Ambient Intelligence for Outdoor Activities Support

Possibilities for Large-Scale Wireless Sensor Networks Applications

Peter Mikulecky, Petr Tucnik
Faculty of Informatics and Management
University of Hradec Kralove
Hradec Kralove, Czech Republic
peter.mikulecky@uhk.cz; petr.tucnik@uhk.cz

***Abstract*— This paper is devoted to a recently running project with a purpose of getting some useful feedback from the interested community. The main point of the project is an attempt to apply approaches developed in the scope of the Ambient Intelligence area and usually implemented indoor (eg., intelligent homes) also in various fields suitable for large-scale outdoor activities (esp. working) applications, like water resources management, forestry, etc. The paper is oriented on investigation and sketching of some possibilities of large scale intelligent sensor network solutions for multi-agent based application in various areas where outdoor activities are frequent, but also where people working outdoor might need some more support because of possible hazardous situations that could appear. All the presented ideas are based on our recent project *SMEW: Smart Environments at Workplaces* that is oriented on bringing more intelligence to workplaces in general, but it has been oriented prevailingly on indoor working activities. Extending the approaches already developed in its scope to selected outdoor activities seems to be very challenging and useful.**

Keywords-wireless sensor networks; large-scale applications; ambient intelligence; outdoor activities

I. INTRODUCTION

When speaking about outdoor activities from the point of view of possible Ambient Intelligence (AmI) applications intended to provide certain support to the people working or simply situated in an outdoor environment, it is impossible to omit recent achievements in the area of large-scale wireless sensor networks. Related to the Ambient Intelligence research, we have to mention the notion of Large-scale Ambient Intelligence [1].

The notion Large-scale Ambient Intelligence was firstly used in [1]. Here, true large-scale AmI realization meant that the users were able to acquire whatever, whenever and wherever. In this concept it is understood, that the AmI vision would be extended from anytime-anywhere to anytime-anywhere-anything. In addition to incorporating intelligence in sensor nodes within a sensor network, Iqbal et al. [1] proposed to upgrade this vision to the next level where these geographically distributed intelligent sensor networks would become intelligent sensor resources accessible to the users anytime-anywhere.

In our earlier papers [2][3][4], we started with some contemplations related towards possibilities of using ambient intelligence approaches in an outdoor environment, especially for river basin management. Here some approaches based on knowledge-based system applications for a particular river basin control were described. The purpose of the knowledge-based system deployed was in supporting decision making processes of the river basin managers. Nevertheless, the approaches used were a bit narrowly focused, intending to support just decision making of several persons responsible for the river basin control. Other people in the vicinity of the river have not been involved. In the case of, e.g., flooding threats the only informed people were the river basin managers, but not the other people potentially endangered by the threading situation. Therefore we started to think about the possibility of enhancing in this particular case the river basin area by a wireless sensor network with some new functionality, involving also the people working or located in the area, potentially endangered by flash floods, forest fire, or other possible environmental catastrophes. In this paper, we intend to go further with the ideas how ambient intelligence used in "large-scale" over a wireless sensor network throughout the open natural environment could be beneficial in supporting various important activities, performed outdoor, in nature. We present here some ideas about possibilities for outdoor large-scale ambient intelligence focused also on such areas, where environmental catastrophes with disastrous effects could appear.

The structure of the paper is as follows:

After the introduction, the second part is devoted to related work in the area. Here, we mention several interesting papers trying to deploy wireless sensor networks for environmental applications. However, these applications lack the ambient intelligence functionality so far, they are just oriented on data collection and processing from a large environmental area. The collected data are broadcasted to a central point, where they are used as support for decision making of certain persons with various responsibilities related to the area monitored. At the end of the second part, we explain importance of ambient intelligence applications for certain types of outdoor activities and we describe a scenario how ambient intelligence applications over a large-scale wireless sensor networks can be beneficial there.

 ISBN: 978-1-61208-231-8

The third part of the paper sketched briefly some ideas for functionality of large-scale ambient intelligence applications for outdoor activities support. Fourth part of the paper is a summary of presented ideas with a view towards further research.

II. RELATED WORK

Outdoor-oriented applications of Ambient Intelligence approaches should be undoubtedly based on recent achievements in the area of wireless sensor networks. Let us describe shortly a few representative related works in this area, in the second part of this chapter we shall bring an overview of true large-scale outdoor (or environmental) applications based on sophisticated wireless sensor networks.

A. Wireless Sensor Networks

Tremendous effort has been devoted recently to the area of sensor networks and their important applications, as mentioned in [5]. A wireless sensor network is usually a combination of low-cost, low-power, multifunctional miniature sensor devices consisting of sensing, data processing, and communicating components, networked through wireless links [5]. In a typical application, a large number of such sensor nodes are deployed over an area with wireless communication capabilities between neighboring nodes.

There is a number of works dealing with technical possibilities of sensor networks. The book [5] lists a number of results, oriented on context-awareness of sensors and sensor networks. The idea behind context-awareness is, that if sensors could know more about their own context, then they could adapt their behavior and function only when needed and to the extent adequate to the current circumstances. This aspect can be important also for power consumption by the sensor. A lot of work has been done by [6][7][8], interesting survey [9][10]. These works are mainly surveys of recent results in the wireless sensors area and their applications in wireless sensor networks. An excellent survey of environmentally-oriented wireless sensor networks has been written by Corke and his colleagues [11]. They review recent experiments with wireless sensor networks for environmental and agricultural applications; they also provide an interesting critical review of recent research and considers future challenges and opportunitiesin the area of environmental monitoring. A comprehensive, yet bit older, survey of wireless sensor networks applications was written by Arampatzis, Lygeros, and Manesis [12]. They try to survey the numerous applications that utilize wireless sensors, or wireless sensors networks and classify them in five appropriate categories, such as military applications, or environmental monitoring.

B. Large-Scale Environmental Applications

Among a number of recent interesting large-scale environmental applications, we can mention the FieldServer Project [13], and the Live E! Project [14].

The FieldServer Project is oriented on development and networked applications of so-called Field Servers. A Field Server [13] is a wireless sensor network that will enhance the monitoring of environmental factors by allowing sensing nodes to be located at precise locations in fields, reducing overhead installation costs, and allowing for real-time data collection. In Japan, Field Servers were developed for applications at farms. They produce real-time images for security guards, and environmental data for farming. Scientists such as agronomists, physiologists and ecologists can exploit high-resolution real-time images in order to react on any specific situation that deserves or requires some intervention in the environment. Many types of Field Servers have been developed up to now.

The Live E! Project [14] is an open research consortium focused on sharing the digital information related to the living environment. Using the low cost weather sensor nodes with Internet connectivity, a nationwide sensor network was deployed [14]. The network has accommodated more than 100 stations. The application of this weather station network is intended for disaster protection/reduction/recovery and also as educational material for students.

According to Yang [15], watershed management administers water resources within a watershed for different water users. The ultimate purpose of watershed management plan is to maximize the profits of different users meanwhile reducing the possible conflicts that might occur between them. Watershed management can be very efficiently modelled using multi-agent systems, nevertheless, there is just a few works taking into account also catastrophic situations [16].

Some attempts to apply the Ambient Intelligence approaches to disaster management in general are presented in [17], where an architecture is proposed aiming to help in decision-making processes in disaster management. Here, several different environments are considered, namely a smart house, an airport and a paramedics unit assessing a victim of a nuclear disaster.

One of the most significant drivers for wireless sensor network research is without any doubt environmental monitoring. Its potential will not only enable scientists to measure properties that have not previously been observable, but also by ubiquitously monitoring the environment and supplying the related data to relevant supervising bodies they can create a basis of early warning systems for various environmental disastrous situations and their management. As Ruiz-Garcia et al. [18] point out, the relatively low cost of the wireless sensor networks devices allow the installation of a dense population of nodes that can adequately represent the variability present in the environment. They can provide various risk assessment information, for example alerting farmers to the onset of frost damage. Wireless sensor networks based fire surveillance systems were designed and implemented, as well. They can measure temperature and humidity, and detect smoke followed by early warning information broadcasting [19]. Sensors are able to consider certain dynamic and static variables such as humidity, the type of fuel, slope of the land, the direction and the speed of the wind, smoke, etc. They also allow determining the direction and possible evolution of the flame front.

However, apart from other similarly serious environmental disasters, floods are responsible for the loss of

 ISBN: 978-1-61208-231-8

precious lives and destruction of large amounts of property every year, especially in the poor and developing countries. A lot of effort has been put in developing systems which help to minimize the damage through early disaster predictions [20]. On the other hand, as drought periods, opposite to floods, cause lot of damage every year as well [21], also this problem deserves high effort. Interesting solutions to the problems can be found in [22][23] [24].

Cardell-Oliver and her colleagues [6] proposed a novel reactive soil moisture sensor network that reacts to rain storms in such a way, that frequent soil moisture readings were collected during rain (approx. every 10 minutes), but less frequent readings (once a day) were collected when it is not raining. The network includes a node with a tipping bucket rain gauge sensor and, in another part of the landscape, a group of nodes with soil moisture sensors. The node monitoring rain is separated from the nodes monitoring soil moisture, and yet these nodes need to share information, whilst minimizing the time spent sending, receiving and listening to messages.

C. Outdoor Activities Support

In order to support a person's activities outdoor, the geographic location must be identified as important contextual information that can be used in a variety of scenarios like disaster relief, directional assistance, context-based advertisements, or early warning the particular person in some potentially dangerous situations. GPS provides accurate localization outdoors, although is not very useful inside buildings. Outdoor to indoor and vice versa activities localization was investigated, e.g. in [25], by a coarse indoor localization approach exploiting the ubiquity of smart phones with embedded sensors.

Outdoor acting person's support should provide relevant and reliable information to users often engaged in other activities and not aware of some hazardous situations that he or she could possibly encounter. There are only a small number of attempts to solve the related dangerous situations that can be described using the following scenario:

A user appears in a natural environment performing her/his working mission, a kind of leisure time activity (hiking tour, mountaineering, cycling, etc.), or because of being an inhabitant of the area. A sudden catastrophic situation (storm, flash flood, debris flow, etc. could put the person in a risky, if not a life endangering situation. A federated wireless sensor network is ubiquitously monitoring the area and estimating the possible appearance of a dangerous situation. If necessary, the network will proactively broadcast an early warning message to the user, offering her/him related navigation services supporting escape from the dangerous situation.

In the literature, there is only a handful of articles oriented towards a kind of a service to the potentially endangered persons in a natural environment; however, the helpful information to the potentially endangered person is never such complex as we intend to provide in our approach.

For instance, there are some attempts of preventing children from potentially dangerous situations in an urban environment. Probably the first ubiquitous system to assist the outdoor safety care of the schools kids in the real world is described in [26]. The research described there was focused on designing a ubiquitous kid's safety care system capable of dynamically detecting possible dangerous situations in school routes and promptly give advice to kids and/or their parents in order to avoid or prevent some possible dangers. To detect the dangerous situations, it is essential to get enough contexts of real environments in kids' surroundings. This is based on two basic assumptions: (1) a big number of sensors, RFID tags (Radio Frequency Identification tags), and other information acquisition devices are pervasively distributed somewhere in and near school routes, and (2) a kid should carry or wear some devices that can get surrounding context data from the above pervasive devices.

A number of papers are devoted to various solutions for tourist assistance, mainly oriented on context-aware tourist navigation on their routes. The usual approach [27][28] is in deployment of intelligent agents, which collectively determine the user context followed by retrieving and assembling simple information that are wirelessly transmitted and displayed on a Personal Digital Assistant (PDA). However, these tourism oriented applications are usually deployed for navigational purposes, without having capabilities of warning the user from potentially dangerous situations that can appear during their routes.

III. RESEARCH TO BE PERFORMED

The environmentally-oriented wireless sensor networks [29] are mature enough to become a basis for more complex support of various outdoor activities. As Efstratiou [30] pointed out, wireless sensor networks are more and more seen as a solution to large-scale tracking and monitoring applications, but, these networks are usually designed to serve a single application and collected information is commonly available to one authority, usually to the owner of the sensor network.

The usual situation in wireless sensor networks applications is that these networks are just collecting - although usually on a very advanced sophisticated level - data from the environment, with further broadcasting them into some central office for decision support of certain specialists responsible for the area monitored by the sensor network. We believe that we can and must want more from them. For instance, if an intelligent system is deployed over the sensor network with the purpose not only to broadcast the collected data somewhere, but also to provide some processing of the data, evaluation of certain patterns in them significant for certain typical or even unexpected situations in the monitored environment, the whole system would be able to provide at least some early warning messages for people located in the monitored area in order to prevent them from potential endangerments.

According to Efstratiou [30], *the vision for the future generation of sensor networks is of a world where sensing infrastructure is a shared resource that can be dynamically re-purposed and re-programmed in order to support multiple applications. Furthermore, multiple sensor networks (possibly owned by different authorities) can be combined in*

 ISBN: 978-1-61208-231-8

a federated fashion in order to create a more complete picture of the world.

We certainly share this opinion and propose a research, oriented not only on certain combination of sensor networks, as Efstratiou proposes, but also on a design and deployment of an ambient intelligence system over a large-scale environmental wireless sensor network in a potentially risky natural environment that will perform the following tasks:

- Monitoring the usual hydro-meteorological parameters of the environment (air pressure, temperature, humidity, soil moisture, etc.),
- Monitoring indications of possible dangerous situations (seismoacoustic signals, smoke, water on unusual places, etc.),
- Monitoring appearance and movement of animals and human beings in the area,
- Evaluating the data collected from the sensor network and identifying possibly dangerous situations,
- Identification of possibly endangered human beings in the area under monitoring,
- Attempting to contact the persons in danger possibly via their mobile devices and starting to provide all the necessary information and knowledge support aiming to help them escape from the dangerous situation (including eventual alarming of a rescue squad.)

As an example of a system that is in a sense a good candidate to be enhanced according to our just mentioned ideas, we could refer to [31]. The deployed sensor network aimed to assist the geophysics community preventing them from possible dangerous situations. In contrast with at that time existing volcanic data-acquisition equipment the used nodes of the sensor network were smaller, lighter, and consumed less power. The resulting spatial distribution greatly facilitated scientific studies of wave propagation phenomena and volcanic source mechanisms. Certainly, we can imagine a number of potentially dangerous situations that can endanger people working closely to the volcano. Enhancing the purely geophysical sensor networks by the features mentioned above could improve the safety of working near the volcano.

Another example belongs also to the area of potentially dangerous workplaces. The result of [32] seems to be one of those attempts that aimed directly at developing a sensor networks for monitoring possible dangerous situations in a large yet closed environment - a coal mine. Nevertheless, the experience with early warning sensor network in a Chinese coal mine is very good and inspirational [32].

IV. CONCLUSION AND FUTURE WORK

Our recent project *SMEW: Smart Environments at Workplaces* is oriented on bringing more intelligence to workplaces in general, but it has been oriented prevailingly on indoor working activities. Extending the approaches already developed in its scope to selected outdoor activities seems to be very challenging and useful.

Implementation of the ideas sketched in the paper still needs a lot of future work. We are working recently on a multi-agent architecture capable to process data provided by the underlying wireless sensor network in such a way that a model of the monitored environment will be created as a basis for further steps of the whole systems. Based on the created model, the multi-agent architecture should by capable to identify any deviation from the expected state of the environment, decide about possible action to be launched, and communicate with any person appearing in the potentially dangerous situation throughout the environment. Of course, at least the following research tasks must be solved:

- Design of the multi-agent architecture over the wireless sensor network implemented throughout the outdoor environment;
- Employment of a suitable decision-making mechanism that will serve in selecting the most appropriate actions to be possibly launched;
- Decide about the most appropriate way of communication with potentially endangered persons appearing in the monitored environment;
- Implement the multi-agent architecture over a real and carefully chosen large-scale wireless sensor network in a real outdoor environment (a forest, a watershed, or any other suitable environment) and evaluate it.

Ambient intelligence approaches have recently proven their usefulness when implemented indoor (intelligent homes or households). We are convinced that outdoor implementations have a large applicability as well and can be at least equally useful.

ACKNOWLEDGMENT

This work was supported by the Czech Science Foundation project GACR P403/10/1310 „*SMEW – Smart Environments at Workplaces*“.

REFERENCES

[1] M. Iqbal, H. B. Lim, W. Wang, and Y. Yao, “A sensor grid infrastructure for large-scale ambient intelligence”, in 2008 Ninth International Conference on Parallel and Distributed Computing, Applications and Technologies, pp. 468-473, IEEE, 2008.

[2] P. Mikulecky, K. Olsevicova, and D. Ponce, “Knowledge-based approaches for river basin management”, Hydrol. Earth Syst. Sci. Discuss., 4, pp. 1999–2033, 2007.

[3] P. Mikulecký, D. Ponce, and M. Toman, “A knowledge-based decision support system for river basin management”, in River Basin Management II, C.A.Brebbia, Ed., Southampton: WIT Press, 2003, pp. 177-185.

[4] P. Mikulecký, D. Ponce, and M. Toman, “A knowledge-based solution for river water resources management”, in Water Resources Management II, C.A. Brebbia, Ed., Southampton: WIT Press, 2003, pp. 451-458.

[5] S. Loke, Context-Aware Pervasive Systems, Boca Raton: Auerbach Publications, 2007.

[6] R. Cardell-Oliver, K. Smettem, M. Kranz, and K. Mayer, “A reactive soil moisture sensor network: Design and field evaluation”, Int. Journal of Distributed Sensor Networks 1, pp. 149-162, 2005.

 ISBN: 978-1-61208-231-8

[7] E. Elnahrawy and B. Nath, "Context-aware sensors", in Proc. 1st European Workshop on Wireless Sensor Networks, pp. 77-93, 2004.

[8] Q. Huaifeng and Z. Xingshe, "Context-aware Sensornet", in Proc. 3rd International Workshop on Middleware for Pervasive and Ad-Hoc Computing, Grenoble, ACM Press, pp. 1-7, 2005.

[9] I. F. Akyldiz, W. Su, Z. Sankarasubramaniam, and E. Cayrici, "A survey on sensor networks", IEEE Communications Magazine 40, pp. 102-114, 2002.

[10] D. Puccinelli and Haenggi, M., "Wireless sensor networks: Applications and challenges of ubiquitous sensing", IEEE Circuits and Systems Magazine, pp. 19-29, 3rd Quarter 2005.

[11] P. Corke, T. Wark, R. Jurdak, W. Hu, P. Valencia, and D. Moore, "Environmental wireless sensor networks", Proceedings of the IEEE, Vol. 98, No. 11, pp. 1903-1917, November 2010.

[12] Th. Arampatzis, J. Lygeros, and S. Manesis, A Survey of Applications of Wireless Sensors and Wireless Sensor Networks, in Proc. of the 13th Mediterranean Conference on Control and Automation, Limassol, Cyprus, pp. 719-724, June 2005.

[13] S. Ninomiya, T. Kiura, A. Yamakawa, T. Fukatsu, K. Tanaka, H. Meng, M. Hirafuji, Seamless Integration of Sensor Network and Legacy Weather Databases by MetBroker, In 2007 International Symposium on Applications and the Internet Workshops (SAINTW'07), IEEE, p. 68, 2007.

[14] S. Matsuura, et al., LiveE! Project: Establishment of Infrastructure Sharing Environmental Information. In 2007 International Symposium on Applications and the Internet Workshops (SAINTW'07), IEEE, p. 67, 2007.

[15] I.-C. Yang, Modeling Watershed Management with an Ecological Objective - A Multiagent System Based Approach. PhD Dissertation, University of Illinois at Urbana-Champaign, 2010.

[16] L. Brouwers, K. Hansson, H. Verhagen, and M. Boman, Agent Models of Catastrophic Events. In Proceedings of Modelling Autonomous Agents in a Multi-Agent World, 10thEuropean workshop on Multi Agent Systems, Annecy, 2001.

[17] J.C. Augusto, J. Liu, and L. Chen, Using Ambient Intelligence for Disaster Management. In Knowledge-Based Intelligent Information and Engineering Systems, Proc. KES 2006, LNCS 4252, Berlin and Heidelberg: Springer, pp. 171-178, 2006.

[18] L. Ruiz-Garcia, L. Lunadei, P. Barreiro, and J.I. Robla, A Review of Wireless Sensor Technologies and Applications in Agriculture and Food Industry: State of the Art and Current Trends. Sensors 9, pp. 4728-4750, 2009.

[19] J. Lloret, M. Garcia, D. Bri, and S. Sendra, A Wireless Sensor Network Deployment for Rural and Forest Fire Detection and Verification. Sensors 9, pp. 8722-8747, 2009.

[20] V. Seal, A. Raha, S. Maity, et al., A Simple Flood Forecasting Scheme Using Wireless Sensor Networks. International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) Vol.3, No.1, pp. 45-60, 2012.

[21] H. - Y. Kung, J.-S. Hua, and C.-T. Chen, Drought Forecast Model and Framework Using Wireless Sensor Networks. J. of Inf. Science and Engineering 22, pp. 751-769, 2006.

[22] R. Marin-Perez, J. García-Pintado, and A. Skarmeta Gómez, A real-time measurement system for long-life flood monitoring and warning applications. Sensors 12, pp. 4213-4236, 2012.

[23] Y. Zhang, L. Luo, J. Huo, and W. Zhu, An Eco-Hydrology Wireless Sensor Demonstration Network in High-Altitude and Alpine Environment in the Heihe River Basin of China. Wireless Sensor Network, Vol. 4 No. 5, pp. 138-146, 2012.

[24] E. Basha and D. Rus, Design of Early Warning Flood Detection Systems for Developing Countries, in Proceedings of the Conference on Informations and Communication Technologies and Development, Bangalore, India, 2007.

[25] A. Parnandi, K. Le, P. Vaghela, A. Kolli, K. Dantu, S. Poduri, and G. S. Sukhatme, Coarse In-Building Localization with Smartphones, Proc. of the MobiCASE 2009, pp. 343-354, 2009.

[26] K. Takata, Y. Shina, H. Komuro, M. Tanaka, M. Ide, and J. Ma, Designing a Context-Aware System to Detect Dangerous Situations in School Routes for Kids Outdoor Safety Care, in L.T. Yang et al. (Eds.): EUC 2005, LNCS 3824, pp. 1016-1025, Berlin: Springer, 2005.

[27] G.M.P. O'Hare and M.J. O'Grady, Gulliver's Genie: a multi-agent system for ubiquitous and intelligent content delivery, Computer Communications 26, pp. 1177–1187, 2003.

[28] O. Krejcar, Threading Possibilities of Smart Devices Platforms for Future User Adaptive Systems, in Intelligent Information and Database Systems, Berlin: Springer, pp. 458-467, 2012.

[29] J. K. Hart and K. Martinez, Environmental Sensor Networks: A revolution in the earth system science?, Earth-Science Reviews 78, pp. 177 – 191, 2006.

[30] Ch. Efstratiou, Challenges in Supporting Federation of Sensor Networks, in NSF/FIRE Workshop on Federating Computing Resources, 2010.

[31] G. Werner-Allen, K. Lorincz, M. Welsh, O. Marcillo, J. Johnson, M. Ruiz, and J. Lees, Deploying a wireless sensor network on an active volcano. IEEE Internet Computing, 10(2), pp18-25, 2006.

[32] X. Wang, X. Zhao, Z. Liang, and M. Tan, Deploying a Wireless Sensor Network on the Coal Mines, in Proceedings of the 2007 IEEE International Conference on Networking, Sensing and Control, London, UK, pp. 324-328, April 2007.

 ISBN: 978-1-61208-231-8