

In_sight: Using Existing Wi-Fi networks to Provide Information on Occupancy and Exploitation of Educational Facilities using at Delft University of Technology.

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Extended Abstract

The distribution of people in buildings, the occupancy of lecture-, work- and study places and the accessibility of facilities are essential information at university campuses who have to cope with limited and even shrinking budgets and huge, rising real estate costs. Only little insight is gained in both occupancy and movement patterns with traditional counting techniques and user-based questionnaires. Management teams state that rooms and facilities are hardly used, though staff and students complain about overcrowded facilities and limited flexibility. Actual and accurate data on a 24/7 scale with high-granularity is missing.

In general Facility- and Asset Management lacks efficient methods for real-time, comprehensive and high-granularity information of location, capacity and use of tangible and intangible assets. Asset management could benefit from more detailed, more accurate and longitudinal data on assets, providing more insight into efficiency and effectiveness on different levels of scale through time.

Existing technologies could provide a platform delivering those required insights. Navigation- and communication technologies such as GNSS, Wi-Fi, Bluetooth, RFID can be used to 'locate' users, estimate intensities and reveal patterns of movement and patterns of use. For Asset management indoor localisation is essential.



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Technology

Wi-Fi is a widespread communication technology used by electronic devices to connect to a Wireless Local Area Network (WLAN) base station or to connect ad-hoc directly between devices. Wi-Fi may be used to obtain internet access, to exchange data, to access an intranet or for sending data to devices like a printer. Today a large range of electronic devices is capable of using Wi-Fi including computers, laptops, smart-phones, tablets, digital cameras, audio players, printers, (video-)game consoles and sensors. Wi-Fi networks are offered in companies, private homes, cities and (semi) public spaces and also at university campuses. Eduroam is a worldwide standard for University Campus WLAN networks.

Wi-Fi cannot only be used as a technology to transfer digital data wirelessly, but also as a tool for Facility and Asset management or as a platform for location-based services (LBS): Wi-Fi Access Points (AP's) can be used as sensors to collect information of connecting devices, delivering dashboards with temporal data on intensity of devices based on the number of unique devices detected and patterns of movement based on detections of the same device at different access points.

Wi-Fi 'user' data can be obtained in two ways: (a) by scanners or (b) by the network.

ad. (a) Wi-Fi scanners register connection attempts from devices within range. Every enabled Wi-Fi device is continuously searching for Wi-Fi access points and therefore broadcasting its unique media access control (MAC) address. No connection between device and scanner is made and no data is exchanged. Scanners can be other Wi-Fi devices as well as (modified) Access Points.

ad. (b) When using the network Access Points the real -established-connections are used. Either the connection start- and endtime is logged, or the system regularly scans for connected devices. At TU Delft a dump of devices connected to Eduroam Access Points is made every five minutes for the whole campus for network management purposes. Personal information such as MAC address and network ID are immediately encrypted (hashed). The research projects described in this abstract use this anonymised data from the Eduroam network for spatio-temporal analysis. Only staff and students from the university connecting to the eduroam Wi-Fi network are incorporated in this research.

In the Geomatics Synthesis Project Wi-Fi is used in a campus-wide experiment to monitor flows and occupation patterns at the TU Delft Campus. Students worked for two months on three parallel projects :

(1) extracting presence of people at specific places;

- (2) unravelling patterns of movement within buildings and between buildings on the campus; and
- (3) identifying activities and irregular use based on Wi-Fi data.

In all projects, the same dataset is used. All project also had to cover four cross-cutting topics: Privacy, Validity and Accuracy, Representativeness and reflection on the system of Access points (data collection).

Project 1: In_sight: Using existing WiFi networks to provide information on occupancy and exploitation of educational facilities using at Delft University of Technology.

The goal of the first project is to estimate the occupation at a location at a certain time. The research question for this team was: *To what extent can the alignment of occupation and exploitation of educational facilities on different scales be indicated through Wi-Fi monitoring?*

Hypothesis.

The hypothesis is that every person has a certain number of devices and that only a limited number of devices is connected to the Wi-Fi. The location should be defined according to the map. This potentially interferes with the distribution and coverage of the Wi-Fi Access Points. The group, therefore, formulated the following hypothesis:

Hypothesis: The alignment of occupation and exploitation of educational facilities can be indicated through Wi-Fi monitoring on all Spatial Levels with adequate reliability.

The approach is to understand the way the Wi-Fi collects and stores information. Wi-Fi does not measure the number of people but the number of connected devices which relates to a connected device per person factor to the number of people. The number of devices represents the presence of people at that place at that time for a certain duration based on an average number of devices per person. This factor needs to be calculated and calibrated. According to earlier research, this factor will vary depending to the kind of activity (use).

Methodology

In general, the methodology used for the project was based on Lemmens (1991): This method distinguishes between data capture, storage, analysis and communication. The data is captured by ICT of TU Delft. After that, the data is transferred to a specific server for the project and stored. Contents wise, the first step in the project was to make a distinction between static and dynamic devices. Static devices such as printers and Wi-Fi extenders should be identified, as well as devices (moving) outside the building. A next challenge is the validation of the logs: Wi-Fi does not automatically connect

to the nearest or strongest Access Point. Measurements have to be done and algorithms have to be developed to correct the 'location'. Theoretical research, tests and multiple case studies were carried out to monitor the quality of the data and validate the data. For example, for a specific area counting cameras and manual counting were issued to validate the results.

Five different scales were defined for the project: (SLO) whole campus, (SL1) building-level or facility, (SL2) floor and (SL3) Access Point and (SL4) room.

Research

The data was provided by ICT of TU Delft to the project on a daily basis (post-processing only). The data was then processed and a dashboard was made for visualisation and interaction at the different scales. A limitation is that only data is included of devices of staff and students connected to Eduroam, no devices of guest, devices connected to other network or devices not connected at all.

Conclusions

Validity and Accuracy: Based on the outcomes the hypothesis could not be confirmed and was rejected. Only on SLO and SL1 the outcomes were reliable. For SL2 (floor), SL3 (AP) and SL4 (room) the system was not reliable enough.

System of AP's: The AP's cover multiple rooms and deliver differences in propagation, which makes scaling to more detailed levels inaccurate. The conclusion is that better algorithms need to be developed to control the number of devices in a room or on a specific floor, i.e. to locally estimate the occupancy rate.

Representativeness: A limitation for the research is the way the data is collected and the data provided by ICT. This limits the representativeness of the data. Besides eduroam users might switch off Wi-Fi or opt out.

Privacy: No direct issues for privacy were detected. Nevertheless, people should be able to opt-out and if specific information, i.e. a schedule is know, 'devices' are retraceable. This conflicts with EU regulations.

Recommendation

Improve the AP system - more consistent naming and addressing of AP's; The suggestions is also to keep the broadcasting level steady to improve the reliability of the collected data.

Improve representativeness by extending beyond Eduroam not only covering connected staff and students;

Advised is to include the visitor network as well.

Extend with Wi-Fi with LAN usage to map position of Wi-Fi devices based on LAN access and include people who switch to LAN.

Acknowledgement

This project is part of the Geomatics Synthesis Project (GEO1101) 'Rhythm of the Campus' which was carried out in Spring 2016. The data is collected by ICT of TU Delft and made available for the project. In a later stage – if no obstructions are encountered – the data will be made open-source.

The course was initiated and coordinated by Stefan van der Spek, director Geomatics for the Built Environment and Edward Verbree, section GIS-technology. Edward Verbree, Martijn Meijers and Wilko Quak mentored the three project teams. Bart Valks and Iljoesja Berdowski represented Facility Management of TU Delft. Alexandra den Heijer and Ruud Binnenkamp (Management in the Built Environment) assisted to the overall scope of the project.

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