Folia Oeconomica
Acta Universitatis Lodziensis
ISSN 0208-6018 e-ISSN 2353-7663

https://www.czasopisma.uni.lodz.pl/foe/
3(372) 2025
DOI: https://doi.org/10.18778/0208-6018.372.03

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Improving Information Services in Smart-City Areas by Means of Modern Technologies

Abstract: The aim of the article is, firstly, to show the evolution of information services in public space in connection with the emergence of new technologies. Secondly, the article proposes new ideas for providing selected information services using the latest technological and organisational solutions. The article aims to show that new technologies not only significantly improve the flow of information but also become the basis for new services in smart spaces. As a leading example, virtual announcement columns, the task of which is to facilitate access to local information depending on a given place (location) and time, are described.

Funding information: Poznan University of Economics and Business, Department of Information Technology, Poznan, Poland
The percentage share of the author in the preparation of the work is: J.R. – 50.00%, J.G. – 50.00%.
Declaration regarding the use of GAI tools: Not used.
Conflicts of interests: None.
Ethical considerations: The Authors assure of no violations of publication ethics and take full responsibility for the content of the publication.
Received: 2024-09-30. Revised: 2025-04-16. Accepted: 2025-10-14

These boards are the equivalent of traditional places for posting local announcements and messages in paper form. However, the comfort of their use is greater, and thanks to this, their usefulness in public space is also more significant. As a result, the collection of residents' opinions, ad-hoc help for tourists, etc., have been improved. The proposed solutions are based on new technologies, such as Bluetooth location beacons with variable information and QR codes. They are addressed to owners of mobile phones and can be used in public urban areas.

Keywords: geolocation services, smart city, Bluetooth low energy, Internet of Things and Services, intelligent spaces

JEL: L96, O35

1. Introduction

Since the beginning of modern civilisation, people have been interested in accessing information in public places. There have been many solutions for disseminating information: from heralds announcing rulers' decisions in the market square through posters posted on walls, advertising columns, and tram stops covered with notices to shop expositions and signposts. Their evolution throughout history has been determined by technological progress, society's level of education, and the development of services. Recently, 'smart' spaces are being created, filled with services made possible by technology: road information systems (popular 'navigation'), location-based marketing (Bansal, 2023), and personalised notification tools such as location-based services (LBS) (Junglas, Watson, 2008), mobile shopping, social systems with immediate connection between groups of people, etc. These solutions increasingly use new technologies, not only location systems (GPS) but also short-range communication (Bluetooth – Verma, Singh, Kaur, 2015, and Bluetooth Low Energy – Liu, Zhang, Zhou, 2021), radio identification systems (RFID and NFC), automation of character recognition, and graphic codes (QR codes), together with traditional photos, images, advertisement, etc. New services that increasingly deserve to be called 'intelligent' are being created.

As services become popular, consumers' appetite for greater comfort in using them and lower costs, including non-monetary costs (such as time-saving), is also growing. We see a clear need for a more effective flow of information, especially in public spaces that are becoming increasingly filled with 'intelligent' services. The preliminary aim of this article is to show the evolution of information services in public space due to the emergence of new technologies. Secondly, the article proposes a new way of providing certain services using the latest technological and organisational solutions. The proposed methods cover, among others, the idea of virtual advertising columns, which are intended to facilitate access to information depending on a given place (location) and time. These columns are the equivalent of traditional places for posting local advertisements. However, the comfort of using them is much greater; therefore, their usefulness in public spaces is also more significant.

The new technologies and methods for implementing ‘smart’ services in public places have made it possible to substantially improve the traditional ways of disseminating public and private information. Firstly, the smartphone is a ‘must-have’ device for almost anyone and adding new functionality to this device by installing an application costs almost nothing. Secondly, the smartphone offers such new functionalities as a high-quality camera and microphone (bidirectional audio/video communication), a touch screen to interact silently using only fingers, practically unlimited memory and computational power, etc. At the same time, cloud-based servers significantly extend the possibilities of mobile devices. Thus, new proposals for using this ecosystem are continuously observed, including many application areas, public places, and services. The paper proposes a slight, however significant, improvement based on a smartphone/cloud environment to replace some solutions widely used in the past with modern, enhanced equivalents. These are only some examples of the possibilities of the technologies pointed out in the text; however, the proposed improvements are probably quite useful in the city area.

The problem we addressed in our research was organising better/faster/more efficient information flow in a ‘smart’ area using modern technologies and organisational solutions. Our research hypothesis is as follows: modern technologies can improve current organisational solutions by providing more effective information flow. As the first stage of validating the hypothesis in this paper, we propose a set of new systems based on the non-standard application of modern technologies for disseminating information in a city to help some users. The future second stage covers the installation of a testbed and the examination of the behaviour of end-users, both in transparent (questionnaires, manually filled/answered by the users by means of their smartphones and ad-hoc communication) and apparent way (collecting and processing log data on the usage/access to certain elements of the system, inspecting meta-data such as timings and geo-location, etc.). This paper aims to concentrate on the first stage, introducing the possibility of other research teams and city administrators organising a full-size experiment/testbed to validate the hypothesis fully and provide new, possibly valuable ‘smart’ services to city users.

The organisation of the paper is as follows. The second section presents current solutions and technologies for creating ‘smart’ urban spaces and services. The third section develops the idea of ‘virtual advertising columns’ and identifies technologies for its implementation. The fourth and fifth sections present several models of system architectures that make up ‘virtual announcement columns’ and include a comparison with other systems characterised by similar functionality. The last two sections describe examples of scenarios for using the proposed system and some of its extensions, as well as conclusions and suggestions for possible development directions.

2. Current Solutions and Technologies

Citizens in public spaces have always strived to effectively transfer information, both addressed to them (e.g., information from the administration) and generated by them (e.g., announcements about apartment sales). They have helped achieve this goal by changing technology and the organisation of social life. Notification and dissemination of information have always been particularly important in public places, especially in places with many potential recipients, i.e., urban centres and their central points (from the Greek Agora, through the markets of medieval European cities to today's shopping centres). Wherever people lived and gathered, information became the basis of their shared fate. During medieval times, when kings decided to organise citizens' lives, heralds announced their edicts in the market square. We are all familiar with posters posted in public places which are still required by law, e.g., in the case of organising elections. Some people also associate alarm sirens and sound notifications about possible threats with information dissemination. Let us note that the primary restriction of these ways of disseminating information is a one-way flow: from the conventionally called 'administration' to citizens. Over the years, systems that offer the flow of information in the other direction, i.e., from citizens to city authorities (e.g., street surveys), have also appeared. However, this channel has a much lower information capacity. Citizens also began to organise and communicate with each other. Hence, the emergence of advertising columns and paper notices stuck on them and all nearby lampposts as well as public transport stops.

Technological progress, which has undoubtedly facilitated the flow of information in both directions, has had a relatively little impact on the overall purpose and method of information. For example, alarm sirens have been replaced by SMS notifications, which are undoubtedly a more effective and widely accepted way of communication, de facto, however, fulfilling the same function of warning about a possible threat. Paper leaflets with store advertisements, which must be taken out of the mailbox and leafed through, are gradually being replaced by personalised advertisements sent directly to mobile phones. Road signs and information tables are no longer noticed by drivers, who instead follow the voice instructions of the on-board navigation. Even if the range of impact and the comfort of using such services have increased (e.g., drivers receive information about road traffic jams practically in real-time instead of listening to the radio before setting out on a trip), the basis of operation has remained unchanged.

It is worth noting that smartphones are the basis for most 'smart' services. A smartphone is mandatory equipment for almost anyone, from a few-year-old child to the oldest people. This device is of particular interest outside the home – in public places, crowded, with numerous points of interest (from minor, such as the nearest road light, to wide, such as tourist tracks and navigation). Smartphones limit the feeling of 'being lost' and filter out unnecessary information, providing valuable 'intelligent' services suited to current situations, thanks to geo-location possibilities, as well as place and time. Thus, for most people, using the smartphone to access some information/service is natural, and this device is treated as a personal assistant, enhancing (well, sometimes replacing) the individual skills and intelligence of its owner.

Smartphones may be used in two primary ways: apparently and transparently. In the first case, it is up to the user to use this device. For example, the user may scan a QR-code tag or manually enter a URL address to find some information. Mobile payments are another example of apparent interaction, as one is obliged by law to provide a 'gesture of will' to pay in a shop (such as presenting the device to an NFC reader or entering a BLIK code). To achieve this goal, the smartphone must be activated manually before the interaction, whereas transparent interaction is based on detecting some radio transmission in the background. A device is responsible for fetching the radio signal, interpreting it, filtering out some unwanted messages, and finally reacting, mainly by signalling that 'something interesting' happened. What is 'interesting' is priorly declared by the user by installing and parameterising some applications. Also, the user chooses the signalisation method (and time, as the information may be cached for some time to be used later). Consequently, people do not have to pay attention to everything and everywhere; instead, the smartphone provides only the necessary information to avoid information overload.

The 'intelligence' of most of the services is not implemented only on the client (smartphone) side. On the contrary, the functionality of these services is usually achieved by means of a cloud, with the servers running 'anywhere' and answering local needs. As each smartphone is continuously connected to the Internet, there is no problem with accessing any cloud service at any time. Moreover, the access may be bidirectional, not only from the service to the mobile device (such as a WWW page) but also from the mobile (such as recent AI chatbots), both in the form of text and voice/video. Thus, the interaction itself is not a technical problem. The problem is how to start this interaction, i.e., how to obtain some initial data about the service. So, a 'starting point' must exist with the necessary information. The traditional solutions are text-based URL addresses and more advanced QR codes. We may also use some recent technological advances such as Bluetooth communication as well as geo-localisation beacons (Jeon, She, Soonsawad, 2018), GPS (European Space Agency, 2024), and aGPS (Wikipedia, 2024) technologies.

Below, please find some examples of 'smart' services provided in public places by means of smartphones, cloud support, and radio communication, as well as the evolution of such services during recent decades. Let us examine the evolution of one service as an example: the previously mentioned popular car navigation. In times unimaginably old, i.e., in practice during the lifetime of the previous generation, drivers had maps and atlases at their disposal. The more prudent people brought a list of addresses of petrol stations or roadside bars. The map had to be carefully studied before the journey, and the route plan had to be determined in advance. If anything disturbed that plan, unfortunately, it was hard to change it, and, as a result, they had to, e.g., wait in a traffic jam on a motorway. Several years ago, what did drivers do in such a situation? They stopped their cars and started listening to the radio (smartphones had not been invented yet). Someone came up with the idea that radio broadcasts could include messages of particular importance to drivers. Nowadays, the somewhat forgotten Traffic Announcement (TA) system has such a task: to inform about unexpected and sudden events so drivers can quickly decide about a possible detour. The main disadvantage of the TA system is the need to listen to the radio in the car, which is relatively rare today. In addition, the range of an FM transmitter is usually much more extensive than the local traffic flow problem, so messages also reach 'uninterested' people. It is also not possible to transfer information between individual road users, as was the case with the so-called citizen radio (CB-radio), which is no longer commonly used by drivers due to technical limitations and the need to operate the device manually.

Another example of the evolution of an IT system is the usage of road signs. Classic symbols and signposts, used for almost a hundred years, have been replaced by automatic and semi-automatic machines, including systems for automatic recognition of the driving context based on location and time, as well as viewing the surroundings via a camera. However, road signs are still passive (they must be noticed by the driver or the car's onboard computer), and concluding the presence of a given sign based on the vehicle's location (e.g., speed limit) is still quite risky. Systems that consider such 'road maps of signs' are slowly emerging; their primary purpose is to limit vehicle speeds and increase safety. In addition to these solutions, systems inform drivers about the so-called points of interest (POI) (Psyllidis et al., 2022), such as petrol stations, restaurants, toll lines, etc.

Please note that some of the traditional road signs are 'alive.' Some traffic signalling devices update their local state cyclically, e.g., the current colour of the light at an intersection tells pedestrians and drivers whether they should stand and wait or move on. Similarly, a text sign placed on the roadside displays information about the company which is repairing the road and when it will be fully operational. Such information is valid only locally (and depends on time, as the colour may change at any moment) and frequently evolves. Traditionally, this information is provided directly to people in the form of visual and audio signs. However, some people cannot access this information properly. For example, crosspoint lights are useless for blind people or when it is raining/snowing, etc. Thus, a replacement and enhancement of such services is needed. The smartphone is an ideal candidate for this task, as this device may alert about significant state changes and use non-standard communication methods such as voice messages and vibrations. Please note that we also need a local-communication radio channel, as it is impossible to represent the state of all existing traffic signalling devices in a centralised way. Instead, this information must be locally propagated, e.g., by the previously mentioned Bluetooth channel.

Let us look at possible ways of evolution of yet another city information system, i.e., advertising columns. The times when they were used for personal information exchange on local topics (e.g., announcements about renting a room) are slowly becoming a thing of the past. Nowadays, the columns are a permanent marketing presentation next to LED screens and advertising boards at bus stops. We also no longer see 'I provide tutoring' advertisements near schools and universities. However, this does not mean that the need to provide this type of information has disappeared, as people are still looking for apartments and help with learning. The ads on the columns became extremely ineffective since they no longer fulfilled their primary function. The Internet and its search systems have taken over part of this task. However, even if one can find everything on the Internet, it does not mean that they will do it effectively and with little effort. Conversely, using a global tool for local search requires specifying a number of filters, particularly the location of the place of access to the offer (service). It takes time and sometimes requires considerable skills. The question arises whether we cannot return to the traditional function of the advertising column, i.e., transmitting well-defined information related to a specific place between people anonymously. We do not have to use a real column for this purpose; it can be virtually accessible via the smartphone. People could receive automatically filtered offers according to their current phone location, situation, and time. Such columns can be conventionally 'placed' where people gather, waiting for something, e.g., at public transport stops. They can provide information only about services that are available locally, e.g., offers of apartments for rent only in the immediate vicinity or offers of tutoring tailored to the nature of the place (primary school – physics lessons, university – help in economics, etc.), offers of shops in the area, bars, restaurants, etc.

We can expand this idea with the ability to 'citizenly place' a virtual column anywhere, depending on needs. For example, city residents see holes in the sidewalk daily on their way from work and decide to set up a notification column informing about this inconvenience. This way, other random passers-by will see not only the obstacle itself but also notice that someone is already interested in this issue and may want to support the initiative to repair the sidewalk. Finally, this information reaches the administration, and someone plans to repair it. It would be similar to informing about, e.g., dead animals, puddles near the edge of the road that cars often use to splash passing-by pedestrians, cars that park incorrectly, etc.

'Electronic advertisement columns' are not the same as popular marketing posters and displays (Kazoulis, 2024). The latter provide only uni-directional, fixed information targeted to the poster/display owner's business, even if a similar technology is used. One is not able to 'have a discussion' with such advertisement, to comment or update the information (e.g., to provide quickly an opinion on advertised goods and services), to create a 'community' to discuss some aspects of this information, etc. On the contrary, the proposed system is aimed at providing such bidirectional interaction provoked by a local situation (thus usually accidental) and can spark a debate across the local community. The rest of the text describes the technologies and architecture used and provides an example of implementing a city system of virtual advertising columns.

3. Applied Technologies

This section of the article will present technologies enabling the implementation of a system of virtual advertising columns. This concept describes the idea of transmitting information in a modified way compared to traditional advertising columns. Despite physical and functional differences, both forms of mass information have a common feature: the simplicity of installation and, in the case of virtual announcement columns, the relative simplicity of using the technology, which provides much more significant benefits due to the increased efficiency of information transfer. Traditional advertising columns were often located near large crowds of people, e.g., in market areas, in places where trade was conducted, or near the central places of housing estates, i.e., in parks or children's playgrounds. Locating the column in a specific place that met the above-mentioned criteria, also taking into account easy accessibility, was crucial. This facility served as a central information point for the local community. People could post certain information themselves, most often relevant to a given group of recipients or those living in a particular area. This was information of a specific type (e.g., about providing tutoring or about a missing dog with a request to contact the owner if the animal was found). Communication was one-way, which is not necessarily a feature that negatively affects the process of conveying the content. However, information posted in this way often needs to be updated more quickly or it is impossible to introduce new elements to update the content. Progressive obsolescence may mislead potential recipients of the content. It may also make it difficult to provide information on current issues relating to a specific time and group of recipients. It is impossible to manage the information posted there in an aggregated manner, e.g., to delete all outdated advertisements. Often, information to be transmitted through such a channel requires the addition of extra information that becomes important after some time, e.g., information about tutoring could include a change in the price or place of the service provided; in the case of a missing dog, one can add information about the area where it was last seen, etc. In such cases, the question arises of how to improve such information transfer points or replace them with another solution that is not solely a passive point of information transfer between participants of social life. The answer to this question is the idea of virtual advertising columns using technologies included in the broadly understood Internet of Things (Kumar, Tiwari, Zymbler, 2019).

A virtual advertising column is simply a marking of a place and its nature (purpose of existence) in real space using virtual space tools: geolocation, smartphones, short-range radio communication, and a certain 'intelligence' allowing automatic filtering and searching for specific information. The column can be treated as part of the city's 'intelligence' and as a public service operating through and for the benefit of residents.

Often, certain inconveniences are encountered in urban spaces, such as potholes in the road, a large dead animal lying on the road, or roadworks at a given point along the route. Some of these problems are slow-moving, and some are fast-moving; some are important only for a specific group of residents (e.g., holes in the road are of interest only to drivers), and some, potentially, concern everyone (e.g., the choice of trees to plant along the road). Roadworks may not only block car traffic but also disturb pedestrians, limit parking spaces, change the location of a bus stop, etc.

Currently, the possibility of notifying the broadly understood administration or other residents is minimal. Passing a dead animal, one does not know if anyone has already reported this fact to the appropriate services. If they call and it is the hundredth call with this report, the person receiving it may feel irritated. If one wants to choose the type of shrubs to be planted along a new road, firstly, they do not know who makes a decision about it (and, consequently, whom to notify), and secondly, they cannot name the plants correctly enough to make their choice unambiguous. If one sees a sign on a column with an advertisement for renting an apartment and a telephone number is noted, the only way to check whether the advertisement is still valid is to call. If the notice with this number has been hanging for a year, replying that the advertisement has long been outdated is unpleasant. At the same time, the author of the advertisement cannot find and remove all the announcements because they forgot where they had hung them a long time ago, or they will appear after some time when the wind blows away other advertisements that temporarily cover them.

On the other hand, almost every citizen has a smartphone equipped with a camera and microphone, with short-range (Bluetooth, RFID, NFC) and long-range (LTE, 5G – Maulani, Jaohansyah, 2023; Gerwing, 2024) connections. The smartphone has the ability to determine its location (geolocation) and even movement parameters (such as 'I am sitting,' standing, driving, etc.), including direction and speed. These technologies can be combined and used to implement a virtual column. Let us assume that a person is approaching the place where there has been an accident and there is a temporary roadblock. This place is equipped with a virtual announcement column that transmits relevant information via Bluetooth, i.e., at a distance of several dozen (in practice up to approx. 100) metres. A popular BLE beacon (Jeon, She, Soonsawad, 2018) can be used for this purpose. The smartphone receives this transmission, checks its location, and adds appropriate information to the map displayed to the driver, or informs the pedestrian about an obstacle via a voice channel. Such information can be much broader than in the traditional approach, e.g., a policeman 'handling' an accident can tell you how long it will take to remove its effects, an employee of a water company handling a pipe failure can inform everybody how many days it will take for the road to be fully repaired, etc. The smartphone can also establish a connection to the selected server or database (a service), e.g., it can find out that there is a dead cat in a given place, but this fact has already been reported to the appropriate services. As a result, the smartphone owner is better informed about the time/place situation.

Note that this way of using wireless transmission via a location beacon and a smartphone allows for the mass transfer of information about an event at a given moment, which will only be valid for a particular time and only in a specific place. In this way, the most up-to-date information about a specific time and place will be provided. Such meta-description of events is not possible with traditional columns and notice boards. The set of technologies that make up the idea of a virtual announcement column can additionally provide information in near real-time about the estimated time of removal of an obstruction, e.g., road works. The information provided can be automatically adapted to the specific nature of the recipients, e.g., drivers will see it on the navigation map, and pedestrians will listen to it via headphones, exactly when they are in the place and at the time covered by the event.

The QR code (Kuyucu, 2020; Hayes, 2024) is another technology that will also be included in the system consisting of virtual advertising columns. QR codes have been widely used for years, mainly in advertising materials, to redirect to specific websites or open various content. In this particular technology variant, one also has to use the smartphone as the recipient and interpreter of such a code. For example, a traditional board describing road renovation can be extended with a code directing to a database with data on the contractor, scope, schedule of work, etc. The administration and city services can generate QR codes, but they can also be a form of communication among residents (e.g., information about planned civic initiatives in a given place) and be a form of assistance for people from outside the city (tourists).

Another technology that creates virtual advertising columns is RFID/NFC (Rao et al., 2015; Nowak, 2023), i.e., remote radio identification systems. The use of this technology will also enable the transfer of information, but it will be an alternative to the use of QR codes. NFC tags may be installed in specific places in the city. Residents using smartphones will be able to access and read the most up-to-date information, such as the tram timetable at the stop, opening hours, office functioning, etc. Note that in this case, similarly to QR codes, it will be possible to manage the shared content in an aggregated manner, and thus effectively avoid its obsolescence.

To sum up, the set of technologies constituting the idea of a system of virtual advertising columns in urban space will consist of four technologies cooperating with each other and used in appropriate cases or interchangeably: geolocation, QR codes, NFC tags, and BLE beacons.

4. System Architecture

In the first variant (based on BLE beaconing), a two-tier architecture model is used, i.e., the so-called fat client (Rouse, 2013; Gillis, 2020) (Figure 1). The oval block means a beacon, the central rectangle means the mobile application installed on the user's phone, and the cylinder means the database from which the application downloads the relevant information. In the first step, all communication is carried out between the locating beacon and the application that runs in the background. The active Bluetooth Low Energy scanner must be turned on – the connection is based on this standard. If the signal from the beacon is received by the application (phone), it is possible to determine the signal strength, i.e., de facto assess the distance of the smartphone from the encountered beacon. Based on the beacon ID and the phone's location, after communicating with the server using LTE/5G transmission, the application obtains relevant information related to a given place, downloaded from the database. The application can also take into account the phone owner's preferences (e.g., to ignore advertisements from nearby stores) and the nature of the movement (one is walking, sitting on a bench, driving a car, etc.), appropriately filtering and adapting the received information to the user's current situation. In this scenario, the user (owner of the phone) does not have to initiate any activities related to access to the system – the application is the active element that will send a notification about the place/time/situation, but only if such information is valuable.

BLE beacons are used in many places, such as museums, public buildings, exhibitions, and fairs. However, the popularity of this technology could be greater, as its use in public space (outside buildings) is negligible. The disadvantage of current solutions is also the lack of ensuring an appropriate level of security and authorisation of devices (Rykowski, 2017), the need to contact the database every time, the practical impossibility of signalling variable data (the BLE beacon generates a permanent identifier that remains unchanged throughout the device's 'lifetime'), and lack of a social campaign to use Bluetooth transmission for purposes other than personal ones.

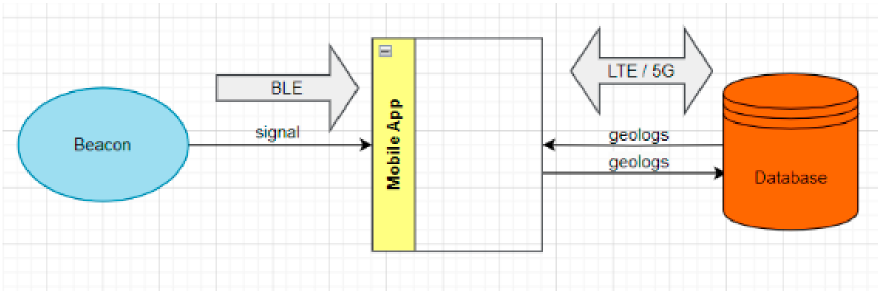

Figure 1. Usage of BLE beacons
Source: own preparation

The second variant of the system (based on QR codes) also implements a two-tier model (Figure 2). The oval block denotes the QR code, the rectangle is the mobile application installed on the user's phone; the rectangular block at the bottom defines the logic of the external service to be presented to the user; the last component on the right is the database with which the application communicates. The initial activity is on the user's side. They must scan the QR code with the phone using a self-launched application. They are then redirected to a specific service, such as a website with up-to-date information about tutoring in the area. The application has information about the QR code number and the location of the phone, processes the data, and based on this information, obtains additional information (access to services) from the server, communicating in the LTE/5G standard. For example, suppose the user is interested in the tutoring offer. In that case, they immediately receive the opportunity to contact the service provider and receive additional information such as price, possible meeting hours, etc.

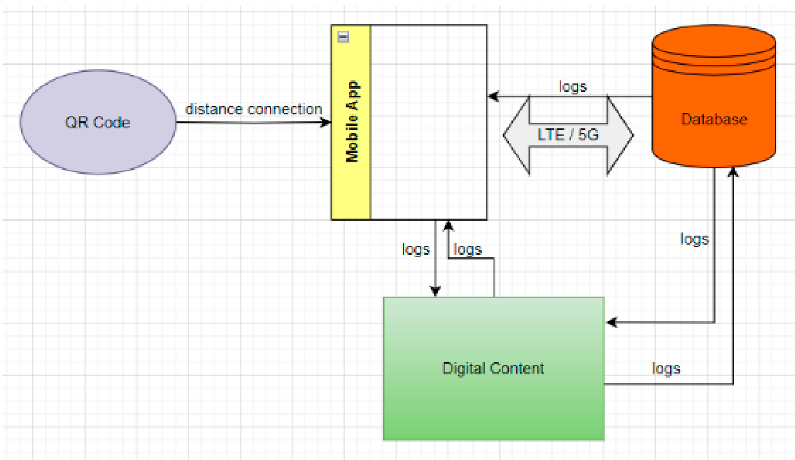

Figure 2. Usage of QR codes
Source: own preparation

In the third variant of the system (using NFC/RFID tags), similarly to the previous ones, the system architecture is also based on the two-tier model (Figure 3). The first block on the left corresponds to the NFC tag, and the remaining blocks are analogous to the model from the system above. As in the QR code example, the user must use the phone to read the NFC tag at close range. Of course, one must turn the NFC module on and register the application on the phone to read specific stamps. After placing the phone with the NFC antenna on the tag, the system reads the tag, which automatically launches the application mentioned above. The control is redirected to a specific service, e.g., a WWW site with tourist information, a board with information about missing animals and lost items in the area, etc. The application communicates with the server in the LTE/5G standard. Based on the NFC tag number (type) and the phone's location, the service is determined, and additional server data is downloaded, enabling the display of specific information or the undertaking of a specific action.

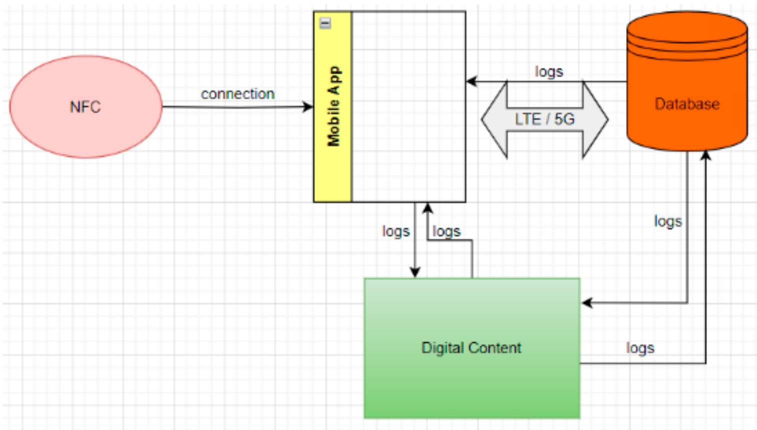

Figure 3. Usage of NFC tags
Source: own preparation

The last variant, based on the automatic tracking of geo-location, just like all the previous variants, is based on a two-tier approach (Figure 4). The first rectangle on the left indicates the application on the phone, the block above corresponds to the enabled GPS module, the block at the bottom indicates an external map service (Sheriff, 2022), and the last one on the right is the database. The mode of operation is as follows. The application registers on the smartphone and runs in the background, periodically monitoring the current location. If the location data match any previously registered points of interest, the application activates and communicates with the server, similarly to the previous examples. The data received from the server is filtered and normalised; if necessary, the service is automatically launched on the phone, or a notification is sent about the possibility of using this service, combined, for example, with a vibration alarm or a short sound signal. The user uses the service in the same way as before. Note that, similarly to the example using BLE beacons, in this case, the user does not have to show any activity (in particular, he/she does not have to run the application and read the tags). The active element is the application itself, as it notifies the user if 'something interesting' is nearby. What is potentially 'interesting' is declared (chosen) by the users earlier on, while setting their preferences and filters accordingly.

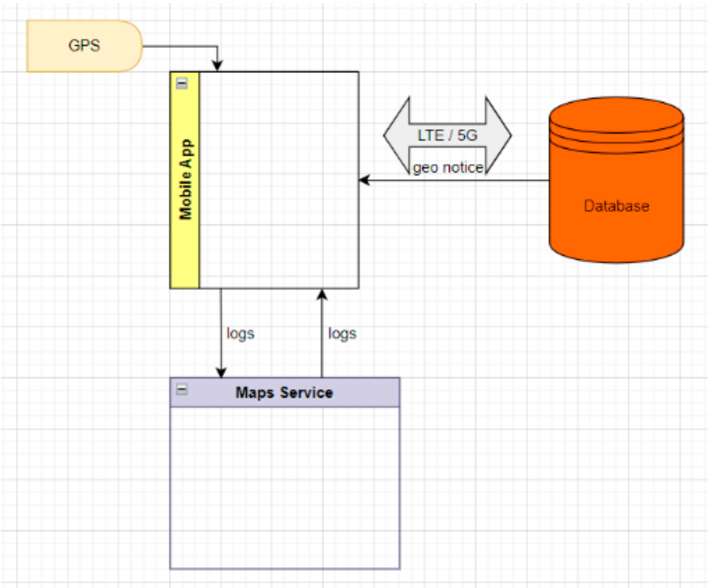

Figure 4. Direct usage of geolocation service
Source: own preparation

5. Usage Scenarios

This section describes several scenarios for using virtual announcement columns and similar information services. In order to simplify the description, these scenarios have been divided according to the technologies used: geolocation, BLE, and QR/NFC. It is important to note that the leading proposal of virtual advertising columns is not just a replication of commercial systems but a unique approach with a different business orientation. Our focus is not solely on generating profits but also on motivating and enhancing social processes in the city, making these applications genuinely innovative.

5.1. Scenario 1 – Helping Tourists in the City Space

Tourists came on holiday to a new location. They do not know the city and do not know what tourist attractions there are. There are certainly many tourist publications in traditional paper form and websites from which one can obtain information important for such people. However, they are usually limited to describing selected places worth visiting or seeing in the city, often unique and exceptional from the point of view of historical value. Such a description is, however, 'dead,' i.e., it does not take into account the current location, access route, suggested means of transport, etc. As a result, people get lost or spend time browsing the description and comparing it with the existing situation.

Virtual announcement columns are changing the way tourist assistance operates. Firstly, tourists receive an app with route suggestions. Each exciting place they can scan has a QR/NFC code. The application will inform that they are approaching such a place and where the marker is located. The fact of scanning is not only a confirmation that the person has reached the next stage, the application can then redirect them to services available in this location, e.g., assist in buying a ticket, suggest and help rent a form of transport based on personal preferences, provide important information in their native language, etc. RFID/NFC tags can be used instead of QR codes. To do this, one places a phone against the marker, there is no need to launch the application manually. The data represented in the tag are functionally identical to the information contained in the QR code. The choice of one of these technologies depends on personal preferences and the smartphone model.

An essential feature of QR codes and NFC tags is that they are easy to install and have low production costs. Therefore, in case of destruction, replacing the tag with a new one will not be a big problem for the managing party. Moreover, one can imagine a situation where such markers (after appropriate verification by the city) are placed by citizens, e.g., directing tourists to private attractions, restaurants, souvenir shops, etc.

5.2. Scenario 2 – Reporting Rapidly Changing Situations in Urban Space

In the morning city traffic, a road obstacle occurs in one of the busiest streets. A dead animal is lying in the middle of the road, so large that it is difficult to pass by. People nearby inform city services about this situation by sending the location of this place via the application. Only the first reporting person must specify the exact details of the accident. All other people will already see that there is a dead animal in this place and will not waste time describing the situation again; they will only confirm this fact. The more confirmations, the greater the importance of the report. Therefore, city employees will quickly arrive on-site and will be able to remove the dead animal. During their intervention, they will set up a BLE locating beacon on site, informing about the accident and the expected time to remove its effects. All those passing nearby are informed in near real-time about the cause of road inconveniences and the duration of traffic interruptions. Suppose the removal of the effects of the accident is prolonged. In that case, the report may be sent to the notification centre of car traffic forecasting companies, which will result in the display of appropriate information in navigation systems. This way, those who are be present in a given place for a moment will learn about the potential problem, and they will have a chance to change their route before they get stuck in a traffic jam. Such reporting can be carried out automatically and in a trustworthy manner. Only when an appropriate group of anonymous and completely unknown people gathers and independently confirms the fact of a collision with an animal will this information be forwarded to all other drivers. At the same time, the system does not need a critical mass to work, just a few people who confirm the problem are enough for everyone else to start noticing it, including those who do not use the virtual column and the city application.

Similarly, water company employees will inform drivers and pedestrians about the procedure for repairing a pipe failure. Instead of a traditional piece of paper with illegible information, they will launch a beacon informing everyone present in a given place about the details of the ongoing repair work, additionally predicting its completion time.

5.3. Scenario 3 – Gathering Opinions on Certain City Problems/Innovations

BLE beacons will also be justified in bidirectional information flow, such as voting on the participatory budget. People who will be asked to vote on a given civic project, i.e., what purpose the available financial resources should be allocated to, will be able to comment on it or vote. For example, building a park or a playground for children in a particular place is possible. A BLE locating beacon is placed in the immediate area. Every person who has the application installed on their phone and is near such a beacon for the first time is asked to express their opinion on how the funds will be used. The information collected in this way will reflect the democratic choice of local residents. The cost of obtaining such opinions will be incomparably lower than the currently used methods (mainly street and telephone surveys), the inconvenience will be much lower, and the quality of results obtained will be higher. Application users will be able to turn off such notifications if they prefer to avoid participating in such city initiatives.

5.4. Scenario 4 – Helping People with Disabilities

Some citizens have specific needs for up-to-date contextual information. A widely known example is a population of drivers interested in the current road traffic. Another specific group is not so fixed and is associated with a varied spectrum of needs: people with disabilities. As for this group, the information needed is highly individualised (each disability requires different data and is characterised by different needs as for the JIP/JIT information). What is needed is filtering the incoming information according to personal requirements. The smartphone is an ideal tool for this goal. All incoming data are inspected by the thick-client application in order to determine whether to present the information to the user. If properly marked, the information is efficiently distributed, and there is no information overload. This is particularly useful for non-disabled users. Most people are not interested in being informed about a higher curb or nearby stairs. However, for a blind person or one travelling in a wheelchair, this information is crucial.

6. Comparison with Similar Solutions

To our best knowledge, the idea of virtual announcement columns or functionally comparable, comprehensive information propagation in a 'smart' city has not been proposed so far. However, several ways of using location and marking technologies for information purposes have been proposed, and these applications are described and compared in this section of the article. QR codes are widely used in many cities around the world (Djaidani, 2024), e.g., in India (Mangaluru), Saudi Arabia (Riyadh), the United States (North Carolina), Vietnam (Ho Chi Minh City), Brazil (Rio de Janeiro), and South Korea (Seoul). These cities use QR codes for different purposes, but each implementation allows for much more than a traditional advertising column. In India, in the city of Magaluru, QR codes present information on waste storage processes, which enables effective management of these activities. In Saudi Arabia, QR codes are used to manage municipal administration, improve the quality of services in hospitals, and check various types of certificates. In Mecca, QR codes ensure the safety of pilgrims heading to holy places. This technology can also be used for navigation, as is done in North Carolina in the United States. People who scan the QR code receive information about the nearest services and parks in the area, and the scan can also redirect to Google Maps. In Vietnam, QR codes are used to provide information on street specifications, such as the name of the street, the history of the street, and its length and width. In Brazil, QR codes are used to connect tourists who visit the city of Rio de Janeiro every year with a community with similar interests. In South Korea, QR codes inform tourists about popular attractions, restaurants, and hotels. The main problem of the above-presented applications is that QR codes do not cooperate with other identification systems and require the initiative of those interested in using them – taking the smartphone out of their pocket, running the application, scanning the code, and manually interpreting the received content. There is no room for automation here (especially information filtering). These systems are also inaccessible to people who do not travel on foot, especially stopping at specific places. Some geolocation systems, including the popular Polish service Yanosik or Google Waze, do not have the above-mentioned disadvantage. In these applications, one can determine the 'importance' and characteristics of a given place, e.g., the fact that a police car with a radar is parked on the side of the road, a pothole in the road is in the front of the car, etc. However, these systems are dedicated to a specific community (drivers) and cannot be extended, e.g., towards a better description of the place. For example, one may see information about a pothole in the road but not know whether it has already been reported to the appropriate services and when it will be removed. In turn, users cannot send a report about a dead animal or a broken tree, even though they can notify a police officer with a radar hiding behind the tree.

Acoustic systems are another type of urban information system, such as alarm sirens. These systems, quite commonly installed in many cities during the Cold War era and beyond, are largely inoperable, so they will be unable to fulfil their purpose in the event of a threat to the city and residents. Another major disadvantage is the public's lack of knowledge about the desired behaviour in the event of receiving such a message. If the system informs, e.g., about the threat of chemical contamination, few people will know how to behave in such a situation, not to mention the correct interpretation of the type of signal itself. The problem lies in the lack of public education in this area, and the smartphone could successfully fill such knowledge gaps, but unfortunately, it does not hear these signals and will not respond.

A similar problem concerns national and regional security initiatives. The Government Security Centre system provides weather alerts and other important information regarding extraordinary events. This system is built into the mobile infrastructure but needs to be parameterised; in particular, it needs to consider the physical location of the mobile phone that receives the alerts. Therefore, its usability is primarily restricted, severely limiting its popularity.

Please note that our proposals address several aspects of a smart-city domain, including e-government and e-feedback from citizens, as well as the organisation and management of private initiatives in public spaces (local and micro-societies, societal cooperation, etc.) (Murray, 2010). This is part of a broader view of city e-management (Duivenvoorden et al., 2021) and smart-spaces design (Skowron et al., 2019), also including e-health and new-energy solutions (Okello, Akoko, 2023). The paper also provides an example of a smart city service (Arin et al., 2023) as well as mobile alerting (Sadiq, 2023).

7. Final Conclusions and Directions of Future Work

The system that is the subject of this article has great potential in urban applications and increases the efficiency of information transfer in public spaces. One of the most significant advantages of this system is its universality, the possibility of cooperation, and the introduction of new technologies that improve operation and replace or supplement current technologies in the future. It is also worth remembering that the application, which is a contact point for city residents, can be continuously improved, and other possibilities can be added to it, allowing for the transmission of information remotely to as many recipients as possible. It is also essential for the city to effectively obtain feedback, including residents' opinions on specific topics. The most important feature of this virtual billboard system is its social nature. The residents will be able to influence information propagation. The city authorities and administration will be able to share some ideas and verify them at-the-place and just-in-time. Cooperation between the administration and inhabitants, i.e., users and co-owners of the system, will reach a new level, introducing new, active social processes, which is one of the essential elements of a 'smart' city (Wade, Pfaffli, 2016; Spacho, Plataniotis, 2020; Gomstyn, Jonker, 2023). Proposals to expand and improve the system may come from citizens. They may include not only some new technologies and solutions but also new application areas and new city services. The proposal seems more democratic and universal than all current solutions.

The paper has not addressed many aspects of the proposed solution, particularly temporal information caching and validation, security and safety problems, implementation aspects, and public acceptance of the proposed services (Yap et al., 2016; González-Zabala, Galvis-Lista, Sánchez-Torres, 2018; Majerczak, Strzelecki, 2022). This is a matter of future work, with such topics as ad-hoc, pseudonymity, and even full anonymity with regard to data quality; broadcasting the information by authorised and well-known entities, only consumed in an anonymous way; trust for bi-directional anonymised services (van Zoonen, Luoma-aho, Lievonen, 2024); privacy protection, technology acceptance (Hee-Cheol, 2015) and digital skills of the society (Taherdoost, 2018; Al-Tarawneh, 2019), business models for e-services (Perätalo, Ahokangas, Pekkarinen, 2022), and many more. Please note that, e.g., the level of trust/privacy violation is not higher than the one observed for any similar smartphone applications; thus, the fear of the end-users is probably limited. It is comparable to the traditional way of information dissemination, such as ads hung on the walls and brick-and-mortar columns. Nobody verifies the 'truth' of such paper-based information except for the 'end-users' – those who read and react to the information. Moreover, paper-based announcements usually include a phone number, which is not necessary for our proposal. The identifying information may be replaced by, e.g., an anonymous e-mail account or a pseudonym in a societal cooperation.

Like traditional paper notices hanging on advertising columns for weeks and months, locally stored information is not validated by the authors or any external service. The information is 'cached' for some time and accessible locally; however, the addressee can validate it only by accessing the source, i.e., asking the sender if the data are still correct. There is no way to provide any external, independent assessment of the published data. Moreover, it is impossible to verify the data quality in advance (simply, if someone is telling the truth in the advertisement). This is exactly the level of traditional, paper-based columns. Also, the anonymity of both the sender and the receiver of the information is preserved until the moment they decide to share some personal information (such as a phone number or an e-mail address for electronic contacts). Thus, we do not discuss these aspects in the paper. This is probably a more general case for any 'smart' public service. However, the discussion of these and related topics is much too extensive to be included in this paper, and it is worth a separate publication.

The idea depicted in the paper was implemented using the technology invented in our research laboratory (namely, variable-code geolocation beacons and trusted beacons). The research resulted in some other publications (Rykowski, 2017) and patent applications (Rykowski, 2018; Rykowski, Jenek, Switala, 2022). As the latter are still pending, for several reasons, we are obliged to keep some technical solutions confidential. Thus, we avoid technical details in the description of the proposed public services. We also prepared an Android application to validate the services in the city area. As already mentioned in the introduction, we are now looking for a city interested in a pilot implementation to extend the research to the second stage, i.e., testing the proposed service with real users and validating the usefulness of the approach.

What is worth discussing (and probably a separate publication) is the acceptance and usage of smartphone applications in public places, particularly in cities. It is still being determined if such services will be as popular as other applications, such as games, navigation, shopping assistance, mobile payments, etc. It is also unclear how to improve the trustworthiness of such services, especially if some will be provided by external, independent, probably local, and thus unknown, small companies or even individual citizens. Such services should be registered (a task for city administration?), digitally signed (by whom?), and automatically verified by the smartphone, especially if linked with payments. All these aspects are still open and hardly addressed by the current research.

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Usprawnienie przepływu informacji w inteligentnym mieście z wykorzystaniem nowoczesnych technologii

Streszczenie: Celem artykułu jest ukazanie ewolucji usług informacyjnych w przestrzeni publicznej w związku z pojawieniem się nowych technologii. W opracowaniu zaproponowano także nowe pomysły dotyczące świadczenia wybranych usług informacyjnych z wykorzystaniem najnowszych rozwiązań technologicznych i organizacyjnych. Artykuł pokazuje, że nowe technologie nie tylko znacznie usprawniają przepływ informacji, ale także stają się podstawą do nowatorskich usług w inteligentnych przestrzeniach. Jako główny przykład opisano wirtualne słupy ogłoszeniowe, których zadaniem jest ułatwienie dostępu do informacji lokalnych w zależności od miejsca (lokalizacji) i czasu. Słupy te są odpowiednikiem tradycyjnych miejsc do umieszczania lokalnych ogłoszeń i komunikatów w formie papierowej. Jednak komfort ich użytkowania jest większy, wzrasta także ich użyteczność w przestrzeni publicznej. W podobny sposób usprawniono zbieranie opinii mieszkańców, pomoc *ad hoc* dla turystów itp. Proponowane rozwiązania opierają się na nowych technologiach, takich jak boje lokalizacyjne Bluetooth ze zmiennym kodem i kody QR, są one adresowane do właścicieli telefonów komórkowych oraz publicznych obszarów miejskich.

Słowa kluczowe:	usługi geolokalizacyjne, inteligentne miasto, Bluetooth Low Energy, Internet Rzeczy i Usług, inteligentne przestrzenie
JEL:	L96, O35