Report on Potential Application of WSN in Malawi

The purpose of this report is to asses the possibility for the Aeronomy and Radio Propagation Laboratory (ARPL) at the International Centre for Theoretical Physics: Abdus Salam (ICTP) and the Polytechnic of Malawi to develop a scientific collaboration. In particular, there is a focus in Wireless Sensor Networks (WSN) research and applications as it seems an interesting shortcut to positively impact the economy of the country.

This exploration phase has begun with a visit to the Malawi Polytechnic (further on referred as Poly) and target installations in the area around the southern city of Blantyre, where the Poly is located. The team was composed by *Kinnock Munthali*, head of the Physics and Biochemical Department, and *Ishmael Kosamu*, Chemistry Lecturer at the same department. Also participated visitors: *Fabio Beraldin* and *Claro Noda*, in mission for ICTP.

The report is organized as follow: first there is a brief introduction to the places and installations visited and then an outline of three potential applications of WSN. These are for a flooding alarm system in the Shire River, monitoring water cleaning in the Blantyre Water Board stations and finally tea processing in the Naming'omba Tea Estate. Then a few ideas are presented to illustrate how the collaboration would be orchestrated. The main goal is to utilize the technology to monitor and eventually automate the processes in a way that everyone involved benefits, while seeking sustainability. This is by no means a final document. Instead, its aim is to promote discussion of relevant ideas and contributions (correction?) from everyone involved.

Figure 1 shows the map of south Malawi, surrounded by Mozambique. During our stay, from the 5th to 11th of December 2006, we visited several areas as described below.

Fig. 1: Section of Malawi map showing southern region around the city of Blantyre.

Head Quarter of the Blantyre Water Board
Here is a small Intake Station which provides approximately 10 % of the water used in Blantyre. It also houses the main laboratories that supervise **physical**, **chemical** and **bacteriological** parameters to control water quality. The water comes from two small rivers: Namimba Stream and Mudi Stream and is collected in a small basin of around 1 km^2 or less. When the container fills up at the end of the rainy season (January-February) the surplus is returned to one of the rivers which ultimately go into the Shire.

Mwanza District
In the eastern side of the Mwanza region along the Shire River, approximately 60 km west northwest of Blantyre, we have visited two installations in order to take a glimpse at:

a) Siltation in the basin of the ESCOM Hydroelectric Facility
b) Intake and Processing Station of the Blantyre Water Board proving 90% of total water consumption. This is similar to the one near Blantyre city centre but much bigger.

Chikwawa District
Water level measurement in the Shire River, the goal is to create a local flood warning system.
We visited two measuring stations, or more precisely the remainder of them.
There have been two projects with similar objectives in the area. The fist back in the 80's and more recently there is the HYCOS project in Central Africa that reports to a South Africa Data Centre. None of the stations of this project in Malawi seems currently operational. For more details see the report from Fabio Beraldin.

NAMING'OMBA Tea Estate
A private owned Tea Estate planted with Tea, Maccadamia, Coffee and Tobacco. Inside there are two tea processing factories one of which is not functional at the moment. All located northwest of Thyolo town.

The tea industry is the larger employer in Malawi and the second most important branch of Agriculture, Malawi's prime economic asset. We had a tour in the factory by General Manager Mr. Roy Crawford, who described the facilities and the tea processing.

The WSN perspective

Flooding in the lower Shire River

South of Chikwawa during the raining season flooding occurs often. This is a wide area along the Valley of the Shire River where there is a need for a flood warning system. It would be roughly 150 km to monitor. Currently the water level data is taken manually. Figure 2 shows the northern region of the area to be monitored.

The long distances between the measuring stations and the relatively low quantity of them would eventually require design emphasis in the operational radio range of the nodes. The wireless network to make real-time data available seems feasible, technology choices to be discussed. The sound advantage of using sensor networks hardware is the low energy required, thus autonomy of measuring stations can be achieved at lower cost. The need to take power from the environment (photovoltaic most likely) and cost reduction would require adapted or reengineered sensors to be employed. Capacitive level sensors are an attractive choice: no moving parts (that is low maintenance) and low power are the key issues.

Fig. 2: View of the Shire River valley in Chikwawa, the river flows from right to left. In the bottom right, the level of water at the beginning of the raining season can be appreciated.

Moreover deploying sensors in the wild will require intensive testing of the system as there will be a sizeable deployment effort involved in the river valley. Also important is carefully sorting out weather and water proof housing for sensors hardware as well as dealing with vandalism of equipment, which is indeed common.

Among all potential applications considered this is, without any doubt, the most challenging one.

Water Board Intake Stations and Processing Plants

The Blantyre Water Board has two intake stations and processing facilities. A smaller one located near the centre of Blantyre and the main station located in Chikwawa by the Shire River, the last one accounts for 90% of the total water used in the city. Figures 3 and 4 show the intake stations and processing facilities in Blantyre and Chikwawa, respectively.

The water pumped from the rivers is first added a coagulant then passed through a set of pools for sedimentation, sand filtering and finally chlorination is performed. The process is monitored by taking samples manually on every step and analyzing them in the laboratory. The most frequent tests conducted are turbidity, ph and red-ox.

Fig. 3: Blantyre Water Board Facilities in town.

As far as automation of the lab is concern, we foresee the use of WSN possible. It's important to notice, though, that adapting commercial sensors to be used with WSN hardware or reengineering this sensors might prove challenging and time consuming.
On the other hand, we have heard more than once that the current method employed *beats all the established standards of international water cleaning regulations*. Therefore we do not see a legitimate need.

Although the installations give the impression of a save territory to deploy equipment, the long term sustainability of any effort in this direction is not clear, particularly from a financial point of view.

Fig. 4: Blantyre Water Board Facilities by Shire River in Chikwawa.

Tea processing in the NAMING'OMBA TEA ESTATE

Tea stem form sprouts of ever green small bush known as *Camellia Sinensis*. In order to make best possible tea from the leaves brought to factory, manufacturing process must be carried out efficiently which involves working within certain well defined limits of time, temperature, humidity etc.

World tea markets seem clearly expanding. Even in coffee nations like the US, the trend is reported: tea is becoming a mainstream beverage of choice for today's active, healthier lifestyle.
Among other reasons, tea is one of the few beverages that contains no sodium, fat, carbonation or sugar and is virtually calorie-free. There is scientific consensus on the benefits of tea to human health and an enhanced knowledge of nutrition and better distribution of this information to the mass market. But, moreover, it's *economical*.

On the other hand, this market is becoming more demanding in the last years. Packing companies are buying tea directly from the producers and entering into forward contracts, specifying exactly the type of teas they want. International regulations controlling acceptable levels of pesticides and other residues, health and hygiene, environmental concern, ethical issues like worker wages and minimum working age, among others, call for more awareness and competence from producers. All of which make measuring and monitoring an essential part of any tea factory operations.

In our visit to the Naming'gomba Tea State we have briefly discussed the possibilities of implementing some monitoring techniques using WSN. The following is a resume of how the factory functions and what we could do there. Mainly the interest currently lies in monitoring temperature, humidity and electricity consumption.

Fig. 5: Tea recently collected right before entering the factory.

The tea processed here is grown in the highlands of the Thyolo area. Plucked and brought to the factory in trails as shown in Figure 5. On its way the tea is very sensible. Outside temperature, solar radiation and compression are important parameters to keep under control to prevent oxidation and burning.

Monitoring humidity and temperature along production would permit to better estimate the quality of the tea been packaged and moreover control the processes. Probably the most convenient start point is controlling these parameters on the withering room, shown in figure 6. Fresh tea leaves are still alive and breathing which creates heat and causes oxidation. The time the tea remains there is of the essence. As oxidation starts within the tea leaf it leads the quality of the final product to drop remarkably. Currently the process last for 15 hours to get the moisture down to 70 %, this is a very tricky process without proper sensor in place.

Fig. 6: Tea enters the withering room where moisture in the sprouts is dropped down to approximately 70%

In our quick tour, we learned another major problem is the use of electricity in the factory. As an industrial electricity consumer, three rates apply (sum up) to deduce the monthly bill of the factory:

1. a flat fee
2. a fixed rate per kilowatt
3. an extra fee if certain threshold is exceeded

In case this threshold is exceeded the extra fee is implemented as a penalty to be paid for the rest of the months, till the end of the fiscal year.

The best tea productions and the most intense processing time for the plant come from February to May, influenced by the rainy season. Therefore the risk of paying the penalty on electricity bill for the rest of the year is high. We understood this is a major problem with a dramatic financial impact.

Consequently, the higher impact instrumentation to deploy at this point is probably related to monitoring and eventually flattening the consumption of electricity during the year, remaining within convenient values along the high demand periods. Implementing such an approach is indeed linked to a holistic view of the process automation, to be studied cautiously. Anyhow, WSN is an attractive technology to leverage the cost of such an effort, especially in an existent installation.

Another important issue to investigate further is the possibility of using electricity or an alternative energy source for drying the tea. Nowadays the plant uses heat from steam which is produced out of burning wood, measured around 10,000 cubes (cubic meters) of firewood per season. See figure 7. Might this be a sizeable contribution to the rapid deforestation the area is suffering?

Macadamia shell is also used to fuel the boilers, it burns like coal. They have planted 650 hectares (6.5 km^2) of Macadamia nuts which are exported to Holland and America mostly.

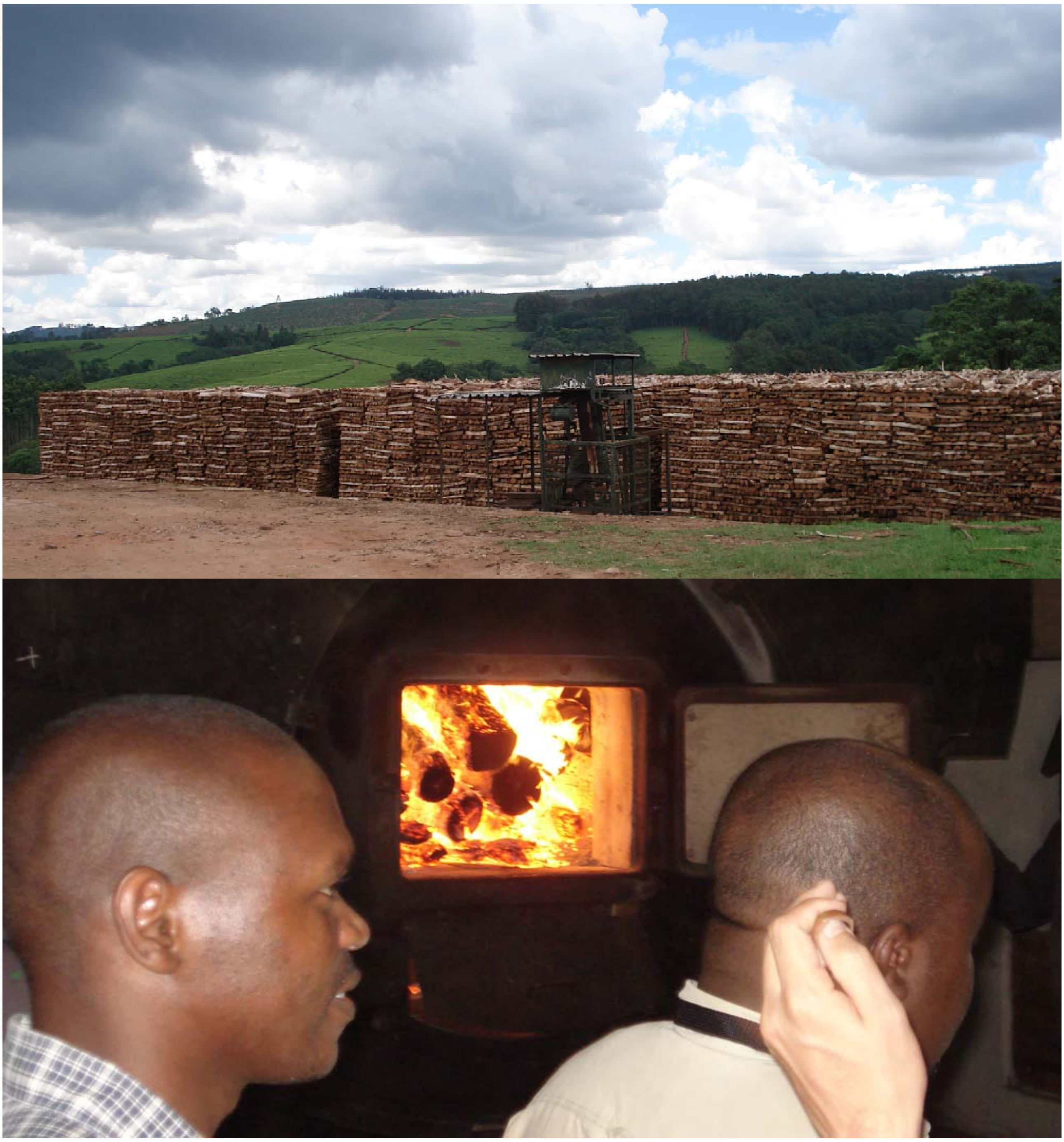

Fig. 7: Firewood is used in boilers to produce steam. Around 10,000 cubes are consumed per season

While drying, atmospheric humidity is most important. In a high RH atmosphere, tea leaves need more time in contact with the hot air to dry, resulting in loss of flavour. Volatile flavours will dissipate at a temperature above 80° C in drying. The conventional drying process takes a long time for drying teas under 80° C. As a result, teas will ferment, thus impairing their quality. Therefore, this delicate equilibrium requires careful sensing and monitoring to maximize quality.

First steps proposed:

Temperature and Humidity map of withering room

Moisture content in the leaves indirectly calculated by measuring weight variation in time (is it a viable approach?)
Exploiting in-network processing and robustness, system will withstand some nodes failure.

Blowing dry/cold/hot air accordingly to obtain uniform 70% humidity across the board (eventually in less than 15h?)

Implementation of an alarm system for non desirable temperatures and humidity values.

Fig. 8: Cutting then drying.

Additional interesting steps for the project would include but are not limited to:

- Extend the Poly wireless network from Blantyre into the Thyolo area so that the factory monitoring can be performed remotely. Offer Internet access and IP based telephony, interconnect Naming'omba offices, connect other nearby hospitals, etc.

- Implement Control system for ventilators/blowers on the withering room

- Variable speed control in Roller Motors and conveyor belt would help on controlling the processing pace (withering-cutting-drying-straining-packaging) depending on the dynamic requirements at each stage.

- Adding wireless video cameras to the network would help provide a better overall understanding of the factory performance in real time and from remote locations like local offices or the Poly. Furthermore, some simple image processing would aid in monitoring the size/colour of the tea grain in the grade sorters. See Figure 9 for desired outcome.

- Tea yield and quality are very dependent on the weather, therefore regular monitoring and collection of data about climatic conditions is convenient as it is often possible to predict such factors as the onset of insect infestation and changes in crop yield, which can be directly influenced by weather patterns. Fine measuring of parameter such as temperature, humidity and rainfall in the field would be greatly simplified by the wireless network.

- On the same vein, monitoring can be implemented for transporting time and conditions since plucking, thus helping minimize processing delays (three hours is reported as the maximum time limit). On the other hand at temperatures over 43 C the cell walls begin to break down, release enzymes and the catechins in the leaf begin to oxidize. Since heat produced by respiration can increase the temperature inside the pack remarkably over ambient temperature, monitoring parameters in the trailers would be very likely convenient and cost-effective.

- Use Voltage to Frequency (VF) converters to optimize energy performance for 3-phase motors on tea cutting machines. Motors' power seems over 10 HP each, currently two of them in place and a third one on its way, at the time of this writing.

- Automate a Methyl chloride processing line for decaffeinating tea, which requires at least temperature monitoring and control on several stages

Fig. 9: Dried tea is later strained in sieves. The results, with different grain sizes, are packages and commercialized in grades accordingly, the finest the grain the higher the quality.

About the Polytechnic Role

Do not simply deploy technology, instead add value
Consider providing a service whenever possible, that's what people really need.

The Concept

Provide means of monitoring and control using open source software, whenever possible
Use donations resources for prove of concept in the industry (private and public)
But then it has to be profitable so that it becomes sustainable: After a pilot run ask for local funding and contributions (government and investors).

How to do that?

Collaboration

Working together with the industry is a symbiotic process for booth the polytechnic and the industry itself. Better understanding the problems they have and finding cost effective solutions will redound in making the whole game affordable and possible for the poly.

Time Horizons

First training and deployment tentatively to be commenced during 2007.

Local Funding

Calling the attention of the local authorities and the investors pass through awaking their interest and showing the polytechnic potential

Other Activities

Introduction to WSN: Concepts and Applications
by Claro Noda.
Seminar at the Malawi Polytechnic.
09h30 on Friday the 8th of December, 2006.

Contact Info

Here is the contact info for some of the people involved so far.

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Further updates of this document could be found on the internet at:
http://www.complexperiments.net/noda/wsn/malawi_report.pdf

and later on at:
http://www.wsn4d.org, along with related material.

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