Project proposal to SPIDER: Online Water Quality Monitoring

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1. Detailed description of the subject

One of the Millennium Development Goals (MDGs) specifically addresses halving the proportion of the global population that lacked sustainable access to safe drinking water supply and basic sanitation by 2015, compared with the 1990 levels. The Project Task Force on Water and Sanitation has stressed that achieving the water and sanitation target and investing in water infrastructure and management are both crucial to the achievement of all MDGs. The experience is also salient in view of the new Decade Water for Life established by the UN agencies for the period 2005-2015.

Access to clean water is widely considered as a Human Rights issue. However, insufficient protection of water sources, non-existent quality monitoring or use of quality monitoring procedures with considerable delays, as well as inadequate treatment, still puts the community at risk of contracting infectious diseases. UNDP and UNICEF studies show that children and elderly are more susceptible to waterborne diseases.

Existing monitoring procedures are currently entirely manual, based on sampling and subsequent analyses in water laboratories. This often causes considerable delays in the monitoring process. The quality of the monitoring process would benefit significantly if at least some basic parameters would be monitored on-line. This will enable the monitoring groups to provide an early warning system that can trigger appropriate treatment. The trend towards on-line monitoring has been growing stronger in the developed world during the last decade [WEKNOW2005] .

In cooperation with the concerned authorities, initially in Malawi and Tanzania, we propose to develop, deploy and demonstrate a self-sustained, low-cost, on-line water quality monitoring system. We have chosen to start our work in Malawi and Tanzania due to the fact that 1) water management is recognized as a critical issue in these countries, 2) we already have all the necessary human and organizational contacts established, and 3) these organizations are well prepared for carrying out this kind of development. A recent overview on the situation in Malawi is available in [UNECA 2004]. A somewhat older but in general still valid overview from Tanzania is available in [IUCN1993]. More recent specific data is available via the Tanzania Government website [www.gov.tz]

Our proposal also includes activities intended to spread awareness of the results, capacity building to reinforce relevant education and training programs and a feasibility study on how to empower and stimulate local entrepreneurs to establish businesses based on the system. These activities will be organized as reinforcements of ongoing related activities at University of Malawi and Dar es Salaam Institute o Technology.

The subjects involved are multi-disciplinary. Questions to address include 1) what parameters to monitor, 2) what sensors to use to measure these parameters, 3) how to design a self-sustained monitoring system, 4)where and how to deploy the monitoring system and 5) what competences and activities are required to ensure sustainable operation of the system.

1. *Water Quality Standards*

The World Health Organization (WHO) has published guidelines for drinking water quality [WHO2004]. The guidelines include those parameters to be monitored and recommendations for acceptable limits for different contaminating substances. There are also national guidelines and rules issued by national governments focusing on local parameters. The actual monitoring of water quality and water treatment is mostly handled on a district or municipality level. Due to lack of resources in many development countries, there are NGOs and donor organizations involved, often with incomplete scientific knowledge about water quality management.

In Malawi, the Malawi Bureau of Standards specifies the physical, biological, organoleptic, and chemical requirements for water quality. These guidelines include parameters such as turbidity, pH, conductivity, hardness, sulphates, nitrates, total dissolved solids and oxidation-reduction potential (ORP).While these water quality parameters are very critical, analysis is done in laboratories using standard methods. This is expensive, laborious and time consuming. The use of sensors to generate water quality data is therefore an interesting area that needs research.

Basic parameters to monitor includes turbidity, pH and redox potential. Other parameters will be considered pending the availability of low-power-consuming sensors.

2. *The availability of sensors*

A market survey of available sensors that can be used for on-line measurements will be an important part of the project. The possibility to manufacture such sensors locally will be discussed. The sensors to use in this project need to be robust, have low power-consumption and low-cost. [Ramanathan2006].

3. *Monitoring systems*

A promising emerging technology for environmental monitoring and management systems is wireless sensor networks (WSN). A WSN is a self-configuring network of small sensor nodes communicating among themselves using radio signals, and deployed in quantity (from tens to thousands) to sense the physical world. These networks provide a bridge between the physical world and the virtual world of information technology. They promise unprecedented and new abilities to observe and understand large-scale, real-world phenomena at a fine spatio-temporal resolution. This is so because one deploys sensor nodes in large numbers directly in the field, where the experiments take place. An interesting application of such networks is to monitor water quality. WSNs are capable of measuring diverse phenomena such as contaminant levels in water. As an example of a potential application, consider the incident of contamination spilling into the Songhua River in China, the main source of drinking water for many people. Determining rate of flow and sometimes direction of the river requires coordination of multiple sampling points. Sensors periodically taking samples at multiple locations along the river could determine the rate, quantity, and direction of contaminant flow using the distributed sensing and processing power of a wireless sensor network.

Researchers have pointed out that ICT4D projects have four main technological requirements in order to be successful: connectivity, low-cost equipment, appropriate user interfaces and power resilience [Brewer2005]. WSN satisfy these technology requirements as explained hereafter:

- Connectivity: wireless sensor networks do not depend on any preexisting infrastructure. They are able to reorganize automatically and they are resistant to partial failures. Because the communication between devices is independent from any external network there is no cost to communicate. Wireless sensor networks can also be used in delay-tolerant applications, which are good solutions in countries with poor infrastructures. Data gathered by the sensors can be stored in a memory in the gateway and then transmitted when the network becomes available. In this way no data is lost, and deployments are possible in rural environments that lack continuous or affordable network connectivity.

- Low-cost: over 100 OEMs or service providers worldwide currently offer or are developing WSN products. Worldwide deployments are expected to grow exponentially for the next 4 years from 2.5 millions to 126 billions devices and cost is expected to fall accordingly in the next years. WSN can be easily redeployed with no loss of investment and expanded when more funds become.

- Appropriate user interfaces: the data gathered from WSN are usually saved in the form of numerical data in a central base station. User interfaces are quickly being developed or already exist, to allow simple access and presentation of these large data sets. Web-based interfaces allow users to monitor or control WSN through a web browser. The product of the devices, being numerical data, can easily be synthesized into graphs, charts and spreadsheets and translated into local languages. Moreover, because the WSN devices themselves are simple, autonomous and self-configuring, they are much like appliance devices, where those installing the devices need little knowledge of their engineering, much like televisions and mobile phones. As such it is envisaged that these technologies will be widely adopted where other more complex technologies have been thwarted by the need for complex interfaces, such as Personal Computers, or more skilled users.

- Power: WSN can be designed so they require very little energy to operate. Sensor nodes often carry their own power sources (such as AA batteries) and may be equipped with effective power scavenging methods, such as solar cells.

To realize the benefits promised by Wireless Sensor Networks, a broad portfolio of successful deployments will be needed as a proof of concept. It is important that the portfolio of deployed networks is appropriate to the environment being investigated. Wider dissemination is needed to engage a greater audience for sensor development activities. Testbeds for systems to be deployed also should be setup. Such testbeds should produce data for scientific understanding and should help gaining experience on how new technologies work in realistic settings. Software should be developed that will enable scientists and the general public to obtain, visualize, and make use of real-time data from the deployed networks. International involvement and technology sharing should be encouraged, and collaboration in the establishment of common network infrastructure should be sought when appropriate.

2. Specific objectives and expected significance of the project in relation to the goals of SPIDER

1. Objectives

The objectives of the project are to:

1. Develop a water quality monitoring system
2. Deploy and demonstrate it at selected sites in Malawi and Tanzania.
3. Spread awareness of the results by workshops and courses
4. Make a feasibility study on how to empower and stimulate local entrepreneurs to establish businesses based on the system

Deliverables

The set of deliverables will include:

1. A series of reports and publications, including technical reports on the water quality monitoring system and a feasibility study of a startup in the area of water quality monitoring based on the system
2. A prototype for a water quality monitoring system based on wireless sensor network with a network gateway
3. Deployment of a system for water quality monitoring at a test site to be selected in the first phase of the project

4. A workshop on ICT for Water Quality Monitoring with invitations to all stakeholder
5. A project course on ICT for Water Quality Monitoring to be offered by universities in developing regions.

Significance in relation to the goals of SPIDER

This is how we fulfill the project evaluation criteria:

1. ***relevance***: Reduce by half the proportion of people without sustainable access to safe drinking water is part of the Millennium Development Goals.
2. ***Originality***: Wireless sensor networks are expected to become one of the most important Information Technologies. The number of applications are still few and the type of application we propose is unique.
3. ***Technology Transfer***: The project itself is organized to accomplish capacity building in the respective developing country, by including team members from local stakeholders. The awareness activities and the feasibility study on local entrepreneurship reinforce this transfer.
4. ***Probability of success***: the human network has been already established both in Malawi and Tanzania. We regard the project as realistic and expect to achieve its primary goals.

3. Working methods and time frame

This being a multidisciplinary project, different competences are needed. In particular, technical and water resource engineering skills are required.

The project will be divided into three phases:

1) Design and implementation of the Water Quality Monitoring System

2) Deployment, Test and Feasibility study

3) Evaluation and Dissemination of Results

The project is expected to start in August 2007 and finish in December 2009.

1. Phase 1

Design and implementation of the Water Quality Monitoring System: Aug 2007 - Jun 2008. In this phase we will organize a project team of students with relevant multidisciplinary backgrounds from the involved academic institutions to do the design supervised by the project partners. The team members will be selected in order to facilitate sustainability.

2. Phase 2

Deployment, Test and Feasibility Study: July 2008 to December 2008. Some members of the development team of Phase 1 will be engaged in the deployment, testing and feasibility study together with local personnel.

3. Phase 3

Evaluation and Dissemination of Results: January 2009 to December 2009. It is up to the project partners to make the evaluations and to disseminate the results.

4. The respective roles of the co-operating partners in carrying out the proposed project

What we propose is of general interest and the developing countries selected are chosen because we have the human and organizational networks well established in these countries.

1. Academic partners

KTH

Marco Zennaro, PhD student in communication systems at TSLab and associated with ICTP in Trieste where he is involved in activities related to the provision of network connectivity for research institutions in developing countries.. Marco will be the project manager and the coordinator of the technical design of the Water Quality Monitoring system.

Neda Farahbakhshazad, Research Associate in environmental engineering at the Department of Land and Water Resources Engineering. Dr. Farahbakhshazad will coordinate the water engineering aspects.

Terrence Brown, Docent in Innovation and Entrepreneurship,TSLab. will lead the feasibility study on entrepreneurship

Björn Pehrson, Professor in Telecommunication Systems at TSLab, will advise on technical issues and serve as administrative contact visavi SPIDER.

University of Malawi/Polytechnic

Harry Gombachika, Dean of Postgraduate Studies and Research of Malawi Polytechnic, Dr. Gombachika will act as a coordinator in Malawi. His responsibilities will include proposing local team members for the development work, discussing with the Malawi Ministry of Water and relevant Districts about the selection of a test site in Malawi, and organizing a workshop and a course offered by university of Malawi Polytechnic.

Ishmael Kosamu, Head of the Department of Physics and Biosciences, Malawi Polytechnic and involved in the (www.poly.ac.mw/centers/washted), will be responsible for the water engineering part of the project in Malawi and the entrepreneurship aspects of it.

Chifundo Tenthani, Associate Lecturer at Malawi Polytechnic, conducting research in water quality management.

DIT (Dar es Salaam Institute of Technology)
Amos Nungu, teacher at DIT Department of Computer Studies, PhD student at KTH and project manager of the Tanzania ICT4RD program. He will act as a coordinator in Tanzania. His responsibilities will include proposing local team members for the development work, discussing with the Tanzania Ministry of Water and relevant Districts about the selection of a test site in Tanzania, and facilitating the organization of a workshop and a course offered by DIT.

2. Public sector partners

Ministry of Water in Malawi and the Blantyre and Zomba districts
ICTP and KTH are working with University of Malawi to establish and interconnecting campus networks in Lilongwe, Blantyre and Zomba, to establish MAREN, the Malawian academic network and with the Malawi ISP Association (MISPA) to establish Internet Exchange points in Malawi. These partners are closely involved with the concerned water authorities in Malawi.

Ministry of Water in Tanzania and the Bagamoyo district
The Ministry of Water in Tanzania is a stakeholder in the Sida-funded ICT for Rural Development (CT4RD) program in Tanzania managed in cooperation by COSTECH, DIT and KTH. The ministry provides dark fiber along the Wami water supply pipeline to the ICT4RD program and have demonstrated an interest in on-line water quality monitoring.

5. Detailed account of available resources including all personnel and equipment

Human resource work volumes are expressed in manmonths (MM). The numbers below include both professional experts, faculty members and students on PhD and senior Master levels.

1. Phase 1: Design and implementation of the Water Quality Monitoring System

Time duration: August 2007 to June 2008. Estimated work volume: 40 MM

2. Phase 2: Deployment and Testing

Time duration: August 2008 to June 2009 Estimated work volume: 40 MM

3. Phase 3: Evaluation and Dissemination of Results

Time duration: August to December 2009 Estimated work volume: 20 MM

4. Budget

Total human resources: 100 MM.

Salaries for advisors in Sweden, technical and field personnel in the partner countries: 200k

Traveling: 11 trips: 300k

Equipment: includes two sets of ten motes, sensors for water parameters measurement and two gateways: 100k

Other Costs: consulting experts and bench fees: 150k

Total 750k

6. References

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