Proposal For Smart Agriculture LoRaWAN Based System Investigation & Design

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Abstract

LoRaWAN is a low power wide area network protocol that allows implementing WANs in areas where infrastructure is difficult or prohibitively expensive to install. Using LoRaWAN, it is possible to implement (large) scale distributed embedded systems, which can span several acres. Such systems can be applied in several areas that we believe are critical to Sierra Leone's technical and manufacturing sectors.

Agricultural endeavors play a significant role in our economy. One of the ways in which yield, and quality can be improved is by the application of intelligent control and monitoring systems. By monitoring various environmental markers such as temperature, soil humidity and pH, and then adjusting watering schedules based on these markers, it is possible to improve the yield and quality of harvested crops, while maximizing the utility of resources such as water and fertilizer. Effective smart irrigation systems can transform agricultural food security by boosting crop yield especially in the dry season.

When designing monitoring and control systems for the local economy, one of the factors that needs to be kept in mind is that many small-scale agricultural farmers and communities have limited financial resources. So, when designing the overall system, minimizing installation and maintenance costs needs to be a primary requirement. At the same time, it is of little use to install a system that has limited functionality (or functionality that cannot be improved over time).

Our project will investigate specific ways in which agricultural control and monitoring systems can be implemented to boost food security through smart irrigation using low-cost micro-controllers, off-the-shelf components and minimal internet-based reliance. We propose to use LoRaWAN as the communication protocol. Using LoRaWAN, allows to maximize the distance spanned by such installation to the order of many acres.

A benefit of using micro-controllers and off-the-shelf components is that as a community, we can own the intellectual property and manufacturing capability of such technology. The experience we will gain is one of the fundamental drivers that allows us to start moving from a commodities-based economy to a high value technical and manufacturing based economy.

A final point to note is that since we are using LoRaWAN based functionality, many of the lessons learned can be applied to other disciplines and multi-sector applications.

Background & Rationale

Sierra Leone experiences a monomodal rainfall pattern characterized by the wet season between May and September while the dry season lies between the months of November and April. Most farming activities occur during the rainy season as our agriculture is mostly rainfed. This means that during the dry season, crop production is drastically reduced due to the fact that farmers are operating at a subsistence level and cannot afford sophisticated irrigation set up. In addition, this significantly limits the area under cultivation.

This inconsistency in crop production during the year adds to the food insecurity issues in the nation. Better and smarter irrigation can lead to greater crop yield, protection against certain weeds and diseases and more. Sierra Leonean farmers having access to a Smart Agricultural LoRaWAN Based System with all its associated benefits will help address the production gap. This system will allow farmers to "smartly" utilize water as an agricultural resource in a sustainable manner. Notably, during the dry season, some areas in Sierra Leone experience drought. So this smart irrigation system will address the issue of water scarcity as well as proper water and fertilizer management.

Farmers in Sierra Leone usually employ the broadcast method of fertilizer application or the ring method. While both have their advantages, there are also issues of misapplication as well as a tendency for leaching to take place. Fertilizer is a very expensive commodity in Sierra Leone. Most farmers cannot afford to purchase enough to meet their needs, further plunging them deeper into poverty.

The proposed technology will enable farmers to produce crops in the dry season which will boost production massively. This is very much in line with the Feed Salone Initiative launched by the Government of Sierra Leone. It is a well known fact that there is insufficient food being produced in Sierra Leone as the Government has to resort to importing to fill the gap between demand and supply. It is the aim of the Government to have the country produce enough food for domestic consumption as well as export. To that end this smart technology will enable cultivation of large acreage of land and help conserve water and better manage fertilizer.

There is a large disconnect between typical research projects and practical application of these projects within the embedded engineering space. Solutions proposed are not easily implemented with resources available in Sierra Leone. As a technical community, we currently have limited access to the resources (and expertise) required to implement embedded product solutions. Such resources include:

· Access to embedded product design experience and expertise

· Access to hardware and firmware design resources

· Access to manufacturing facilities.

The open-source movement has made access to design resources much more available. However, we still lack consistent high-quality access to product design experience and expertise. Therefore, whenever we attempt to implement such systems, we must rely on outside parties. We could remedy this situation by starting our own design efforts. Implementing embedded systems using the LoRaWAN protocol allows us to address significant technical challenges we face as a community, while gaining valuable experience in design, manufacture, deployment, and maintenance of such systems. The reason we target LoRaWAN as a communication protocol is that our infrastructure capabilities, especially in rural communities, are currently lacking. Using LoRaWAN allows us to work around this limitation while still providing highly functional systems.

Project Goal & Specific Objectives

Our goals within this project are as follows:

1) To propose and implement a systematic approach to moving from a proof of concept (POC) design using dev kits to a product implementation using custom designed prototype hardware and firmware. Such implementations should be:

   - Realizable at an attractive price point, while providing a high level of functionality.
   - Deployable into practical applications.
   - Allow for means of extending the system functionality and scale at some point in the future, if required
   - Allow for system maintenance, by commissioning and replacing individual nodes with minimal system downtime.

2) To architect and design re-usable firmware and hardware building blocks that can be used not only in this project but can also be re-purposed for other projects. Since we propose to use LoRaWAN as the communication mechanism, the end nodes designed and implemented could also be used in other applications.

The specific objectives we will accomplish with this project are as follows:

- Detail a systematic process to move from a set of application requirements to a product-based implementation of said requirements.
- Use said process to implement product-based hardware and firmware, albeit in prototype form.
- Understand the various factors involved in realizing custom hardware. We feel this understanding could be used as initial steps to establishing our own PCB population facilities (and eventually our own PCB generation and manufacturing facility)
- Attempt to establish collaborative mechanisms to produce custom product-based hardware within the Sierra Leonean technical community. We feel that our best chance to

establish hardware production facilities is to work with other entities. This allows us to share knowledge and pool resources.

- Document the commissioning and deployment process. Since we anticipate that applications realized will utilize the LoRaWAN protocol as the communication mechanism, we expect that the lessons learned during commissioning and deployment can be applied to several scenarios.
- Document the overall approach from start to finish in a summary paper. We need to capture the set of challenges overcome and the various lessons learned during this project.

Project Methodology/Approach

The set of objectives enumerated in the previous section are all motivated by the need to increase our national knowledge base. History has shown that economies that move from a labor/commodities-based economy to a technical/manufacturing-based economy have positive outcomes. Therefore, the set of objectives and the underlying activities are all extremely practical in nature. The activities will use industry standard practices as a guide. This will allow us to achieve positive outcomes and maximize the use of our available resources.

A diagram of the system to be investigated and implemented is shown below

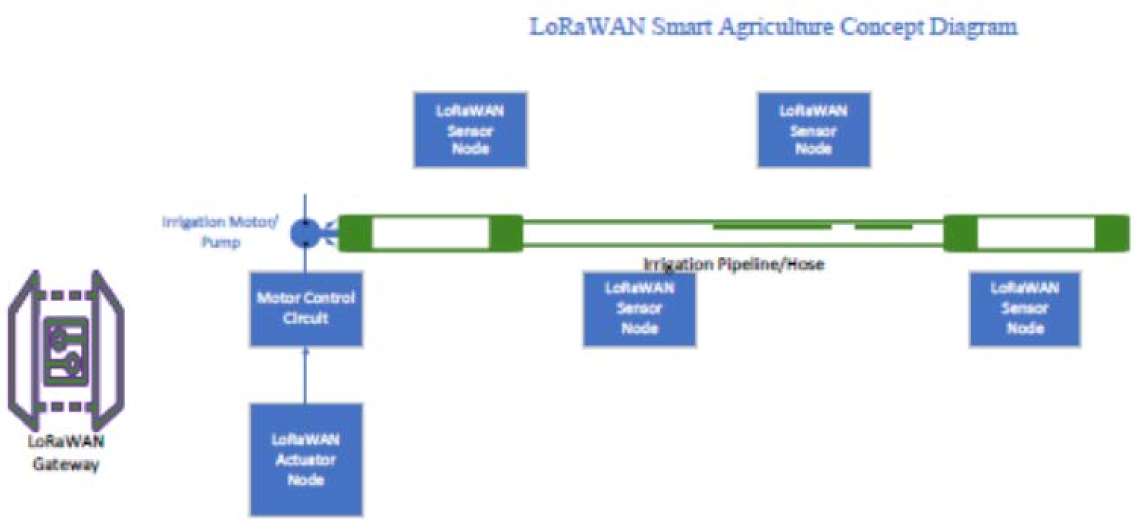

Figure 1 - LoRaWAN Smart Agriculture Concept Diagram

The system components are enumerated below:

· **LoRaWAN Gateway.** This device allows the user to monitor and control the overall system. It could also interface to an internet connection.

· **Actuator Node**. This device allows the user to control various motors and/or pumps in the system. Motors and pumps control the opening and closing of system irrigation pipelines/hoses. By controlling the state of system flow, water use can be minimized. It could be possible to use actuator nodes to also control fertilizer pumps and sprayers.

· **Actuation Device**. This could be either a motor to control water flow or a pump to control fertilizer feed rate. Other types of actuation devices are possible in this system.

· **Irrigation pipeline/hose**. Allows for the flow of water and/or fertilizer to various agricultural plants within the system.

· **Sensor Nodes**. These devices monitor the environment and provide information about the current soil humidity and pH, indirectly providing information about plant health and viability. This information can be transmitted back to the gateway periodically. The gateway can then make decisions to actuate various nodes within the system to initialize irrigation and/or fertilizing application.

The basic system described above can be expanded using these building blocks. This allows the system to scale as deployment needs dictate.

We propose implementing the above system using a combination of embedded microcontroller modules and custom-designed hardware. Using modules will allow us to leverage current high performance 32-bit microcontrollers, while minimizing the design effort and risk. By designing custom hardware, we can implement solutions tailored to our needs, while also improving our knowledge base.

Significant work is being done around the world in the design and implementation of efficient, smart agriculture systems. Our goal is to catapult Sierra Leone to the forefront of technology transformation by improving agricultural production, supporting the government's flagship program -Feed Salone, while aiding technical knowledge transfer and human capital development in embedded systems manufacturing.

Our approach would be to conduct the research using a phased product lifecycle approach in four phases.

The detailed set of activities (based on industry product design best practices) would be :

Phase 1 - Feasibility Study and Selection of farms Duration: 1 month

Lead by **Principal Investigator, Dr Mohamed Blango with Project team**

The first phase will include an assessment of local farms for technical feasibility and future field tests, focusing on vegetable farms, subsistence farmers and small acreage. The feasibility study will include an evaluation of suitability for the irrigation system, potential product demand and adoption by farmers. This will take about one month and culminate in the selection of specific parameters, indicators, and farms for the research. Proximity to the Njala University campus will be given consideration.

Phase 2 - Prototype development **Duration: 6 - 8 months**

Lead by **Investigator, Oluwokay Victor Johns with Project team**

This phase will incorporate the following activities based on industry best practices.

- Collect and document hardware and firmware requirements based on application.
- Generate hardware and firmware architecture documents using requirements as input
- Select LoRaWAN modules and associated microcontroller modules that will run the firmware images.
- Generate prototype hardware design using KiCAD as the design tool
- Implement prototype firmware using dev kits to run initial implementations.
- Provision and commission LoRaWAN nodes using dev kits running developed firmware.
- Review hardware design schematics internally and with external stakeholders
- Contract PCB layout and send design to external PCB manufacturer for layaout and fabrication.
- Receive and verify populated PCBs.
- Integrate firmware on prototype PCBs
- Provision and commission LoRaWAN nodes on custom prototype hardware

Phase 3 - Field Trials **Duration: 9 months**

Lead by **Investigator, Dominic Ibrahim-Sayo with Project team**

This phase involves running field trials of the application. To carry out field tests, local soil analysis needs to be carried out to determine factors such as infiltration rate and other drainage characteristics. Short duration crops such as cucumber, pepper and cowpea will be cultivated under sprinkler irrigation up to 5 times to have a rich data set. During the field tests, irrigation quality determinants such as irrigation efficiency and distribution uniformity will be investigated in order to assess the effectiveness of the system.

A control test will be done prior to the application of the system to ensure effective comparison of the impact. During this phase, we will document field trial results and lessons learned.

Phase 4 - Feedback and testing of market acceptance Duration: 5 months

Based on the feedback from the field trials and perfection of the LoRaWAN system, the product will be fine tuned and a patent application will be made to ensure protection of Intellectual Property Rights(IPR). Ing. Victor Johns who leads the innovation will take the lead on the patent application. Parameter and data set results will be used to inform the market research on potential customer base for commercialization and future work based on the lessons learned. The results will be peer reviewed and published in a Science and engineering journal to prepare for future work. The results will be used to prepare a full business plan model for commercialization when further funds are available.

Anticipated Outputs & Outcomes

The anticipated outputs and outcomes of this project are as follows:

1) Implementation of industry best practices process to define and implement prototype field tested units

2) Documentation of process followed to serve as a template for future projects and endeavors

3) Dissemination of process and results so that the Sierra Leone technical community can provide valuable feedback which we will use to further improve our process and practice

4) Possible engagement of private and public sector entities to further improve the technology base by using the principles explored in industrial scope projects.

5) Improvement of local students' grasp of industry practice and practical knowledge.

Knowledge Utilization and Dissemination Plan

One of the objectives of this project is to document the design and implementation processes used, so these can be used as templates for future work and development. We feel that the basic building blocks used in this system can be used for other applications. This documentation will serve as the basis for our knowledge utilization and dissemination plan.

We plan to serve as a resource for the educational engineering community. To this end, we will hold a series of workshops at FBC and MMTC to share the details of our work.

Project Governance

All funds associated with this project will be deposited into an account that will require signatories from both investigators listed on this proposal.

Key Personnel & Roles

Key Personnel	Role	Description /Experience
Dr. Mohamed Blango	Principal Investigator	Over 16 years of experience in agriculture, soil and water engineering and agricultural engineering. Former Head of department at Njala University. He has been working on extending cropping into the dry season using a micro-dam rainwater harvesting system and has published several articles in renowned journals in areas including Supplementary Irrigation, Rainwater Harvesting and Agricultural Water management. See CV.
Ing. O. Victor Johns	Investigator	Over 20 years of experience in embedded systems
Dominic Ibrahim-Sayo	Investigator	Has 12 years of experience in agriculture, He possesses a BSc (Hons) in Agricultural Engineering, MSc in Soil and water engineering. Participated in several training opportunities in Agribusiness Management, crop production, irrigation and biogas production.
Francis Manna	Researcher	An MPhil Student at Njala University
Elizabeth Blango	Junior Researchers	
Catherine Johnny	Junior Researchers	

Suitability Of the Host Institution

The investigators involved in this project have:

§ Extensive project management and deep expertise of local needs and markets.

§ Deep knowledge and extensive practical product development experience at both firmware and hardware level.

§ Extensive technical networks that can be leveraged to provide guidance in several areas. Such areas include:

- PCB design and layout
- Hardware troubleshooting
- RF and antenna design

Capacity Building

We believe that it is necessary to provide opportunities for young people in our community to be exposed to, and participate in, challenging projects. This allows us to grow our local talent base. Therefore, students from the Agricultural Engineering Department and Computer Science Department of Njala University will be closely working with the project during the implementation stage. Student dissertation topics will be centered on analysis and improvement of the irrigation system as well as upgrading both the software and hardware. Students at relevant academic institutions as well as businesses will be exposed to this technology with the aim of improving the quality of products. While the investigators will provide rigor, project oversight and direction, we anticipate that the students involved will also play a major role in the success of this project.

We believe that this project could be used as a seed project for several products that could be commercialized at a later stage. Such product commercialization could be achieved by partnering with local public institutions and/or private entities. Since such entities would require some concrete demonstration of functionality, we anticipate that having a compelling demonstration of the project capabilities will be an important output of our efforts.

Monitoring & Evaluation Strategy

This is a TBD. We anticipate that the advisory board will play a major role in our monitoring and evaluation (M&E).

Proposed Project Timeline

Project Activities	Year 1				Year 2			
	Q1	Q2	Q3	Q4	QI	Q2	Q3	Q4
Gather Requirements for System/Investigation	x							
Define Architecture & Generate Architecture Documents	x							
Select micro-controller modules & initial design of hardware circuits		x						
Implement LoraWAN End-Node functionality/firmware		x	x					
Submit final hardware/circuit design for layout review & verification		x						
Initial Integration of LoraWAN firmware on dev kits. Perform basic functional testing using dev kits			x					
Integrate prototype HW & FW			x	x				
Commissioning & field trials of prototype system				x	x			
Document & publish results of field trials, lessons learned, future work					x	x		