Approach for Wireless Resources Access Control

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Abstract — *This paper describes research in field of wireless nodes indoor localization and controlling access to wireless network resources.*

Existing methods implement location based services and optionally allows controlling user access only at the authentication stage. Proposed approach, first of all, is aimed to continuous access control. That is significant in applications where unapproved access zones exist. The aim of this research is to develop an approach for realizing the task of wireless networks access control, using physical coordinates of user.

Localization is based on time difference of arrival (TDoA) method and triangulation.

Keywords: access control, localization, wireless networks.

1.Introduction

The public resource aim is to provide access for a lot of persons and in such case accessibility and easiness of connection will serve as an advantage. Nevertheless, there are a lot of wireless network applications where public accessibility must be avoided, keeping easiness of connection establishment. Due to signal attenuation, wireless access point's signal strength need to be powerful enough to reach every point of area where resource will be used. But in such case the signal could be received there, where access to wireless resources is undesirable and even dangerous. For example, to improve industrial machine operator's mobility and quality of work, wireless operator panels are used. Using them the operator could accidentally or purposely leave the zone of visual contact with the machine, where wireless connection still exists. And without knowing the machine's current situation it is highly dangerous to operate it.

Therefore, while controlling user access to resources it is critical to know the user's current physical placement and not only a identifying him with password. Moreover, the information about the user's current physical placement noticeably increases functional capabilities, effectiveness of work and possible area of application. Using user's physical coordinates along with wireless resources access control it is possible to use effective methods of geographical routing. Also there are a lot of applications where information about mobile user placement would give possibility for new services. For example: a) virtual guide – interactive system that could provide to user a great amount of information to the user about an object, which is close to him; b) Global Positioning System (GPS) inside buildings – a system that assists users in finding an object, room, person or service in large buildings (supermarkets, parking place, etc.); c) tracing children movements at home.

The task of resources access control could be formulated as follows: continuously track user location while he is using the controlled wireless resource; manage user rights for accessing resource, using predefined unapproved zone map, without affecting initial users' identification mechanism. User localization needs to be performed with errors not greater than several tens of centimeters, a distance that is commensurable with possible change of wireless element placement at user hands.

2. Existing methods and proposed approach general comparison

Localization algorithms can be divided into two categories: range-based and range-free. In range-based algorithms, nodes estimate their distance to seeds using some specialized hardware or a special functioning mode of casual hardware. As a result high (up to sub centimeter) localization accuracy could be achieved at the expense of extra hardware. Range-free algorithms do not need any special hardware, they require that each node knows: which nodes are within radio range, their location estimates, ideal radio range of sensors. This method is mainly used for low cost outdoor solutions, with low accuracy (the error is more than 1/10 of reception zone) [1].

The specialty of defined task defines significance of localization methods parameters. And accuracy is much more significant, than the price of special hardware. Therefore range free method does not suit us. Range based algorithms can also be divided into several categories, based on range finding technique. Most popular techniques: TDOA (time difference of arrival), TOA (time of arrival), AOA (angle of arrival), RSSI (Received Signal Strength Indication). RSSI needs less effort to implement, but its accuracy is too low. AOA and TOA methods have high accuracy, but require great implementation effort. TDOA has acceptable accuracy with moderate implementation effort, therefore it has been chosen for the given task's realization [2].

During research stage following existing systems of wireless user localization and location based services where examined: "Olivetti Active Badge system", "AT&T

Bats", "Microsoft RADAR", "MIT Cricket". The goal of these systems is providing user access to nearby public devices and services (network printer, projector, print spooler, etc.). "Active Badge" system user IR (infra red) beams, thus it can only sense presence of user only if he is in line of sight with transceiver. "AT&T Bats" is more functional than previous system, due to replacing IR with ultrasound and radio signals, which allows finding the distance from user to transceiver without the line of sight need. Nevertheless the need in large amount of wires and fully centralized topology makes this system unsuitable for realizing figured task, because wired connection system is costly and hardly expanded, also centralized control makes system unstable in case of large user amount. "RADAR" and "MIT Cricket" systems are cost effective, due to the absence of extra hardware, but that makes these systems inaccurate [3]. Measuring user distance to some beacon, using radio signal strength (RSSI), is useful for applications that need to acquire user proximity to some devices using only standard equipment (notebook, Personal Digital Assistant (PDA), cell phone). In case of ensuring reliable access control, especially in industrial applications, there is no task to use only standard equipment, reliability is the thing that matters. So, existing user localization systems are not capable of performing the needed task. Their application field is limited to office use.

There is some equipment among industrial devices that allows implementing access control functions that are similar to proposed one. For example, Siemens company offers transceiver system that is capable of limiting access to industrial device from special operator mobile panel [4]. Researching its functioning some weaknesses were spotted. This system has high level of errors in user localization, because mobile panel needs to be in the line of sight with controlled equipment transceiver. Such problem possibly arises due to simplicity of localization algorithm and method of ranging. Ranging is probably based on RSSI method that is measuring radio signal strength, which makes two situations when user leaves approved access zone or user just turns his back to transceiver undistinguishable. Moreover localization algorithm is realized using only one transceiver (beacon), even if there are several beacons, which operate in radio receive zone.

As a result it is clear that none of existing methods and systems are capable of performing contiguous user access control with high localization accuracy. Proposed approach solves mentioned problems and thanks to relatively high accuracy it will be possible to create detailed maps of unapproved zones for the operator.

3. System architecture and functioning principle

Taking into account the information about examined systems topology and given task, the system topology was chosen as follows: local access controlling with link to centralized system storing user access rights and unapproved zone maps. User access will be continuously controlled with local system without the help of central system. Only at user identification stage the local system will connect to central system and query required user access data and unapproved access zone map. Therefore there will be centralized system for continuous controlling of user access to wireless resources, which will be able to simultaneously control many users access without high load on central server. All system will consist of: central server, cells with wireless resource to control, wireless access points from each cell to central server. Central system access and use of access points is taken as an example. They are not to be considered as basics of proposed approach. Each cell will have controllable wireless resource, three or more beacons with known coordinates (local or absolute) and a user with mobile wireless device for accessing resource. User mobile device and beacon architecture will be described later. Possible scheme of cell is depicted at Fig. 1.

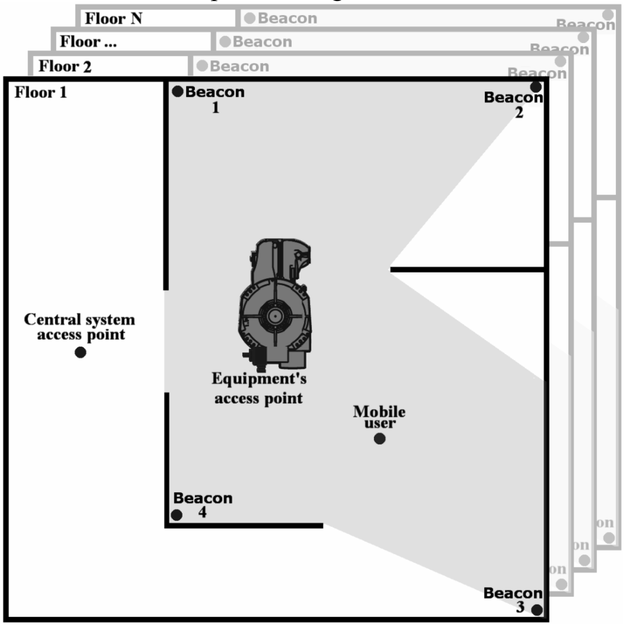

Fig. 1. Example of system topology. One of autonomous cells of user access control.

Principle of functioning:

- system is installed and configured,
- beacons simultaneously transmit radio and audio signals by defined schedule,
- user establishes connection to wireless resource access point and identifies himself with the original system's method,
- proposed system's device, which is integrated to user mobile device, is requesting user access rights and unapproved zone map from central system, through central system's access point,
- integrated system continuously obtains user coordinates and controls his access accordingly to unapproved zone map.

Since the proposed system is range based, it requires additional hardware – high frequency sound transmitters and sensitive microphone. Fig. 2 depicts architecture of beacon. Device that is integrated to user mobile device (operator panel, PDA, etc.) is almost the same as beacon hardware, Digital-to-analog converter (DAC) is replaced with Analog-to-digital converter (ADC) and speaker is replaced by microphone. Of course, the functioning algorithm is different too.

Central Processing Unit (CPU) does all calculations (at beacons – schedule forming, at user device – position calculation and access controlling). CPU is also controlling external communication, radio and audio components. Mobile device that controls access is connected to user device by Universal Serial Bus (USB) interface, which also serves as energy source. Beacon station is autonomous and it's controlled using special radio commands or using USB (for initial configuration). Type of beacon station energy source depends on particular application requirements. If beacons need to be mobile, batteries could be used and if the beacon placement will not change very often, wired energy source could be used.

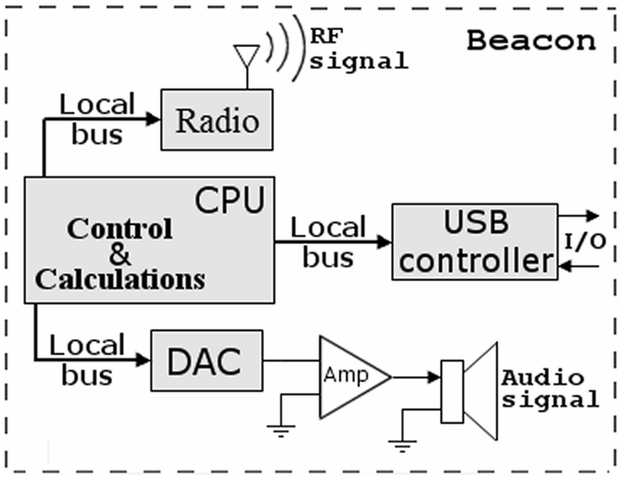

Fig. 2. Architecture of beacon

There are following rules for positioning beacons: their position need to be such that every point of the approved access zone would be inside of triangle made by three beacons. Maximal distance between the beacon and user device needs to be less than 100 meters, such number results from bluetooth standard. Proposed approach uses bluetooth standard only as example and does not oblige to use it. The only requirement for wireless data transmission technology is using a high frequency carrier with propagation time significantly shorter than audio signal's.

Since industrial devices are mostly specialized, the fact that the access limiting features are realized inside user device doesn't compromise security, because user has no possibility for changing any parameter. If the user must use only standard equipment, localization and access control could be realized inside the beacons, which in such a case would listen for user emitted signals.

Beacon system is established on the bluetooth standard's wireless sensors, it is autonomous and self organizing. Beacons can form pico (very small – only few nodes) network with a minimum of 3 and a maximum of 8 nodes. Their task is to autonomously organize audio beacon signals transmission schedule and keeping correctness of their structure, caring about new node connection and existing node disconnection. Schedule is formed in such a way that all beacons are transmitting their signals one by one maintaining defined transmission and waiting times. Beacon signal is formed from audio and radio signals, which are transmitted simultaneously. Audio signal is specified by frequency, amplitude and duration. Radio signal contains its emitter beacon's unique identification number and coordinates.

Knowing audio and radio signals receiving time difference (t_2 and t_1 respectively) it is easy to find range (r) in meters from beacon to user, knowing time and speed, using formula (1).

$$r = c \cdot (t_2 - t_1) \qquad (1)$$

, where c is the speed of sound in a current environment (approximately 340 m/s).

To find unknown mobile node coordinates (x, y) it is necessary to get range to three closest beacons and their coordinates. Using equation (2) of circle

$$(x - a_i)^2 + (y - b_i)^2 = r_i^2 \qquad (2)$$

it is possible to compose set of equations, the solution of which will give unknown coordinates x and y.

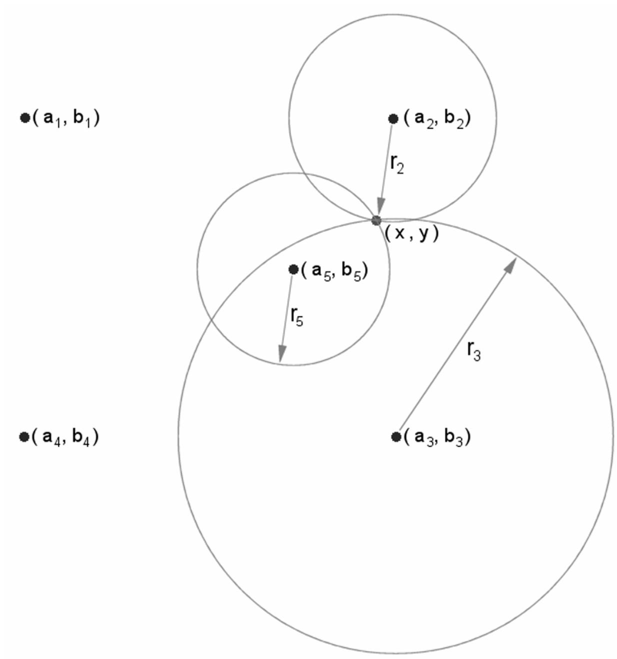

Fig. 3. Mobile user localization principle. Five beacons with known coordinates $a_{1\text{-}5}$, $b_{1\text{-}5}$; mobile user with unknown coordinates x, y; obtained distances $r_{1\text{-}3}$.

Set of equations is formed from three equations (3), since one equation gives only range to one beacon, two equations will give two points of possible user position in circles intersection and only by solving the set of equations from three equations we will acquire the exact point of user location in two dimensional space, as seen on Fig. 3. Practically we will have not a precise point, but an ellipse, since there will always be some error in range estimation. Adding some more equations with extra beacons data, localization error could be decreased.

$$\begin{cases} (x-a_1)^2 + (y-b_1)^2 = r_1^2 \\ (x-a_2)^2 + (y-b_2)^2 = r_2^2 \\ (x-a_3)^2 + (y-b_3)^2 = r_3^2 \end{cases} \quad (3)$$

One hard task to beat is extracting the exact starting time of beacon's signal from recorded audio signal. Audio signal's type and signal to noise ratio (SNR) will determine accuracy of front edge detection. Easiest way to detect beacon's audio signal start is assuming that SNR is high enough and the signal is simple enough for detecting it with simple threshold element, which is set for certain microphone frequency. Such experiments where conducted for testing global system logic. For implementing such algorithm in real world's noisy environment, there is a need in a more complex audio signal (e.g. mix of different frequencies) [5] and of course the detecting algorithm is needed to manage such signal. For such purposes the following algorithm is proposed: shortly after radio signal is received audio signal starts recording. Since calculation resources are limited, this operation could not be accomplished in real time. Recording lasts for time that audio signal need to pass maximal range from beacon to user - 100 meters. This time is equal to 350 milliseconds (taken greater for safety reasons).

On all recorded signal fast Fourier transformation

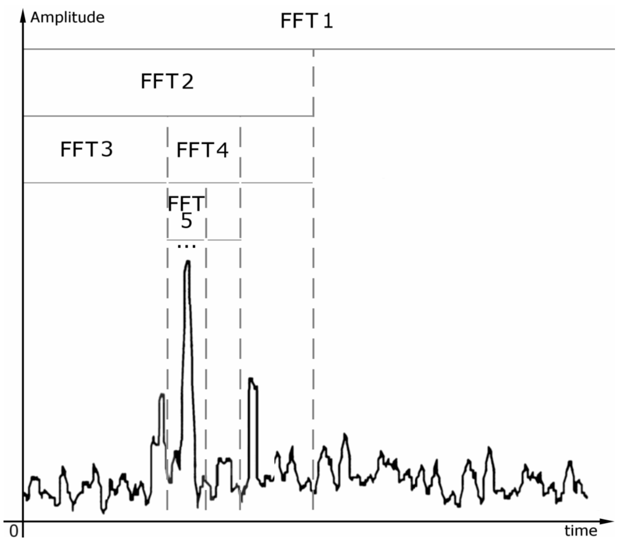

Fig. 4. Detecting audio signal starting time, using set of Fast Fourier Transformations (FFT).

(FFT) is performed several times, for finding needed frequency pattern (see Fig. 4). Algorithm is concluded in performing binary type search (each iteration signal's part from previous iteration is divided in half). The criterion for selecting one of the two parts of the signal at each iteration is the needed frequency pattern existence with spectral energy greater than predefined threshold. Iterations end when the window size, that contains searched frequency pattern, is equal to some predefined constant. Starting time of that window will be taken as beacons audio signal start. If beacon signal start position is known, it is easy to find its offset from radio signal receive time.

The proposed approach places some limitations, like the need of minimum three beacons in wireless signal receiving range and maximal localization distance dependence on transmitted audio signal power. Localization error lies in several centimeters range. Mostly it depends on accuracy of audio signal rising edge allocation against noisy background. Audio and radio signal arrival timestamps precision is also important. Due to limited calculation resources, finding the corresponding audio signal sampling rate, which would give acceptable accuracy, at the stage of rising edge detection, with moderate calculation effort, is the tough task to beat.

4. Conclusion

The approach for wireless resources access control, by user physical coordinates, was formulated. Necessity in proposed approach was proved. Exact applications examples were given. Advantages of proposed approach usage in existing industrial equipment are shown. Use of the proposed approach in combination with other access control methods gives qualitative improvements in providing access and operation in wireless networks.

The localization method that was chosen in the proposed approach has some weaknesses, peculiar for such localization class. For example it is increased localization error if multiple obstacles are situated on course of signal's path, effective zone limitation due to usage of audio signal. All of these problems define path of future investigations.

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Acknowledgments

This work has been partly supported by European Social Fund within the National Program "Support for the carrying out doctoral study program's and post-doctoral researches" project "Support for the development of doctoral studies at Riga Technical University".