A Communication Method for Remote Control of Grid-tied Converters

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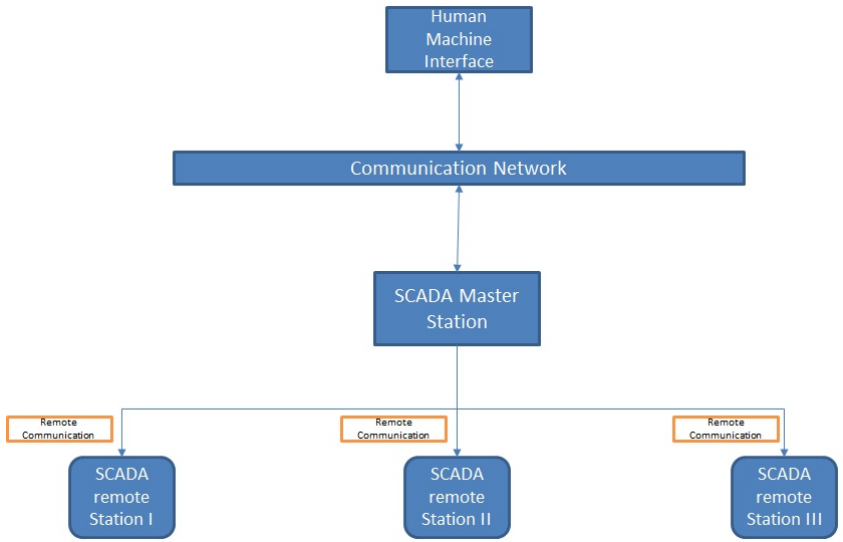
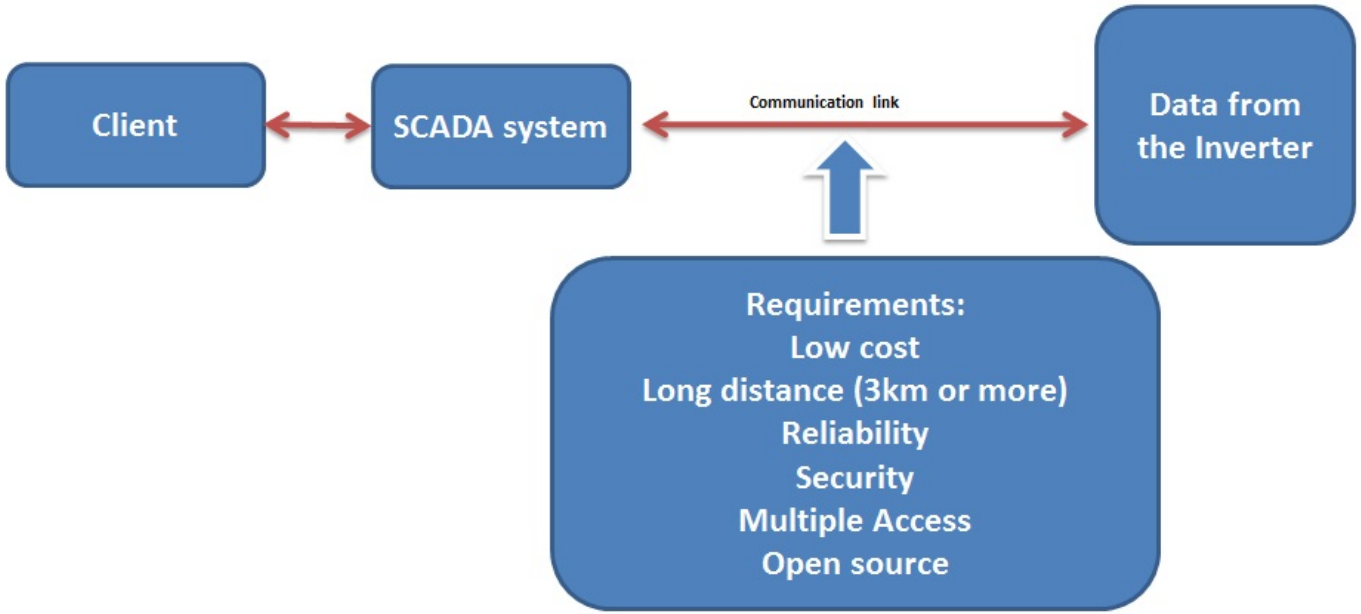
Outline

Motivation

- Communication is a key factor in a SCADA system.
- Failure of the communication link can cause loss of data and loss of control over the system.



Motivation


Client
SCADA system
Communication link
Data from the Inverter
Requirements:
Low cost
Long distance (3km or more)
Reliability
Security
Multiple Access
Open source

Introduction

Wired Communication

- Power Line Communication
- Digital Subscriber Lines
- Optical-Fibre Communication

Wireless Communication

- Cellular network communication
- WIFI
- Blue-tooth

Comparison of wireless technologies

Table: **Comparison of Available Wireless Technologies**

Technology	**Service**	**Data Rate**	**Coverage**	**Spectrum**	**Cost**
Cellular	Data	Low-Moderate	Large	2GHz	Operating cost
LTE(4G)	Data	High	Large	1.7GHz-2.6GHz	Operating cost
Wi-fi	Data	High	Small	2.4GHz	Operating cost
Bluetooth	Data	High	Very Small	2.4GHz	Low
RF	Audio, Data	Low	Small	300-400MHz	Low
LoRa	Data	Very Low	Large range	ISM band	Low
UHF/ VHF	Data	Very Low	Large range	UHF band	Low
Radio Tele-type	Voice	Very Low	Large range	UHF band	Low

Low cost, long range ?

Related Works

- Zhou et al. present a communication system using general packet radio service(GPRS) and code division multiple access (CDMA) wireless communication networks in SCADA system.
- M. Y Zhai et al. [**?**] present the measurement results of channel properties of LV PLC systems after giving a general overview of the topologies for the typical LV distribution networks in China.
- Conti et al. [**?**] proposes a method combining Bluetooth and GPRS to make a vehicle to vehicle communication protocol and to make a smart grid.

Research Objectives

Goal

Develop a low cost, long range, secure and reliable communication method for remote control of a grid-tied inverter

Objective 1: Identify a low cost, long range, a secure and reliable communication method

Objective 2: Develop the selected communication method regarding security and reliability.

Objective 3: Develop a model to analyze reliability of the developed communication method.

A low cost, long range, secure and reliable communication method

Four communication methods in three technologies were tested,

- Radio Teletype (Ham Radio)
- VHF/ UHF data modules
- Two types of LoRa
  - Dragino LORA
  - Libelium LORA

Long Range (LoRa)

- Low Power Wide Area Networking technology
- Introduced for IoT applications.
- Developed by Semtech and LoRa alliance
- Uses 915 MHz ISM band
- Following features,
  - Long range for communication
  - Low path loss
  - Good sensitivity
  - Good obstacle penetration

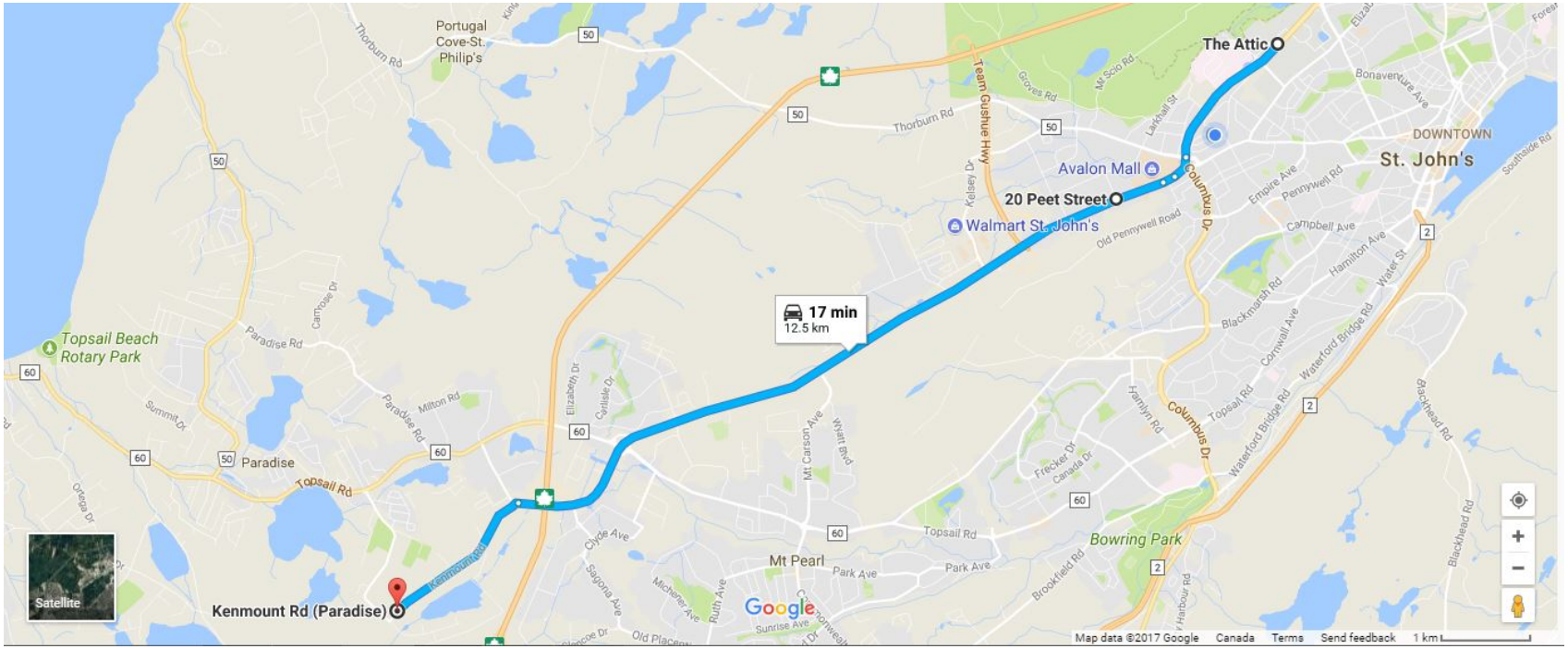
Radio Teletype

- Use Land Mobile Radio (LMR) networks data communication.
- Four ham radios have been used to get a full duplex communication link.
- Software: FLDIGI (Open source)

UHF / VHF data transmission

- Very high frequency band has been using for data communications.
- Two set of data radios made by Lensen are being used.
- Any serial interface can be used.

Range Testing



Comparison

Table: Comparison of Tested Open Source Wireless Technologies

	Cost (CAD)	**Power (tx)**	**Range**	**Data Rate (bps)**
Dragino LoRa	55.00	100mW	220m	9600
Libelium LoRa	250.00	25mW	4.5km	9600
Ham Radio	140.00	5W	7.2km	50
1W Data Radio	120.00	1W	3.3km	1200,2400

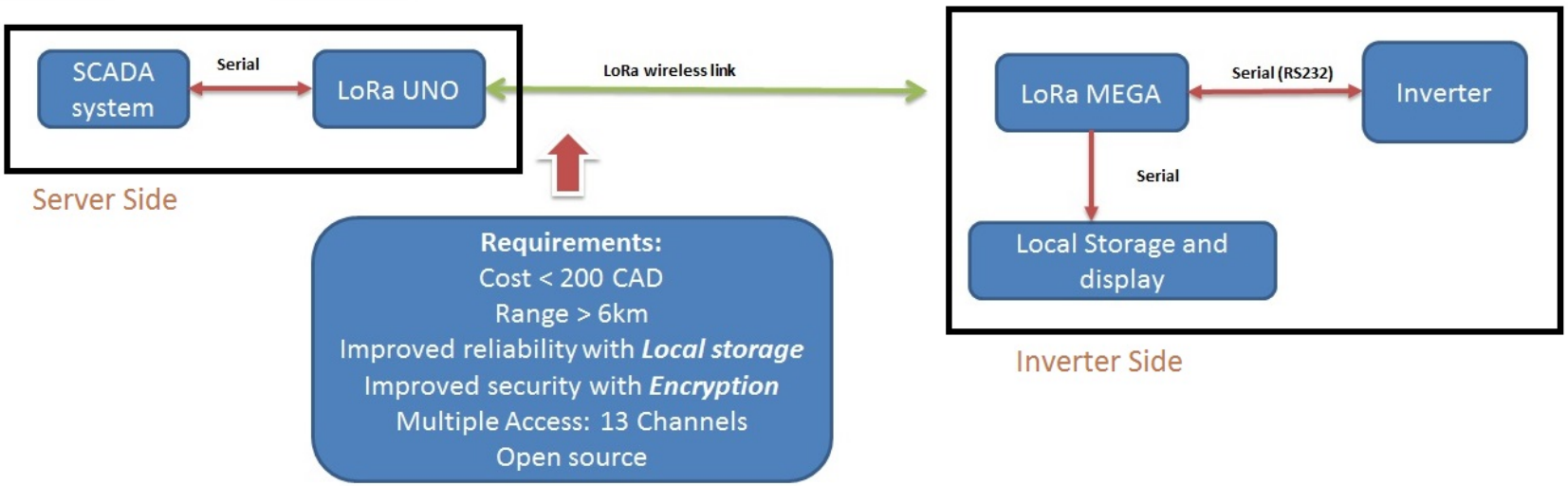
Develop LoRa in terms of security and reliability

Issues with LoRa

- **Security:** No end to end encryption
- **Reliability:** Packet loss

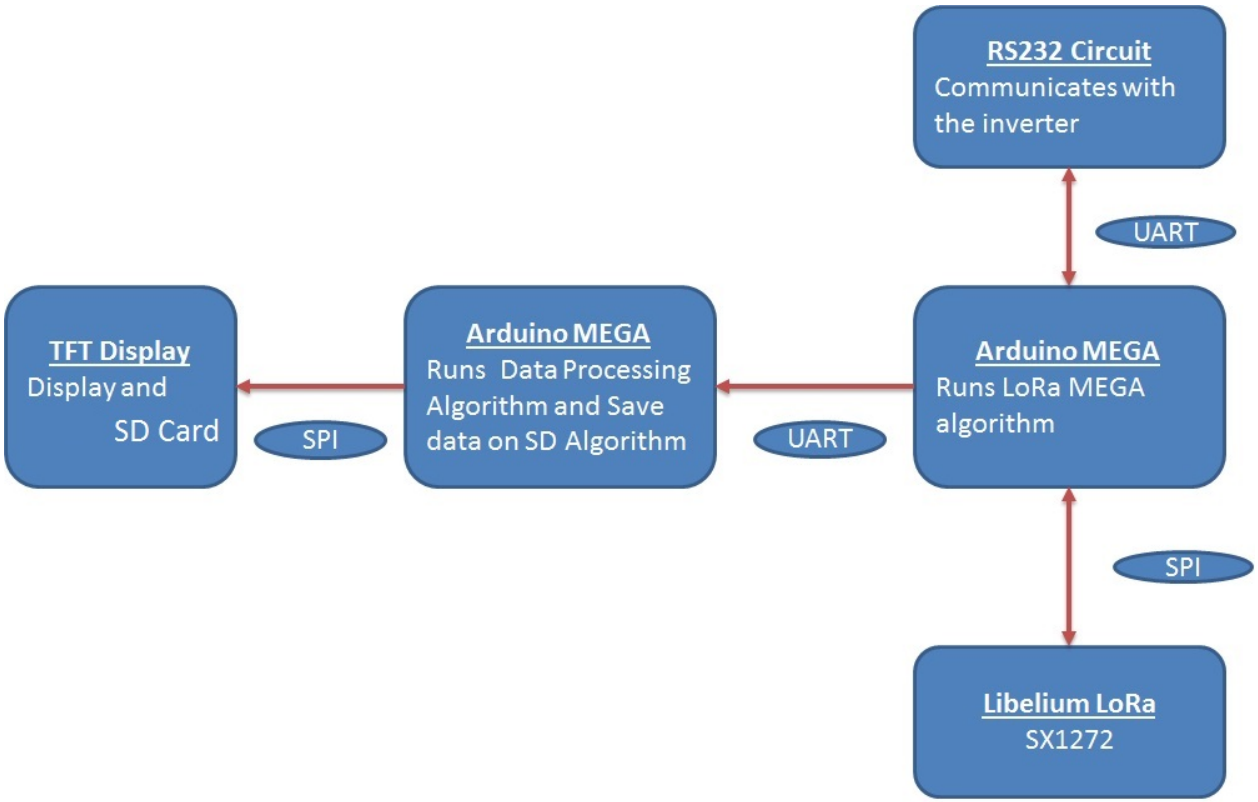
Solution

- **Security:** encryption algorithm is developed and embedded in the Arduino.
- **Reliability:** local storage is added with a self data cleaning algorithm.

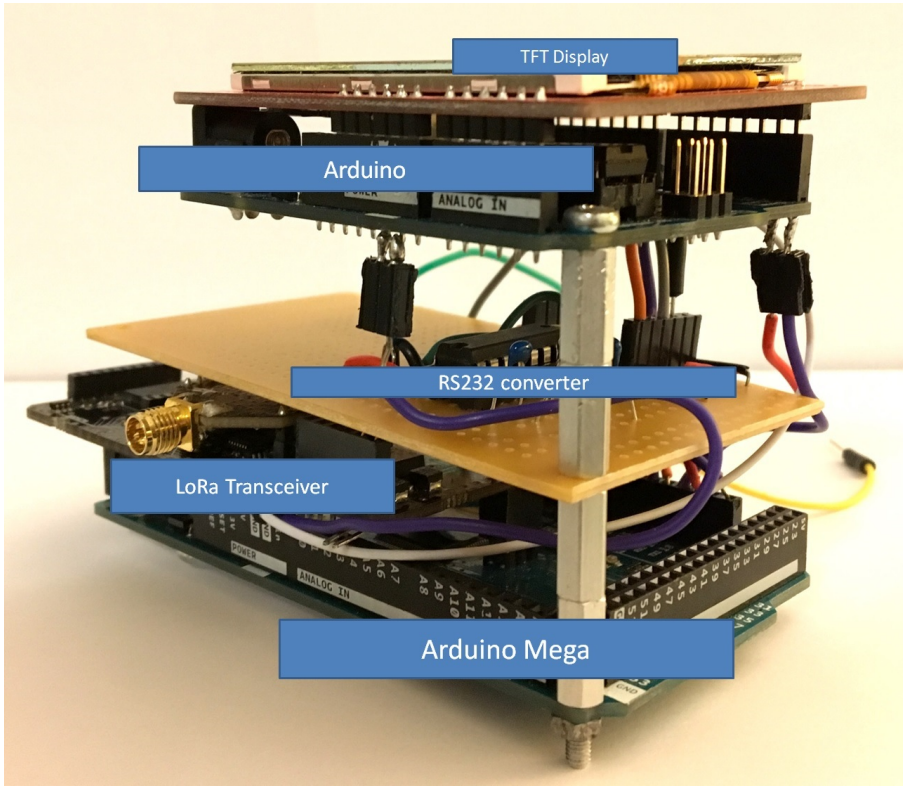


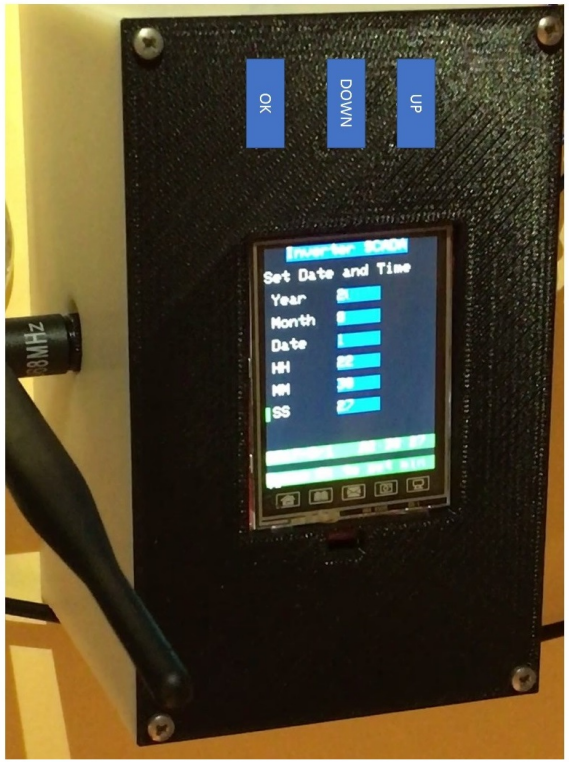
[1] https://www.lightwell.eu/fr/portfolio/lora/

Inverter Side



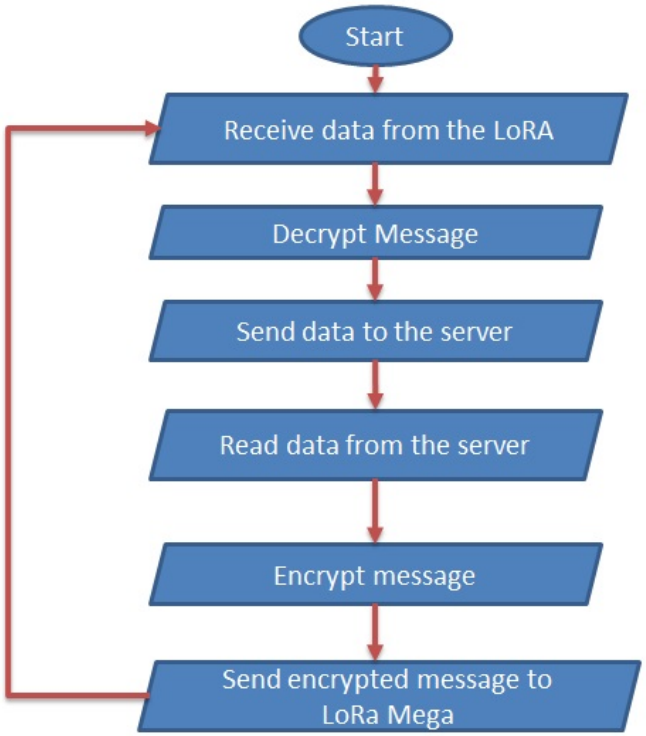
Inverter Side





Server Side

- Receive data from server side through LoRa and uploads to the server
- Send data received from the server to the inverter side



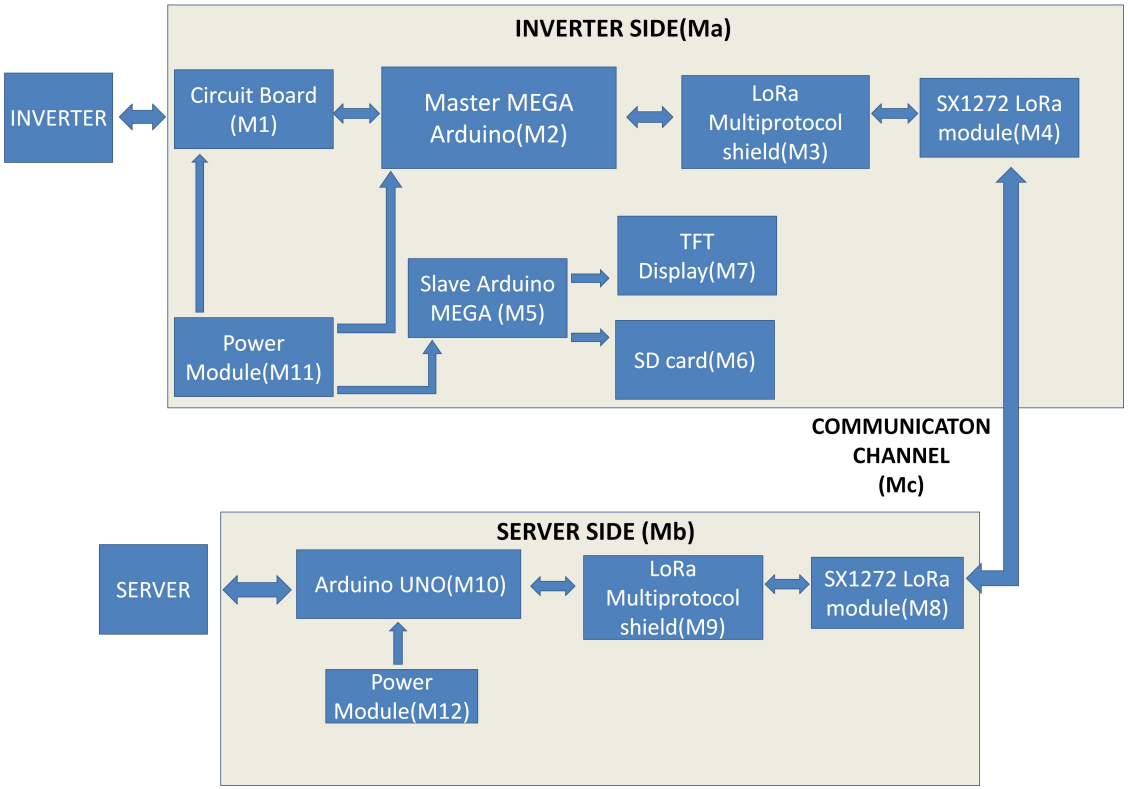
Evaluation

- Tested with an inverter developed by the UNB.
- Successfully communicated over 4.6 km.

Reliability modeling of the developed LoRa link

- Since this developed for a SCADA, measurement of the reliability of the system is important.
- There are analytical and simulation approaches to analyze the reliability.
- In this research fault tree and Monte-Carlo simulation based approach is used.
- Cetinkaya E. K. et. al. show that hte typical unavailability is 0.01 for a SCADA and it is low mostly due to communication link failures.

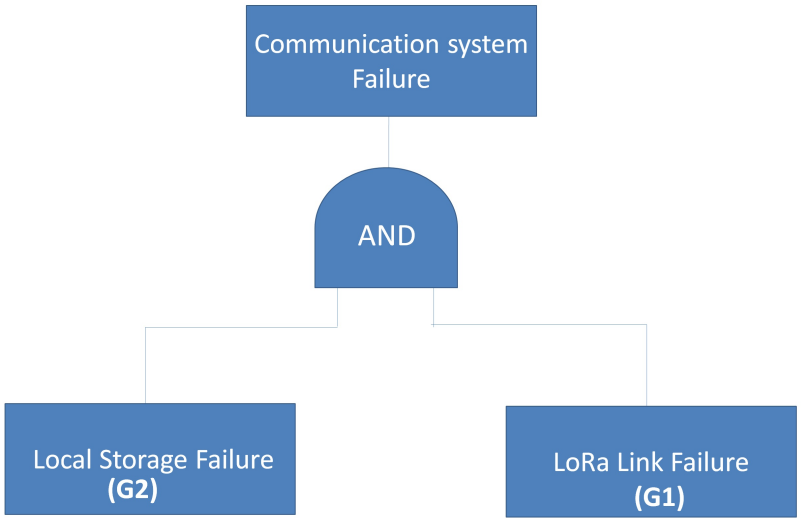
Developed System



Model

Structure of the communication link

Communication system failure



- Failure in both LoRa link and the local storage will result a total communication failure

Results

$$Availability(A) = \frac{uptime}{uptime + downtime} \tag{1}$$

- The analysis shows that the communication link has the lowest availability.
- Addition of a data storage parallel to the system has increased the availability of the system. From 0.994288 to 0.99946

Summary

To summarize, this thesis has made following key contributions in the field of SCADA systems by fulfilling all of the outlined research objectives,

- A framework has been developed to compare communication technologies.
- Improved a LoRa communication link regarding security and the reliability.
- Successfully demonstrated a combination of LoRa and PLC.
- Reliability model has been developed to analyze the reliability of the developed communication method.

Future Work

- Develop directional antenna.
- Develop a LoRaWAN network for Inverters
- Develop high secure encryption for low power processors
- Reduce power consumption of the developed system

Publications

Journal Articles

- Kumbalatara Arachchige, M. T. Iqbal, G. Mann, Data logging and control of a remote inverter using LoRa with local storage, submitted with IEEE Access 2017

Peer-reviewed Conference Articles

- Lasagani K A. Terashmila, Tariq Iqbal, George Mann, A comparison of low-cost wireless communication methods for remote control of grid-tied converters, presented at CCECE 2017, Windsor ON Canada.

Abstract-reviewed Conference Articles

- Terashmila Lasagani, Tariq Iqbal, George Mann, Reliability Analysis of a Communication Link Developed for a SCADA System Using Monte-Carlo Simulation Approach, accepted to present at 26th IEEE NECEC conference 2017.
- Terashmila Lasagani, Tariq Iqbal, George Mann, Data Logging and Control of a Remote Inverter Using LoRa with A Local Storage, accepted to present at 26th IEEE NECEC conference 2017.
- Terashmila Lasagani, Tariq Iqbal, George Mann, the Best communication method for remote control of grid-tied converter for an energy storage system, presented at 25th IEEE NECEC conference 2016.

Poster presentations

- L. K. A. Terashmila, T. Iqbal and G. Mann, Data logging and control of a remote inverter using LoRa, Arduino, RS232 and SD card, Poster session presented at: NESTNet Technical Conference. 1st Annual conference. 21-22 July, 2017; Toronto, ON.

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