Przemysław NOWAK, Michał WOJTERA, Piotr MAZUR, Jan, MURLEWSKI, Piotr PIETRZAK

Politechnika Łódzka, Katedra Mikroelektroniki i Technik Informatycznych

Distributed system for noise levels monitoring

Streszczenie. *W poniższym artykule przedstawiono koncepcje rozproszonego systemu monitorowania, zaprojektowanego w celu generowania map akustycznych obszarów zurbanizowanych. System tworzą oddzielne węzły pomiarowe połączone z sobą za pomocą sieci bezprzewodowej ad hoc. Do budowy węzłów wykorzystywane są powszechnie dostępne telefony z systemem operacyjnym Google Android. (**Rozproszony system monitorowania poziomu hałasu**).*

Abstract*. In this article a distributed system for noise levels monitoring created for generating acoustic maps of urban areas is introduced. The system comprises of a set of separated nodes interconnected via an ad hoc wireless network. It is also created for use with Google Android operating system which makes it available for use in a wide range of cellular phones available today.*

Słowa kluczowe: Android, monitorowanie, hałas, rozproszony, system.
Keywords: Android, monitoring, noise, distributed, system.

Introduction

Acoustic maps of urban areas (cities, districts, housing estates) or maps of noise emissions from industrial sites are now the basis for assessing the acoustic climate. They are created in order to graph the acoustic field distribution in a certain area. Acoustic maps are calculated taking into account the location of noise sources and their associated acoustic parameters. Depending on the type of map, sources of the input acoustic noise may vary: roads, railways and tramways (traffic noise maps), airport (airport noise maps), machinery and plant (industrial noise maps). Modeling acoustic parameters of these sources may be performed on the basis of acoustic data itself (e.g., acoustic power obtained from field measurements of sound levels, the information provided by manufacturers in catalogs, etc.) or non-acoustic data (e.g., intensity and structure of the movement of vehicles on the route, the frequency of flights, aircraft types, etc.). A geometric model of an analyzed area is an equally important element of each acoustic map. It influences directly the correctness of the calculations of sound propagation in the environment surrounding the studied area. The geometric model must take into account actual or projected location: noise sources, noise shielding objects (buildings, screens, slopes, embankments), the dense greenery of the existing lanes and also terrain topography.

In this article an universal system for noise levels monitoring is described. The system consists of mobile measurement nodes which can communicate freely via a self-organizing ad-hoc network. A single node consists of a management module (PDA[1] or smartphone) and a sensor module.

A data exchange between devices is (is going to be) implemented by designing a specific wireless protocol that allows for communication in a distributed ad hoc network with no provided infrastructure.

Acoustic Maps

The sound propagation in any environment (the sound level distribution) is usually calculated on the basis of the predefined geometric and acoustic model for an area. After the accession of Poland to the European Union, the 2002/49/EC Directive of the European Parliament was introduced.

According to this directive, the preferred method of noise propagation calculation in an external environment is described by "ISO 9613-2:2002 Attenuation of sound during propagation in open space. General method of calculation" standard. These calculations are carried out by specialized computer programs (e.g. CadnaA, SoundPlan, Lima, Immi, Mithra, etc.), which not only allow for modeling the environment and set the level of noise In specific locations, but also cooperate with the relevant GIS[2] data formats for importing and exporting data, making it possible to visualize results and perform more advanced calculations, which take into account the diversity of protected areas and population density.

Fig. 1 Exemplary map of road noise emission

Acoustic maps represent an essential element of acoustic expertise and acoustic studies, that involve:

planning of residential areas, spatial development plans, rational management of emissions,

assessment of impact of construction investments on the environment (construction of new roads, ring roads, upgrading existing routes),

assessment of impact of industrial investments on the environment (construction of a new industrial plants, analysis of the possibility of reducing noise emissions from the site of an existing facility, obtaining emission permits, etc.), identification of noise sources responsible for exceeding noise limit values in the area, rational planning of scope and order of sound-proofing works, assessing effectiveness of planned sound-proofing activities on site.

[1] PDA – Personal Digital Assistant – an advanced mobile device providing (among others) functionality to run custom applications

[2] GIS – Geographic Information System – a digital system providing geographical information along with other data that can be used for geographical analysis

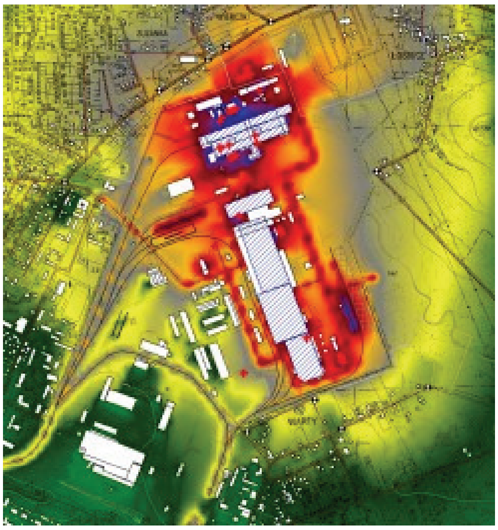

Fig. 2 Noise map of the industrial plant

Wireless Ad-hoc Networks

Ad hoc and sensor networks are formed by autonomous nodes communicating via wireless network, without any additional network infrastructure - the whole communication infrastructure is provided by the nodes themselves. When deployed, the nodes initially form an unstructured radio network, which means that no reliable and efficient communication pattern has been established. Before any actual communication can be carried out, nodes must establish a media access control scheme which provides reliable point-to-point connections for use by higher-layer protocols and applications. The problem of setting up an initial structure of a wireless network is of great importance in practice. Even a single-hop ad hoc network such as Bluetooth comprising of a small number of devices tend to spend a considerable amount of time performing network initialization process. In a multi-hop network with many nodes, the time consumption for establishing a communication pattern increases even further [3].

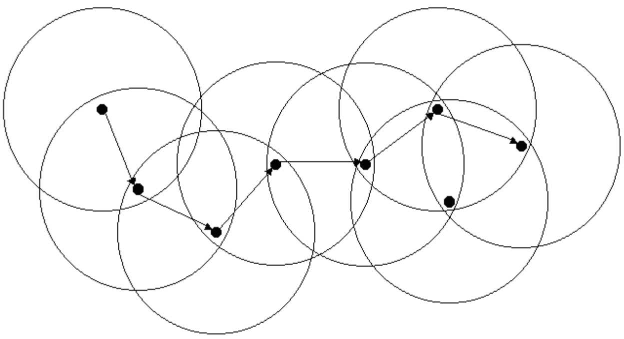

Fig. 3 Routing between two nodes [1]

A dynamic mobile ad hoc network can be defined as network of heterogeneous mobile systems, which is created on the fly and is capable of sustaining itself in conditions when a number of nodes are being added or removed from it. Following a change in the number of networked nodes, new traffic routes may be created In order to maintain stable communication.

This kind of a network maintains coherence through continuous reorganization. An ad hoc network is temporary, acting without aid of any fixed infrastructure or a rigid central administration. The basic premise is that although any two devices wishing to communicate in such a network are outside their mutual wireless operating ranges they can communicate with each other through other devices belonging to the same network. Devices may be widely distributed and can change location in a dynamic manner. Ad hoc networks are characterized by high, dynamic changes, dependence on limited energy resources and a connection scheme that is not clearly defined. Traditional routing protocols used in wired networks are not able to meet these high demands. They have not been designed to accommodate, in a satisfactorily short time, to changes in position of network elements and connection configurations between them. Computational requirements involved with the necessity of dynamic network reconfiguration require using greater amounts of energy. Most battery-powered devices cannot afford an extensive energy loss – energy is also required to provide data transmission capabilities [4]. With such demands imposed on mobile systems, ad hoc networks require the existence of new routing methods, to ensure its functionality while maintaining energy conservation

Application structure

The described system should integrate two components:

The measurement system which should be responsible for collecting and recording environmental data to generate detailed noise maps. This system will also allow to generate graphs for the purpose of visualizing collected data. Furthermore, it should employ methods for monitoring the status of each device's power and provide compensation for low battery charge. Appropriate methods for data distribution between network nodes (e.g. to provide consistent data set in a scenario when a certain node's power source is depleted) are also to be developed.

The communication protocol should provide connectivity between the devices involved in the measurement process. The main objective of this protocol is to organize the logical structure between the freely distributed measurement nodes using the information derived from the geographical location of the node and additional information describing available power reserves of the device. Based on the gathered information a hierarchical structure should be defined allowing to route packets in the distributed measurement system. Monitoring and predicting new interconnection scenarios in response to an infrastructure change is also being considered. Gathered diagnostic data may be transferred to a remote system in order to ensure network consistency and allow for quick reaction time when an inconsistency is detected or predicted. Proposed protocol should also consider many different methods of packet routing in order to provide transmission efficiency while simultaneously taking existing power reserves into account. For this purpose, different types of routing protocols are being studied [1]:

Proactive protocols, also called table-driven protocols, which are based on routing tables. These protocols maintain information about network topology and store routing paths to all nodes, regardless of their location change. This methods require a periodic refresh of routing tables to adapt to changing network conditions, such as loss of connection or link congestion. Altering of route tables is a time and power consuming process. Refreshments of routing tables have to occur quite frequently in order to eliminate outdated routing information in reaction for a network infrastructure change. In addition, an increased amount of information introduces a negative impact on energy consumption of mobile devices. The advantage of this protocol type is fairly throughput efficient packet routing.

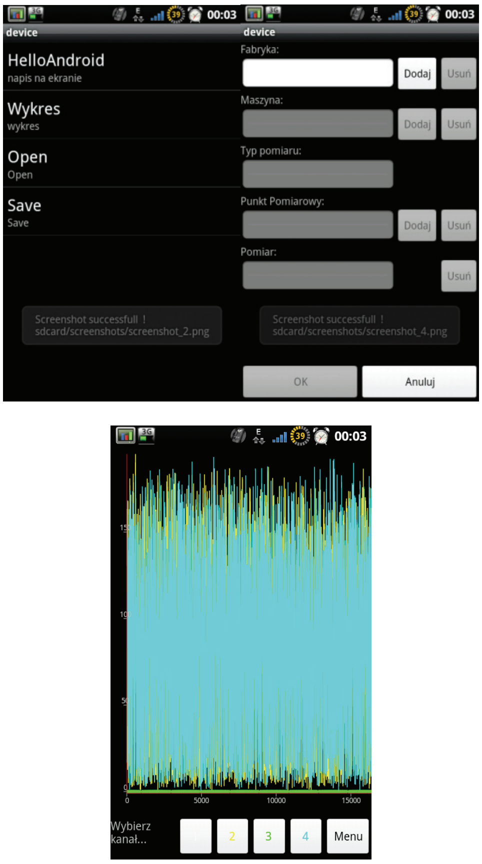

Fig. 4 Exemplary screenshots from the measurement system

Reactive Protocols - also called on-demand routing protocols. This type of protocols focuses on searching for a route only when it is necessary to transmit data to specified node. Usually the diagnosis of network topology occurs when a new transmission is being initiated. The characteristic of these protocols is a reduced control traffic and associated lower energy consumption. The need to search routes affects the time of delivery to the destination, and may introduce significant delays.

Hierarchical Protocols - protocols created order to improve efficiency of the hierarchical form of network. Nodes belonging to a higher levels exchange degraded versions of routing tables providing only general route directions. Nodes belonging to lover levels contain more specific route data. Such structure allows to reduce content of routing tables in the network and relieve the burden of processing large sets of routing data.

Geographical Protocols - protocols, whose work is assisted by geographical location data. Control packets are sent In accordance with location data and, consequently, reduce network traffic of control data in the entire network.

The proposed protocol will combine the advantages of different types of protocols for use in ad hoc mobile wireless networks. It should allow to automatically select most efficient route scheme for specific conditions that arise in this kind of network.

Conclusions

The proposed solution will allow for performing efficient and convenient noise measurements in urban areas. The use of the open-source Android operating system allows for monitoring not only noise levels, but also gathering data from other built-in sensors (e.g. vibration monitoring via accelerometers). Using commonly available PDA or smartphone units should significantly reduce costs compared to commercially available dedicated measurement devices which should, in response, increase popularity of distributed wireless monitoring systems and increase cultural awareness of noise and vibration effects on the environment.

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***Autorzy**:*
dr inż. Piotr Pietrzak, Politechnika Łódzka, Department of Microelectronics and Computer Science, ul. Wólczańska 221/223, bud. B18 , 90-924 Łódź, E-mail: pietrzak@dmcs.pl;
mgr inż. Jan Murlewski, Politechnika Łódzka, Department of Microelectronics and Computer Science, ul. Wólczańska 221/223, bud. B18 , 90-924 Łódź, E-mail: murlewski@dmcs.pl;
mgr inż. Piotr Mazur, Politechnika Łódzka, Department of Microelectronics and Computer Science, ul. Wólczańska 221/223, bud. B18 , 90-924 Łódź, E-mail: pmaz@dmcs.pl;
mgr inż. Przemysław Nowak, Politechnika Łódzka, Department of Microelectronics and Computer Science, ul. Wólczańska 221/223, bud. B18 , 90-924 Łódź, E-mail: pnowak@dmcs.pl;
mgr inż. Michał Wojtera, Politechnika Łódzka, Department of Microelectronics and Computer Science, ul. Wólczańska 221/223, bud. B18 , 90-924 Łódź, E-mail: mwojtera@dmcs.pl