SDI-12 Project Applications

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I. Introduction

The use of sensors and dataloggers are prevalent in all our modern day technologies. As hardware costs have steadily declined, and their power and capabilities have increased, the use of interconnected systems that include various sensors have exploded over the last 30 years.

SDI-12 was first developed in 1988, with the goal of having sensors work with all data recorders using this standard[1]. This communications protocol is mostly used for applications where projects are battery powered, or have power constraints, and require an overall low system cost.

This paper outlines a brief description of the project being developed, a review of another SDI-12 driven system, and how learnings of this review can be incorporated into the projects development.

A. The Project Introduction

Within the project, two sensors will be used to log external environmental data, which will then be delivered using the SDI-12 communications protocol when requested. The project will allow a nearby computer to query an Arduino system for system identification and for gathered environmental data by the attached sensors.

The two sensors to be used within this project are as follows:

- BME680 - A temperature, humidity, pressure and gas sensor.
- BH1750FVI – A digital light intensity sensor.

In addition to these sensors, two converters will be connected between the Arduino and the receiving device. These convert the Arduino's UART protocol to SDI-12 and then convert this SDI-12 protocol to USB. A block diagram of this system can be seen within Figure 1 below.

A team of three students will program the Arduino read the sensor data, store and display this on board, and deliver this to an external device when prompted by direct USB command.

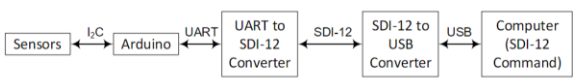

Figure 1 - Block Diagram of Project System[2]

B. Division of Tasks

1) James & Thomas

The team working on and delivering this project is a group of three students, Thomas, James and myself, Aaron. The project has been divided into nine individual tasks and five group tasks, making a total of 14.

A division of tasks for the three students can be seen graphically below, in Figure 2.

Four of the five group tasks are simply review and approval steps. These allow each group member to evaluate the design and production of the project, and determine if the result is satisfactory enough to proceed. These tasks are critical, as they ensure all previous tasks are completed and working before adding more complexity to the project design. The final group task is the demonstration of the project.

Breaking down the tasks for both James and Thomas, we can see the following.

For the first group of tasks, James will program the Arduino to understand and communicate SDI-12 communication protocols, and Thomas will review the code base for readability, such as adjusting variables or formatting errors.

For the second group of tasks, James will develop the LCD Menu with user input capabilities, while Thomas will develop the data storage capabilities.

For the final group of tasks, James will develop and implement an interrupt service, and Thomas will apply event-driven programming using interrupt and advanced interrupt driven coding.

2) Aaron

The first main task for this project is to program the Arduino to read the relevant data from the two sensor modules. This task also becomes the foundation for the following steps, ensuring the inputs are configured and programmed correctly, and variables and functions within the code are named appropriately.

The first approach will be to test each hardware component for functionality, and mapping these components to the relevant inputs and outputs. Once this step is complete, functions will be created so the sensor data can be read from each component, then be returned wither through a serial monitor, or further into the project, be stored within memory. The use of functions will allow data to be requested when needed, and allows flexibility should the code need a redesign.

During the second group of tasks, the LCD will be programmed to display sensor data captured within the memory, specifically data stored on the SD card. This display of data will be selectable within the user menu, allowing the user to hide the data, or review other settings, if required. The displayed data will provide a relevant graphical representation where possible.

The final task is yet to be determined. However, this will involve evaluating the project within the team to decide on an additional improvement. For example, if there is a malfunction of the device, either within the hardware or code, a buzzer could generate an alarm tone to notify users of the event, prompting troubleshooting to begin.

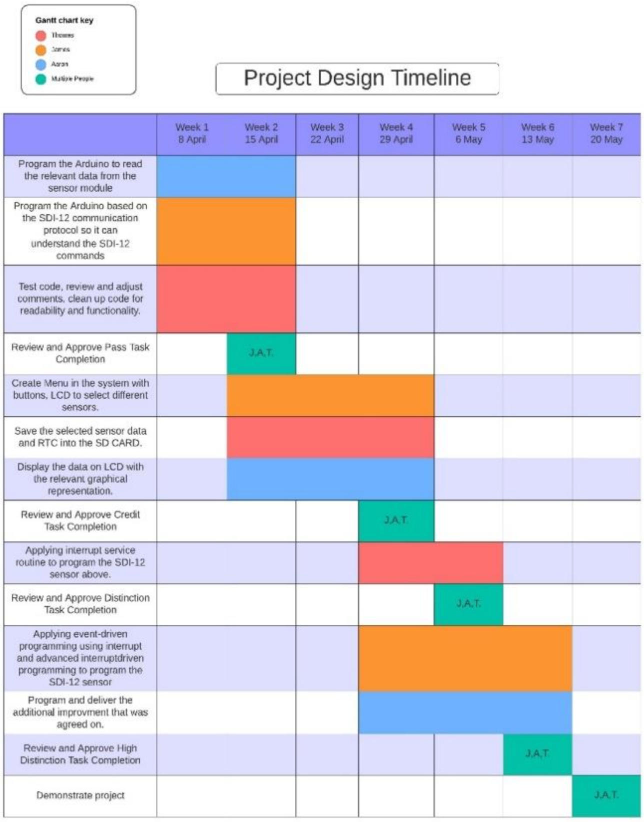

Figure 2 - Gantt Chart of Project Tasks

II. IoT Sensors System for Vinetard Monitoring

A. *The use of Sensors*

Sensor modules using the SDI-12 protocol have been in use for decades, providing low cost, and scalable solutions for any type of problem that can be envisioned. Within the paper being reviewed, sensors have been used to identify vineyard diseases that may be prevalent [3]. The aim of this data gathering is to identify diseases early, allowing for prompt treatment and reduction in crop and financial loss.

Within the system implemented, two nodes were constructed, allowing for two different networks to exist and communicate to a central hub. The first node provided an SDI-12 interface, with an Arduino Mega being used for the data gathering. The five SDI-12 sensors and NPK sensor were connected within this Node. The second node used an additional Arduino Mega, with eight dedicated Arduino sensors, communicating data using a one wire, Serial Protocol Interface (SPI), Two Wire Interface (I2C) and analogue voltage.

As the system runs, the two Arduino Mega boards collect and store the gathered sensor data at determined fixed intervals. This data is locally stored on SD cards, and also delivered wirelessly to nearby gateway, using Long Range Radio (LoRa). This data is then communicated through the internet for review and access away from the vineyard.

This paper has been chosen for it's similarity to the aforementioned project. Fourteen sensors, five using SDI-12 protocol, have been configured to relay environmental data to another location, while also storing this data onboard where required.

While this paper does include five unique environmental sensors that use the SDI-12 protocol, as well as other multiple sensors and protocols, this project brief will only be reviewing node one in depth. As this node holds all the SDI-12 sensor components, it has been chosen as it has the closest practical abilities compared to the project.

B. *Application & Strengths*

To monitor a plant and determine its susceptibility to disease, multiple points of data are required. Underground, the soil must be measured for moisture, temperature and oxygenation. While above ground, solar irradiance, wind, precipitation and humidity are just the beginning of the measurements required. The main strength of SDI-12 within this paper is in its cost effective way of having multiple sensors for one data-logger, effectively enabling the system to gather all the mentioned data points and more. As this protocol allows multiple sensors to be connected in a series, with all data being carried along a single input line, it reduces the amount of ports required for data capture, therefore reducing the resources used within the Arduino Mega.

While node two uses different sensor protocols, such as I2C, it can seen as an advantage within node one to use the SDI-12 protocol. In comparison, the use of I2C requires an additional wire between the sensors and the Arduino Mega, reducing the available resources. As the sensors connected to node one could require lengthy wires, for example from a specific plant to the data-logging station, I2C's short range limitations would result in a loss of data. SDI-12's ability to communicate over approximately 65 metres essentially removes this possible negative impact [4].

SDI-12 has a data delivery constraint (it must use 1200 baud), however within this paper it can be seen that sensor sampling will only occur at a minimum of five minute intervals, up to a maximum of 65535 minutes. As the sampling is being conducted on such large intervals, SDI-12's data delivery constraints do not have an impact, therefore allowing this to be ignored.

The final strength of note is the level of accuracy SDI-12 can allow compared to the SPI, I2C and analogue voltage communication methods used in node 2. This is due to the sensors ability to include onboard microprocessors to perform corrections on the collected data before sending this through to the Arduino Mega. The accuracy of data within this paper's application is paramount to ensure disease identification can occur quickly, and to limit the number of false positives presented by the system output.

C. *Constraints & Improvements*

One main constraint of the SDI-12 sensor use within this paper is that the sensors are connected within a series within the same port of the Arduino Mega. While within this system there are only five sensors, if one malfunctions or otherwise goes offline, every other sensor will also become unavailable until the faulty sensor is removed or fixed. A circuit diagram of node one showing the serial connection can be seen in Figure 3. Diagnosis of an issue such as this can further increase the cost of the system to a point where other protocols may be more cost effective.

An improvement could be made within the system to minimise the impact of such an event. Including all sensors on the same input line is the major advantage of SDI-12, however, potentially splitting this into two input lines could allow some sensor data to remain online, while the impacted sensor group is troubleshooted.

As we have discussed, multiple sensors connected to one Arduino Mega has multiple strengths both for the system resources and the user. Despite this advantage, there is a limitation of the number of sensor addresses that are available within the system. The risk of this constraint providing an overall negative impact is minimal, but would need to be considered if or when scaling the project. For example, if the vineyard was larger, or required more plants to be monitored at the same time, many more sensors would need to be connected and configured. The maximum amount of sensor addresses available can vary from manufacturer to manufacturer, but cannot exceed 62 [5]. Within this system, due to other constraints such as available power, input pins, and sensors used, the maximum number of addresses available is ten (0-9), therefore ensuring only ten sensors can be used at a time. This drawback could be counteracted by creating additional nodes, provided the gateway can accommodate these.

D. *Further Review*

The advantages and constraints of the SDI-12 protocol within this paper can also be seen in similar applications. A review of *A LoRaWAN IoT System for Smart Agriculture for Vine Water Status Determination [6]* shows similar equipment in use. The cost effective nature provided by this protocol, and it's ability have multiple connected sensors, allows for effective vine review and management.

An article referenced by the paper in review, *An IoT proposal for monitoring vineyards called SEnviro for agriculture*[7], shows that within the application of agriculture monitoring, the advantages of SDI-12 outweigh it's drawbacks. The ability to have a low cost solution, that can communicate over a great distance, while still maintaining accuracy, makes other protocols such as I2C undesirable.

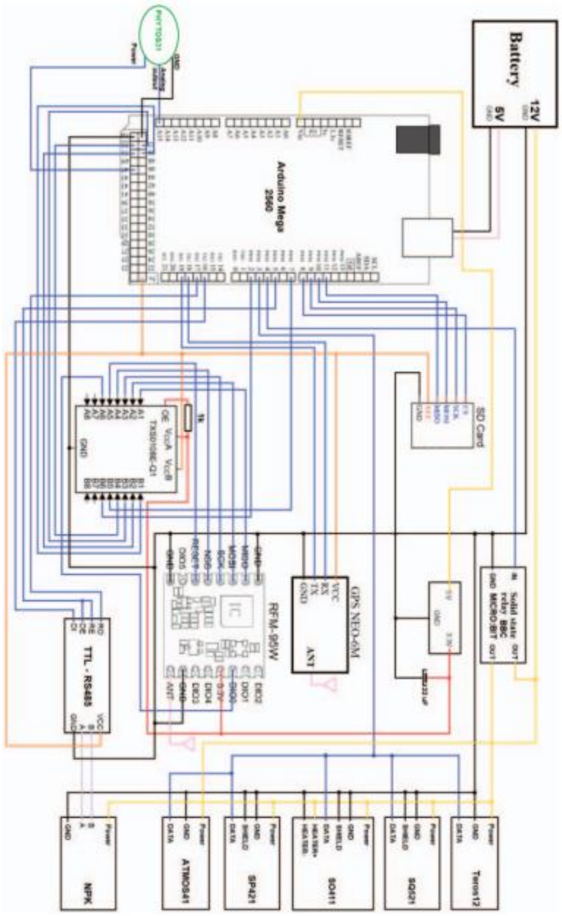

Figure 3 - Node One Circuit Diagram[3]

III. Conclusion

In conclusion, *IoT Sensors System for Vineyard Monitoring* has provided a wonderful insight into how SDI-12 protocol can be used. Not only can this protocol provide environmental data as needed, it can facilitate multiple sensor results, and communicate to a larger system with ease. This protocol, and the sensors that use it, has allowed a reduction in system cost both financially and internally.

Reviewing the strengths and opportunities of this paper, further improvements have been identified for the project. For example, ensuring there are failsafe's for faulty hardware, such as running SDI-12 reliant sensors in parallel or separately where possible, will ensure sensor failure will not impact data collection.

Analysing other paper's that have implemented a similar system within the agriculture space, and reading those referenced within the paper itself, we can see that the decisions made, such as using SDI-12 in node one, are the best suited.

While other protocols exist and can be used in similar ways to SDI-12, it can be seen that the constraints of these protocols would not outweigh the strengths. The current system configuration seen in Figure 1 for the project is sufficient in completing the required tasks. Should the project become a more complicated system, or require higher accuracy or resilience, only then would other protocols need to be considered.

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