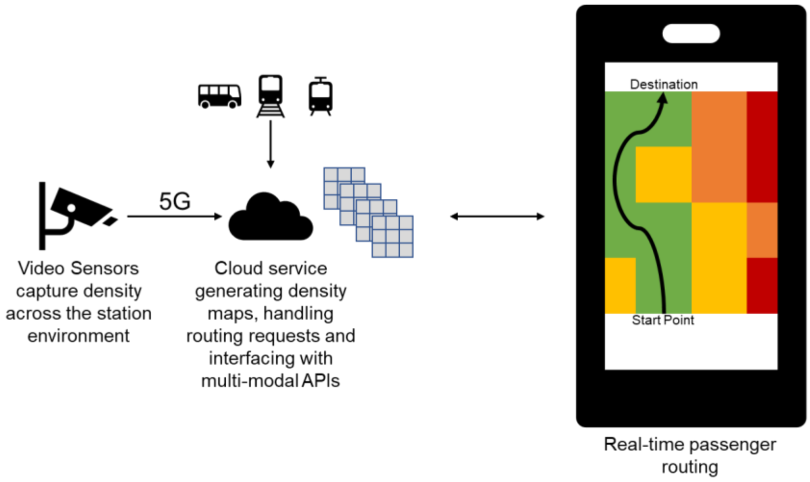

Figure 1: The Travel XR System Architecture

Figure 2 illustrates the underlying process of the TravelXR framework, which operates in four distinct stages: *Data Gathering*, which establishes the point-cloud data of the station; *Data Preparation*, which annotates and converts the point-cloud data into a suitable format for the Routing Engine; *Routing Engine Bootstrap*, which imports the converted data and constructs the data structures used to track density information and compute suitable routes; and the *Intrastation Routing Algorithm*, which find the optimal route based upon Routing Engine parameters. The following sections provide a high-level overview of the process; for a detailed explanation of the mathematics and computation, please refer to Preece et al [4].

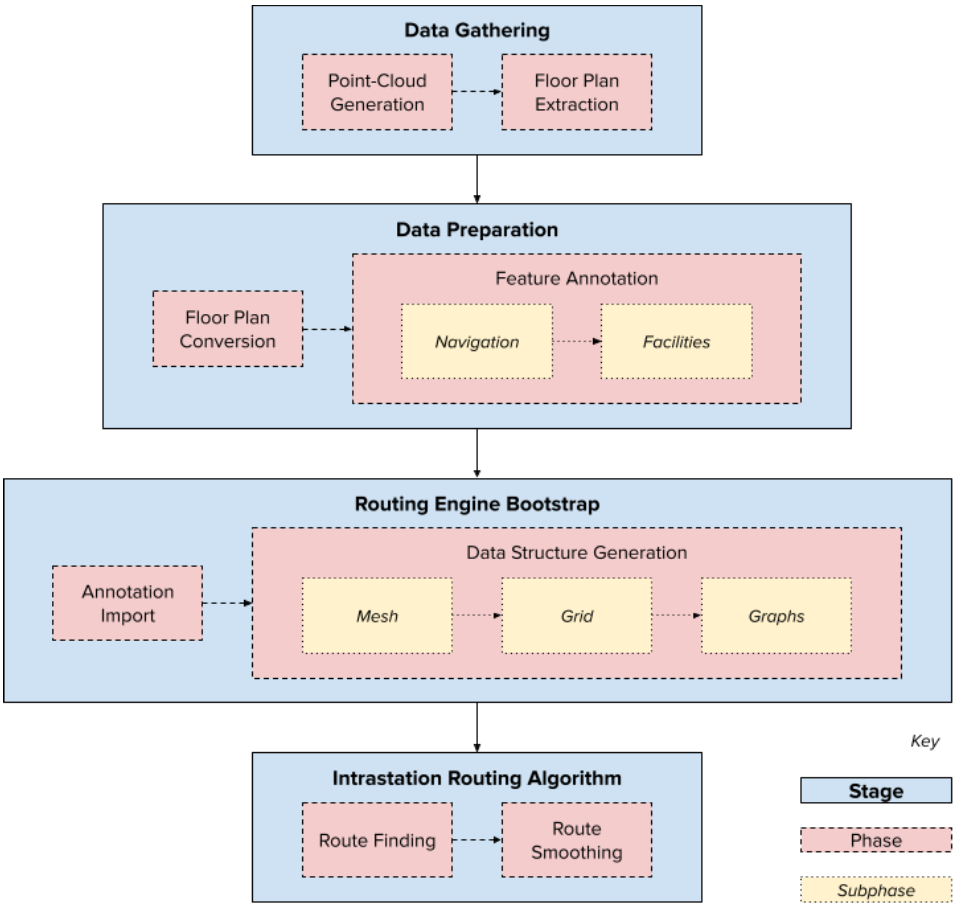

Figure 2: The TravelXR framework process.

2.2.1 Data Gathering

The Data Gathering stage consists of two phases: *Point-Cloud Generation* and *Floor Plan Extraction*. Within the former, a one-off exercise using LiDAR and Matterport establishes a 3D point-cloud of the station. This point-cloud has two purposes. The first is to visualise the station during the augmented reality routing on the mobile app. The second is to extract the 2D floor plan, which the latter phase handles. To demonstrate this technology, we captured a point-cloud of Smethwick Galton Bridge station. Figure 3 illustrates the point-cloud from a dollhouse view.

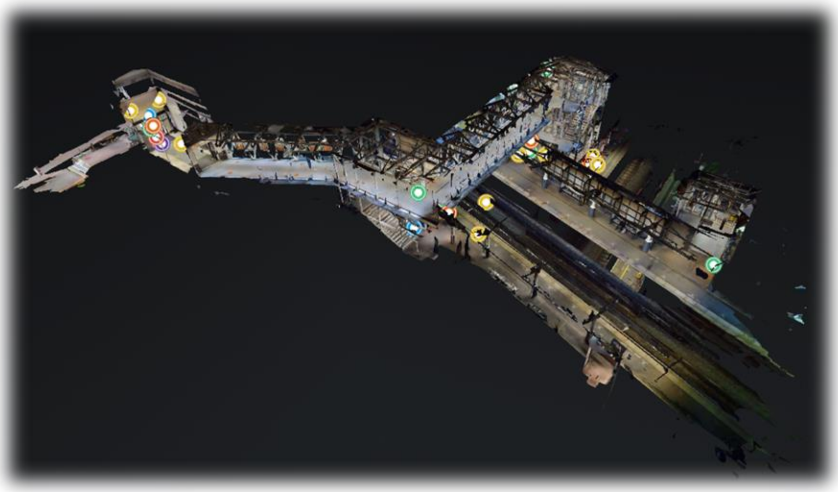

Figure 3: Dollhouse view of the point-cloud of Smethwick Galton Bridge (SGB) station.

2.2.2 Data Preparation

The Data Preparation stage consists of two phases. Firstly, it converts the Portable Document Format (PDF) floorplans extracted during the Data Gathering stage to a suitable format. In this instance, the framework converts to a Scalable Vector Graphic (SVG) format. We selected this format for two reasons; firstly, as it retains the geometry and dimensions of the floor plan, and secondly, as it allows annotating the floor plan to indicate the properties of various parts of the station. The *Feature Annotation* phase provides the opportunity to do this, whereby we annotate two categories of station feature; *Navigation* and *Facilities*.

Navigation annotations mark the navigable areas within the station, split into labelled zones. (For example, Platform 1, Ticket Hall, etc.) Facilities mark points-of-interest within the station. For example, the vertical transportations (stairs and lifts) and amenities (ticket machines, toilets), that passengers may seek to visit as part of their journey through the stations.

2.2.3 Routing Engine Bootstrap

The Routing Engine Bootstrap stage consists of two phases: *Annotation Import* and *Data Structure Generation.* The Annotation Import phase ingests an SVG file to import the geometry of the station. The Data Structure Generation phase uses this imported data to construct various abstracted data structures suited for real-time routing and crowd density information. There are three such data structures: the *Mesh*, the *Grid*, and the *Graph*.

The *Mesh* structure triangulates the navigable areas of the station, splitting the areas into triangles. This methodology is inspired by video-games and enables a more accurate representation of stations than grids. The *Grid* structure is a two-dimensional grid that overlays the station. Each grid cell stores the crowd density information of the section of station the cell overlays. The *Graph* structure is constructed of vertices and edges. The vertices represent information about the mesh elements, whilst the edges represent information about the neighbouring elements.

Figure 4 illustrates the mesh structure generated for the levels at Smethwick Galton bridge.

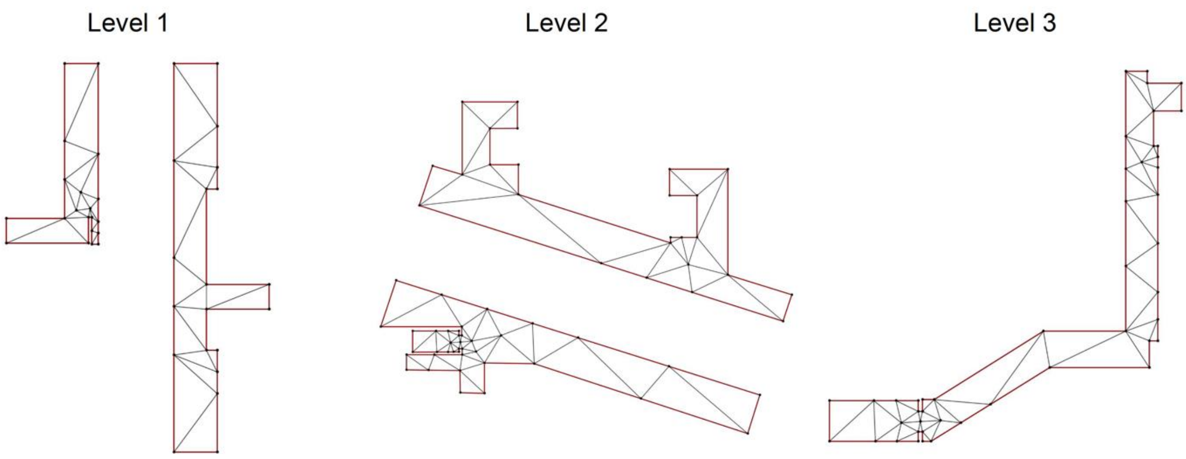

Figure 4: Triangulation produces a mesh for each level of Smethwick Galton Bridge station.

2.2.4 Intrastation Routing Engine

The Intrastation Routing Algorithm determines the optimal path between two or more points within the station, based upon the distance, the crowd density, and accessibility factors. The *Route Finding* phase utilises the graph data structure to achieve this, performing the A* path-finding algorithm to return the shortest path of nodes subject to the aforementioned factors. This node-based path is converted to a geometric format, specifying the coordinates of the nodes traversed, and when vertical transportation facilities are used. The *Route Smoothing* phase optimises this geometric route for real-life usage within the station environment, by converting the 'jagged' line into a smoother one.

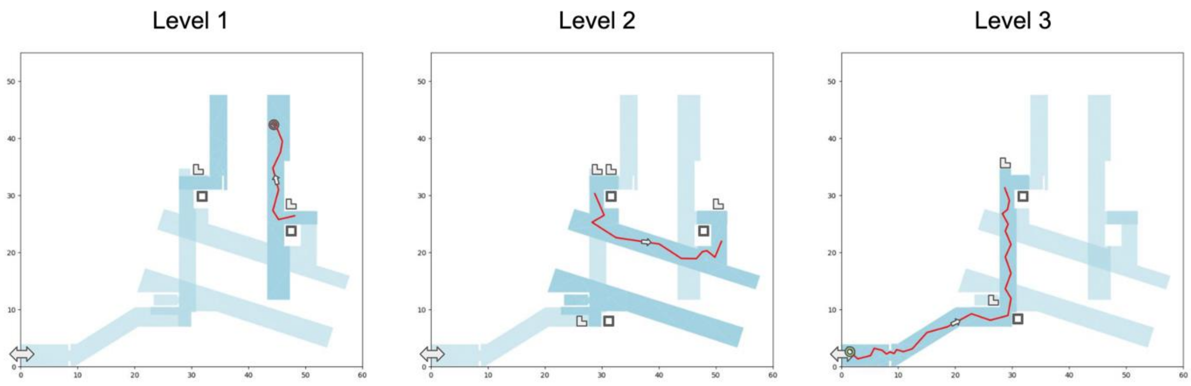

Figure 5: An example route within Smethwick Galton Bridge.

2.3 Results and Discussion

The TravelXR framework is an initial step towards the key outcomes we propose in Section 2.2. By putting the passenger at the core of the project, we have built a framework that enables improved decision making and makes for a more pleasurable experience when travelling through stations. A significant result of this work is the ability to find the optimal route based upon crowd density factors. This enables a process like that of Google Maps' traffic system, whereby users are directed via alternative routes that have lower levels of traffic. This has the advantage of alleviating the strain on the affected areas and provides the user with a quicker route, based upon their preferences and accessibility requirements. For example, if there are two footbridges within a station, and one bridge is crowded, the route will opt for the alternative bridge, even if this is a longer distance in total. Furthermore, the Routing Engine utilises principles from other industries to generate the route efficiently, using real-time crowd density data stored within the grid. An additional benefit is that station operators are able to work proactively towards crowd management through the new data-driven insights, highlighting potential conflicts and supporting real-time decision making.

Despite the positive contributions of this research, it has not been without drawbacks. While the transition to 5G to shift computation into the cloud has significant benefits in whole-lifecycle cost of a deployed solution, the deployment and exploitation of 5G, especially in station environments, has remained a limiting factor in the types of environment in which the TravelXR framework can be deployed. Within the UK, 5G deployments have primarily targeted residential and city spaces, where station environments present a challenge in 5G deployments (especially for those in underground/built-up environments. Another aspect for consideration is that a number of key benefits that 5G provides (e.g. private networking and quality of service) depends on specific 5G releases being supported and enabled. Finally, strong collaboration with the station operator and supply chain is essential – whilst 'off-the-shelf' equipment is currently not readily available on the market, engagement with stakeholders to ensure rapid installation, deployment and certification throughout is important.

3. Conclusion

This paper has presented a novel routing algorithm that enables passenger routing within an interior space. The algorithm itself exists within a framework that utilises 5G in order to provide a high data bandwidth, removing the need for legacy networks that rely upon WiFi.

Initial results have proved successful, demonstrating a product that puts passengers at the heart of the decision making. We intend to continue developing the TravelXR in two areas: firstly, by making alterations to the underlying mechanics to achieve greater computational efficiency; and secondly, by testing the framework in new locations.

Acknowledgment

Funding for this paper was provided by West Midlands 5G (WM5G) via the Travel XR project.

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