Developing a Sustainable and Transferable Visitor Information System 2.0 with the Internet of Things - A Prototype

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***Abstract*— In response to the COVID-19 pandemic, there is a growing need for accurate information about the real-time flow of visitors in public buildings, such as schools or university campuses. Conventional monitoring methods, including entrance checks and wide-area cameras, face challenges in terms of technical complexity, public acceptance, and privacy concerns. This paper proposes an alternative solution based on Internet of Things (IoT) sensors to establish a visitor information system. The system leverages the concepts of smart city and smart campus design to create a more intelligent, connected environment. The system uses smartphones, wearable devices, and low-cost sensors to collect and transmit data packets via Wi-Fi or Bluetooth. The received Signal Strength Indicator (RSSI) is used to draw conclusions about the distance between the transmitter and receiver, enabling the system to locate visitors. Thus, this paper reflects the growing use of assistive applications in IoT scenarios in terms of spatial orientation systems, as well as for smart management systems.**

Keywords-IoT-based solution; smart campus; visitor information system; low-cost sensors; real-time information

I. Introduction

Information about real-time visitors and circulation in public buildings, such as administrative or school buildings, has become increasingly important since the COVID19 pandemic. However, especially for those premises that are larger, monitoring by controlling visitors at building entrances is insufficient to obtain reliable information on how visitors are allocated. Implementation by area-wide cameras is not considered to be effective, not only because of the high technical effort involved, but also due to acceptance problems and possible infringements of personal rights.

The presented approach for a visitor information system is different, as it is based on the use of connected IoT (Internet of Things) sensors. It incorporates concepts of smart city and smart campus design.

Urbanization has resulted in large populations gathering in metropolitan areas, requiring a smart management solution for issues, such as traffic, pollution, energy, waste, and security. In this sense, a campus can be considered a miniature version of a smart city. In terms of integrating technology and communication, this brings both new opportunities, as well as challenges [1].

In order to provide fine-grained, but privacy-compliant position data for a visitor information system, not only established devices, such as smartphones or tablets are used, but also the growing number of so-called "wearables" (e.g., smartwatches, fitness bracelets, bluetooth headphones). These devices are capable of communicating with one-another and exchanging information through standardized information technologies, often generating an enormous but unused amount of data.

Before the components of the prototype are outlined in Section III, the following Section II introduces into sensors used. Section IV explains the web-dashboard in which the collected data is brought together. The paper ends in Section V with a conclusion and an outlook regarding future potentials.

II. Using Sensors to Capture Individuals

Various methods exist for measuring the number of individuals at a specific point in a building (e.g., entrance), room, or area (e.g., hallway). Wahl, Milenkovic, Amft [2], and Tsou et al. [3] used Passive Infrared Light (PIR) sensors and motion detectors, respectively, to count people and detect visitor flows in buildings. However, if there is not a sufficient number of motion sensors, this method will not provide reliable results for estimating on how many visitors are present.

The smartphones and wearables mentioned above, by contrast, communicate via Bluetooth or Wi-Fi to each other or to available Wi-Fi access points, transmitting data packets to the area around them. Conversely, these data packets can also be used to capture people in close proximity. The received Signal Strength Indicator (RSSI) is an essential factor in detecting communication with devices nearby. Narvaez and Guerra [4], for example, have already shown that this can be used in order to maintain safety distances. The RSSI enables conclusions to be drawn about the distance between the transmitter and receiver. In combination, Bluetooth and Wi-Fi can also be used to locate people [5][6][7].

Single-Board Computers (SBCs) equipped with low-cost sensors can be utilized to collect these data packets. In this case, a Raspberry Pi 4 Model B with 8 GB RAM is used as the SBC. The sensors include Wireless Local Area Network (Wi-Fi) and Bluetooth (BLE) modules, and a PIR motion detector and a second Wi-Fi adapter. One Wi-Fi adapter is required for communication with the data link layer, while the second adapter is set into monitor mode. The sensor

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setup also takes into account information from the indoor Wi-Fi or its controller interface.

III. PROTOTYPE OF THE VISITOR INFORMATION SYSTEM

The prototype was developed at Mainz University of Applied Science and consists of three components in its basic design: Client, Web Service(s) and Sensors. The detailed structure – see Figure 1 - with its individual components is shown below. The sensors used are either the SBCs outlined above or the controller interface of the indoor Wi-Fi network, which provides information about connected and logged-in devices per access point. A total of just over 180 indoor and outdoor access points are available at Mainz University of Applied Sciences with its two campuses and one external building.

Data management and storage of the values collected is handled via the Open Geospatial Consortium SensorThings API *(*OGC SensorThings API) [8]. The implementation of this standard is based on the Fraunhofer Open Source SensorThings API Server (FROST), which is freely available from the Fraunhofer IOSB. The background maps of the buildings, floors or rooms required in the web dashboard are integrated according to the OGC Web Map Service [9] and OGC Web Feature Service specifications [10]. The publicly available GeoServer of the non-profit Open Source Geospatial Foundation organization (OSGeo) is used for implementation. The geodata originates from the OpenStreetMap project (OSM) and was extended by the university's own floor plans.

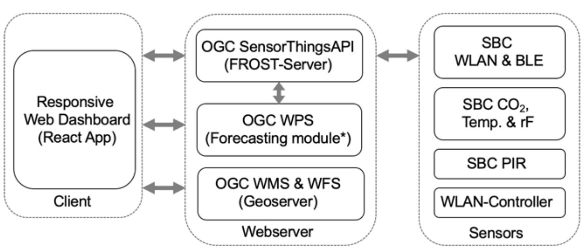

Figure 1. Architecture of the visitor information system.

Furthermore, the information system is designed in order to generate the necessary knowledge on the basis of the differently collected measured values in an effort to be able to determine future projections on visitor numbers and allocation, as well as movement flows. This will be realized in a forecasting module - see Figure 1 - which has not yet been finalized. It is planned to implement a process via the OGC Web Processing specification [11], which recognizes patterns from the input data by applying machine learning methods in order to draw conclusions from the actual to its future utilization of a building's capacity. This allows a smart building and visitor monitoring to be carried out.

IV. WEB-DASHBOARD

The data collected from the sensors and analysis results are combined in a web dashboard – see Figure 2 - for users (e.g., university management or students orienting themselves in the building).

Figure 2. Web-Dashboard of the visitor information system.

Unlike existing systems, not only static but also real-time information for one or more buildings can be displayed. In addition to the number of people present in the buildings (or floors or rooms), the visualization of flows or hot spots is an alternative. Visitors can thus call up information about building or room occupancy in advance or, if necessary, be automatically notified if the maximum number of people is exceeded, as long as there is an integration into the existing systems.

V. CONCLUSION

To ensure the sustainability of the presented prototype in terms of technology, the implementation was carried out using open source software, open data and open standards and data formats. This has resulted in a modular and open-source spatial orientation system for the use case of a visitor information system that can be widely shared and customized by other universities, small and medium-sized enterprises, and public institutions. Thus, a technological transferability is made rather easy to achieve. By adding low-cost sensors, the system could be supplemented with further metrics, such as air quality or temperature. For example, this allows the monitoring of hygiene concepts, but also provides relevant information for other issues.

Additionally, the implementation outlined here is intended to contribute to the discussion of subcomponents of a smart campus in terms of the expected multiplication of sensors, devices, and terminals. Considering future developments, it is possible to argue that the ability to combine smart technologies with physical infrastructures to improve services, decision-making, and efficiency of public buildings is an emerging trend [12].

A concrete extension would be, for example, the use of modern machine learning techniques based on the various sensor inputs as part of the aforementioned forecasting module. This can be used to predict future room occupancy in order to support the management of visitor flows and reservations. Roussel et al. shows that especially the use of multiple sensor sources - as also proposed in this publication - is promising for these use cases [13].

In this context, the transition to an a more integrated digital building or a smart campus will rely significantly on Information and Communication Technology (ICT) and IoT infrastructures.

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