Information

Educating on Wireless Solutions for Environmental Monitoring

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Abstract—Environmental monitoring is of growing interest around the globe and there is a clear need for better education in this area. However, the progress is incredibly fast here and wireless sensor networking is a relatively new area of research, so no standard curricula are available yet. In 2012, the International School "Sustainable Wireless ICT Solutions for Environmental Monitoring" was organized by the International Center for Theoretical Physics (ICTP) in collaboration with a few other entities. The school aimed at exposing young scientists from around the world to the newest wireless solutions for environmental monitoring. The school was followed by an awareness conference, which aimed at identifying issues that would benefit from a wider scientific collaboration. This paper begins with general information about the ICTP educational activities related to wireless technologies and applications. Then it focuses on the program of the school and conference. It shows what topics were included (and what were disregard) and what approaches were applied in order to achieve the best results with the (very) limited resources available. Details are omitted here as the complete materials of the both events are available at the Internet (http://wireless.ictp.it) under the Creative Commons.

Keywords—DIGI, Fundación Escuela Latinoamericana de Redes, EsLaRed, International Center for Theoretical Physics, National Institute of Telecommunications, Network Startup Resource Center, NIT, wireless sensor networks, WSN.

1. Introduction

Wireless sensor networks are attracting more and more attention. Collection of empirical data has been always enabling advances in science and contributing to improvements of the quality and safety of life. However, until recently, especially in environmental applications, it is based mainly on expensive equipment and wired infrastructures necessary to collect the data in one point where they could be further processed. The data collection was a costly and difficult task, limited to a relatively small number of fixed, sparsely distributed locations, and maintained by organizations with large budgets. As a result, the data gathered are often incomplete, especially when concerning developing countries and remote areas. Wireless sensor networks (WSN) could change that radically. It is a low-cost and low-power technology that does not require any pre-existing infrastructure and can be deployed in most the remote regions. The vast range of sensors that can be connected to the devices makes them flexible for many different applications, such as air-quality, water-quality and soil-moisture monitoring.

This paper describes the 2012 school on "Sustainable Wireless ICT Solutions for Environmental Monitoring" and "International Awareness Conference on Sustainable Wireless Solutions for Environmental Monitoring" where the participants could discus their cases with the participation of invited experts. These events were organized at the International Centre for Theoretical Physics (ICTP) in Trieste, Italy, from February 6 to 24. That was a common activity of ICTP and the International Telecommunication Union (ITU) Development Bureau, with collaboration of the International Telecommunications Union (ITU), national research entities such as the National Institute of Telecommunications (Poland), Fundación Escuela Latinoamericana de Redes – EsLaRed (Venezuela), and the Network Startup Resource Center – NSRC (Oregon, USA). This short report offers some details on the school and on the case studies discussed there and starts with a brief information about the ICTP and its activities in the field of radio.

2. ICTP

The mission of Abdus Salam International Centre for Theoretical Physics (ICTP) is to foster advanced studies and research in developing countries. Founded by Abdus Salam (Nobel Laureate in Physics), ICTP operates under a tripartite agreement among two United Nations Agencies, UNESCO and IAEA, and the Italian government. While the name of the Centre reflects its beginnings, its activities today encompass most areas of theoretical and applied sciences, including information and communications technologies (ICT).

ICTP embraces a large community of scientists worldwide. Since its creation, the Centre has received about 120,000 scientists, half of whom have come from the developing world. Visitors have represented some 180 nations and 40 international organizations. In recent years, more than 6,000 scientists visit ICTP annually to participate in its research and training activities, and to conduct their own research. The ICTP team is convinced that knowledge sharing, open access, and know-how transfer are critical for sustainable development. Appropriate training is fundamental and the most cost-effective long-term investment and ICTP has been playing a leading role in the field. ICTP con-

Fig. 1. The ICTP Miramare campus (courtesy ICTP).

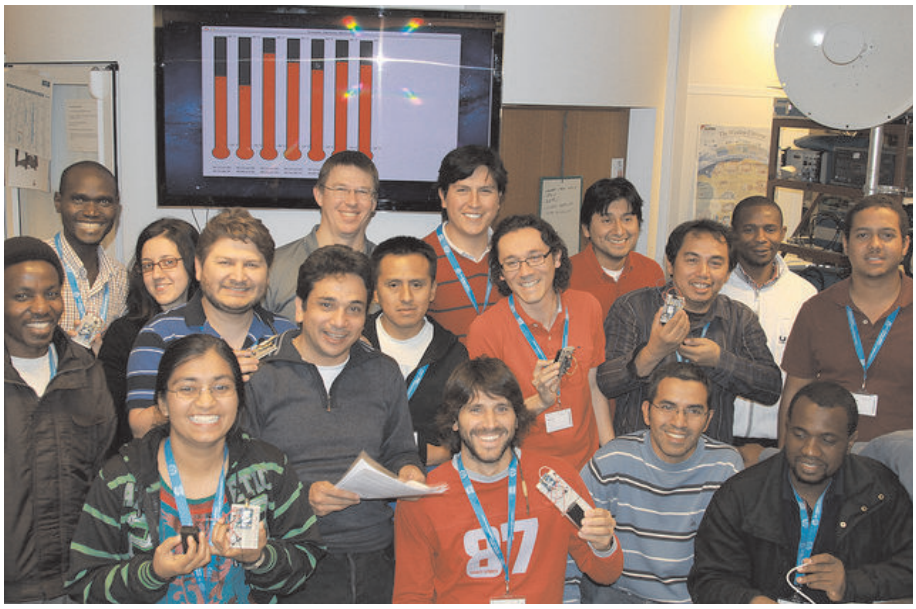

Fig. 2. Group of the participants in the 2012 WSN School at the ICTP Gulliemo Marconi Laboratory. Some of them with wireless sensor nodes in hands (Photo: M. Zennaro).

siders the "training trainers" at academic level as its major mission.

Since 1996, it has established extensive *in-situ* training programs on wireless communications technologies to facilitate Internet access to unconnected academic and other institutions. Its Telecommunications/ICT for Development Laboratory (the former Aeronomy and RadioPropagation Laboratory) has held some 40 training activities, attracting more than 1600 participants from Africa, Asia, Oceania, Europe, and the Americas, as well as from international organizations.

Starting from 1998, the ICTP has offered an annual school, focused on wireless networking for developing countries for local-area networks in academic campuses. Topics include theoretical and practical training on low-cost radio techniques, planning, installation, and maintenance of short- and medium-distance point-to-point digital radio links. The schools have used modern technologies and teaching techniques. Emphasis is put on hands-on laboratory sessions and in-the-field practical exercises. In addition to activities held at ICTP headquarters in Italy, training has been also given in developing countries. From 2000 to 2011,

Fig. 3. Exercises with programming of wireless sensor nodes: (a) hard work and (b) joy of success (Photo: M. Zennaro).

Table 1
Topics included in the program

General topic lectures (10% of total time)	Specific topics & case studies (40% of total time)	Hands-on exercises (50%of total time)
• dB Math • Telecommunications • Protocols • IPv6 • Cloud networks • Bb Internet • Wireless Communities • Wireless Sensor Networks (WSN) Applications • RF Channel & Modulation • Transmission lines • Antennas • Radio propagation • Radio Measurements • EM Co-existence • Wireless Security • Spectrum management • Regulatory issues	• Planning a radio link • Intro to RadioMobile • Wireless network Protocols • Introduction to WiFi • Intro to IEEE 802.22 • Configuration • Outdoor installations • Off-grid powering • Mesh Networking • Network monitoring Tools • Wireless Mesh Networks • Low Power WiFi • WT KIT • Community networking • Testbeds • Simple and Advanced WSN • XBee, ZigBee, iDigi • Gateways • Building Environmental Sensor Network	• Antenna Building • Antenna Testing • Cable testing • WiFi links • WSN planning • WSN programing • WSN deploying • AP and client configuration • Link Budget planning • RadioMobile tool • Indoor links • Indoor campus networks • Outdoor & Long Distance WiFi • Mesh Networks • Network monitoring • Channel configuration • Spectrum use • Outdoor Links • Doorbell Project • Solar power • Sensing events • Sensing light • Sensing temperature • Sensing moisture

the ICTP group has been involved in training activities on wireless for broadband connectivity and computer networking in Benin, Cameroon, Ghana, India, Indonesia, Kenya, Nigeria, Peru, Sudan, Venezuela, and Zimbabwe, to name a few countries.

Starting from 2007, the school's program included the topic of "Wireless Sensor Networking". The potential applications of this technology included water-quality monitoring, intelligent irrigation, and disaster warning, the topics extremely relevant to rural and remote areas. The Radio Science Bulletin has published selected presentations from the Previous ICTP School held in 2011 [1], and training issues related to wireless environmental monitoring have been discussed in [2] .

3. The 2012 Activities

An international team of some 10 lecturers presented at the school and led practical exercises. They came from Denmark, Germany, Italy, Spain, Switzerland, United States,

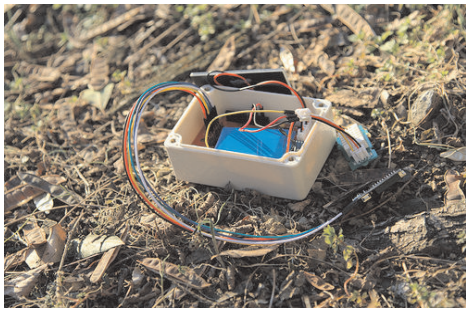

Fig. 4. Experimenting with wireless sensor networks (Photo: M. Zennaro).

Poland, South Africa, and Venezuela. Their names are listed at the ICTP homepage (http://www.ictp.it/).

The school consisted of lectures, individual programming of wireless sensor nodes, experimenting with wireless sensor networks in the laboratory and in the field, as well as collective discussions on specific topics. Table 1 lists major topics included in the School program. The experiments took about a half of the total time. The Company "DIGI" generously donated some of the materials for the workshop and provided with two lecturers. The students will take back home what they've learned to build a wide variety of environmental systems for agriculture, solar schoolhouses, water quality, radiation sensing, energy, emergency response and other purposes. The detailed list of lectures is available at the ICTP homepage, together with all the material presented there.

A total of 30 participants from more than 20 countries participated. The students were educators, scientists and engineers from Malawi, Nicaragua, India, Ecuador, Venezuela, West Gambia, Philippines, USA, South Africa, Tanzania, Jamaica, Columbia, Ukraine, Argentina and Albania. Many of them presented practical case studies from their countries. These covered the following wireless sensor networks in environmental and health applications in remote areas using radio:

- WSN in water quality monitoring (Jamaica)
- WSN at breeder reactor facilities (India),
- Environmental Monitoring (Italy),
- Sensing & control in bioreactors (S. Africa),
- Wireless Sensor Network (Italy),
- VSAT & WiLD networks in Amazon jungle (Peru),
- SMS for remote data transmission (USA),
- WSN at a University (Zimbabwe),
- SMS for health applications (USA),
- Smart metering in (Colombia),
- Nigerian Experience (Nigeria),
- Integrating WSN with conventional system (Argentina),
- Monitoring nuclear reactor (Ukraine).

4. Conclusions

Environmental monitoring could enable important advances in science, agriculture, forestry and disaster mitigation. However, only limited research is currently carried out in many countries using modern technologies. The School has exposed participants to new wireless technologies, amenable also for Developing Regions. These technologies can work with low power and are not dependent on any existing electrical network. These are low- cost sustainable solutions. Once the environmental data are collected in remote areas (volcanoes, mountains, lakes, etc.), they have to be transmitted to a central database for processing and further analysis. The cost of providing the wiring infrastructure to support such transmissions is simply out of the question. In the last couple of years we have witnessed an incredible evolution of wireless technologies that can provide a viable solution. The 2012 School presented the use of various low-cost and sustainable wireless technologies. A compound of these technologies is probably the best solution not only to build environmental sensor networks but also to allow scientists to communicate. Training at the level of Academic and Research institutions on the subject of the School is essential to develop sustainable human capacity. In the Awareness Conference, workshop participants and Telecom Administrations, Regulators, Operators, Researchers and international experts presented their cases and discussed advanced wireless solutions for environmental monitoring. The 2012 events have been well received by all participants. On that basis, the organizers have planned similar activities for 2013.

The full documentation of the 2012 events (available under the Creative Commons license) can be found at: http://wireless.ictp.it.

References

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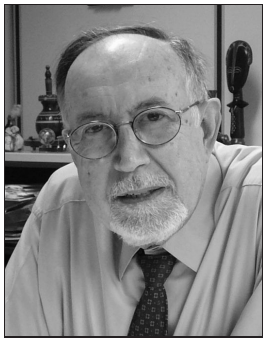

Sandro Radicella is the Head of the Telecommunications/ICT for Development Laboratory (former Aeronomy and Radiopropagation Laboratory) of the Abdus Salam International Centre for Theoretical Physics (ICTP). He has published more than 1400 papers in the fields of aeronomy and radiocommunications. The most important achievement of his recent scientific production is the development of models of vertical distribution of electronic density in the ionosphere in collaboration with colleagues from the ICTP and of the University of Graz, Austria. One of these models is being used by the European Space Agency in areas related to the use of EGNOS and the new GALILEO satellite system. He has organized and directed since 1989 a series of Colleges, Schools and Workshops, for participants mainly from developing countries, in the fields of Ionospheric Physics, Radiocommunications and Information and Communication Technology. He has been awarded in 2001 with the Doctor Honoris Causa degree from the University of Bucharest, Romania, and in 2005 with the Doctor of Science degree Honoris Causa from the Obafemi Awolowo University in Ile-Ife, Nigeria.

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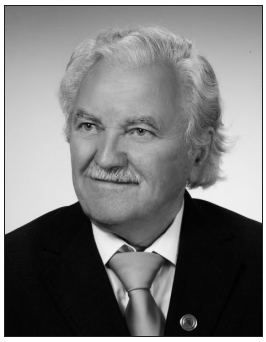

Ryszard Strużak is a Professor at NIT, a Co-Director of ICTP Schools on Wireless Networking, a Life Fellow of IEEE. He authored/co-authored many papers as well as 10 patents in the areas of radiocommunications, spectrum management, and electromagnetic compatibility. He was a consultant to ITU, IUCAF, PWC, UNOCHA, WB, and to industry and government agencies in several countries including Switzerland, UK and USA. He served as the Head of Technical Department and Acting Assistant Director at CCIR-ITU, a Visiting Professor at Institut National Polytechnique de Toulouse, a Professor at the University of Information Technology and Management at Rzeszow, and at the Wrocław University of Technology, and the Editor-in-Chief and Chair of Editorial Board, Global Communications. He co-founded and chaired the Electromagnetic Compatibility (EMC) Laboratories at NIT and the International Wrocław Symposium on EMC (now EMC Europe). He was elected to leading positions in international organizations: ITU, URSI, IEC and CISPR; among others he served as the Vice-Chairman of ITU Radio Regulations Board. He was elected a member of New York Academy of Science and an Academician of the International Telecommunication Academy. He was honored by the ITU Silver Medal, by the IEEE EMCS Special Symposium Recognition Award, by the Prize Paper Award at International EMC Symposia (twice), and by the highest national awards and decorations.

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Marco Zennaro received his M.Sc. degree in Electronic Engineering from University of Trieste in Italy. He defended his PhD thesis on "Wireless Sensor Networks for Development: Potentials and Open Issues" at KTH-Royal Institute of Technology, Stockholm, Sweden under the supervision of Prof. Bjorn Pehrson. His research interest is in ICT4D, the use of ICT for Development. In particular, he is interested in using Wireless Sensor Networks in Developing Countries. He is one of the authors of "Wireless Networking in the Developing World", which has been translated in 6 languages, and of "Science Dissemination using Open Access", available in English and Spanish. He has been giving lectures on Wireless technologies in more than 20 different countries. He is the editor of wsnblog.com.

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