Lirima

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Agrinet
A Wireless Sensor Network for Smart Agriculture

Nathalie Mitton

Riaan Wolhuter

ELECTRICAL & ELECTRONIC ENGINEERING
STELLENBOSCH UNIVERSITY

Partners & Locality (1)

Inria

Self-Organizing
Future Ubiquitous Networks (FUN)
Nathalie Mitton

ELECTRICAL & ELECTRONIC ENGINEERING
STELLENBOSCH UNIVERSITY

Partners & Locality (2)

Stellenbosch University - Dept of E & E Eng
Dept of Viticulture – Agrisciences
Thomas Niesler, Albert Strever, Riaan Wolhuter
Denzil Christians

Background

General:

- In both France and South Africa, agriculture is hugely important
- The economic- and social consequences in both countries are serious
- The natural environment present more and growing constraints
- Any contribution towards more efficient farming should be a priority
- We seek to make a contribution by establishing a WSN based platform for better management of crops and resources

France:

The proposed system is not very crop specific, but:

- In France the potato crop is the most important farmed vegetable
- One third of production is exported
- Annual production is app. 8Mtonnes, no. 2 in Europe
- 170 000 ha under production
- Major production also in Euro context
- Work is already being undertaken by Inria with an industrial partner ito. WSNs for potato farming

South Africa:

- For viticulture in particular, the Western Cape and Northern Cape are very important farming areas
- Water is very often a limited resource and becoming more so
- Both these areas are currently facing drought conditions
- These are having a significant impact on food production
- The social economic impact is very high
- App 130 000 ha under production for wine & table grapes
- Big contributor to SA economy
- SA is 7^{th} in the world volume wise for grapes

Objectives

- To create an advanced, flexible, WSN for wide area agricultural
- data measurement
- To enable the forwarding thereof to a central monitoring centre
- To adapt current machine learning and pattern recognition
- algorithms to:
  - ➢ obtain an area wide and in depth view of crop and soil conditions
  - ➢ enable optimal crop management and harvest conditions
  - ➢ exploit and explore the interdependence of different parameters and their locality variability to obtain a statistically reliable view of trends and overall conditions
- Great potential value in presenting early warning signs of disease and other unwanted conditions

Workplan (1)

- Small, low cost, ISM communication enabled nodes, specifically for deployment in vineyards
- Nodes form an adhoc WSN, with dynamic, ML based routing strategy
- Increased network footprint
- Compensate for propagation problems due to variable
- crop-, climatic- and vineyard topography
- Multiple paths increase data transmission reliability to central gateway or server
- 433/900 MHz the frequencies of choice
- Well established, proven hardware, available at low cost
- One or more gateway nodes with cloud connectivity
- WiFi data link, existing LAN, or mobile network
- Enable utilisation of data at a remote location of choice

Workplan (2)

- Field nodes will also accept sensor inputs eg. temperature, humidity, sap movement, spectral and image data
- Data will be analysed from all nodes by pattern processing strategies
- Multiple inputs from multiple nodes integrated into a ML classification framework
- Complementary and inter-dependent data input will enable detection of converging patterns
- New level of confidence for early warning strategies and sensing accuracy
- Increase cost efficiency and accuracy in farming

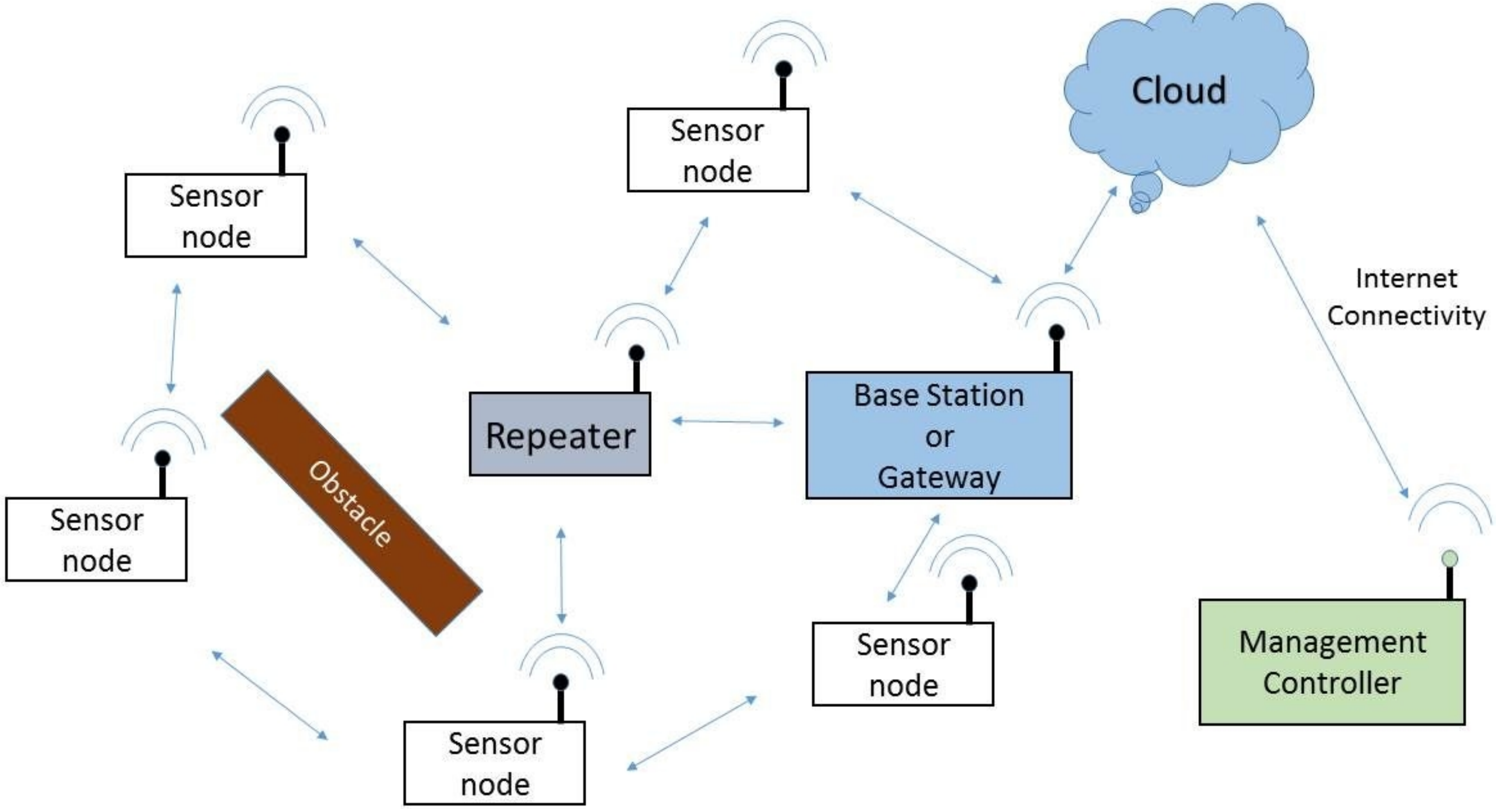
System Design (1)

Application environment

Variable terrain and plant cover

System Design (2)

Typical WSN configuration:

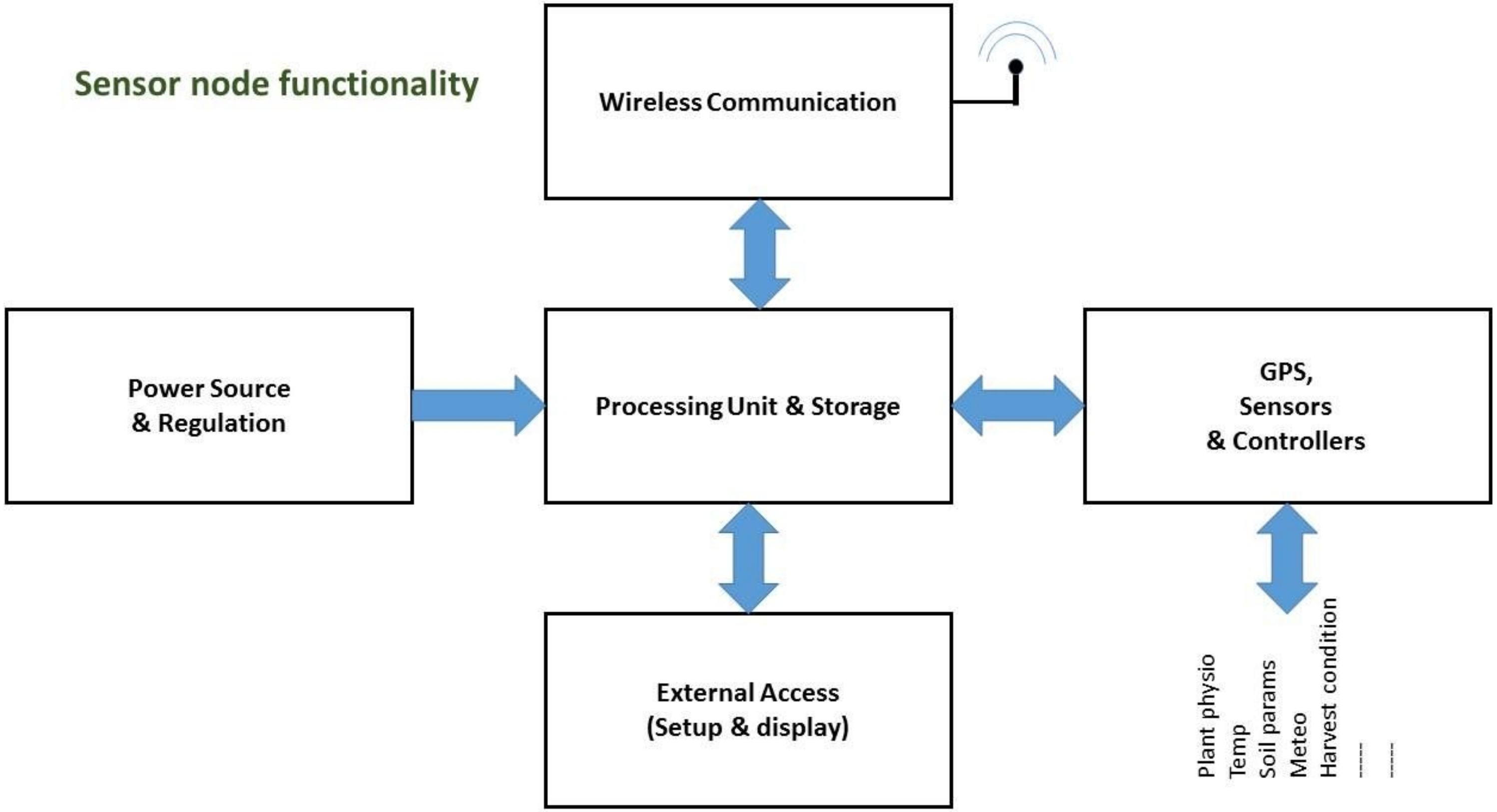


Sensor network architecture

System Design (3)

WSN Block Diagram

Sensor node functionality



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Progress to Date (1)

- System specifications defined
- Hardware identified and tested, NB 433MHz (TI CC1200) and LoRa (HopeRF RF96W)
- LoRa based sensor seems to present a good choice as WSN platform
- First round practical tests carried out
- Simple adhoc protocol seems to be more robust and feasible than very sophisticated strategies
- Error mitigation strategies should be implemented as part of the communications strategy
- First predictive algorithm developed from existing dataset
- Actual power measurements on each transceiver to determine true/real power output of each transceiver in progress
- Results are not always as per the spec sheets

Progress to Date (Measurements)

TABLE II
KEY CHARACTERISTICS OF THE 5 CONSIDERED RADIO DEVICES.

Device	SI4463	RFM96W	RFM22B	RFM23BP	E31-TTL
Vendor	SI	HopeRF	HopeRF	HopeRF	EByte
Tx power [dBm]	+20	+20	+20	+30	+30
Sensitivity [dBm]	-120	-148	-121	-114	-126
Current Tx [mA]	88	120	85	550	510
Current Rx [µA]	13.7	12.1	18.5	18.5	15.5
Current sleep [µA]	1	0.2	1	1	1.7
Supply [V]	3.3	3.3	3	5	5
Modulation	FSK	LoRa	FSK	FSK	FSK
Interface	SPI	SPI	SPI	SPI	UART

Fig. 2. An example of the terrain and vegetation found in the testing environment at Cape Point nature reserve.

in received signal strength between the two frequencies lessens as the receiving antenna height is raised. At a height of 0.63m this difference is 3.47dB m and at 3.5m it is only 1.85dB m.

The radius r (in meters) of the widest point of the Fresnel zone is given by the Fresnel equation $r = 17.32 * \sqrt{\frac{d}{4f}}$, with d the distance between links (in km), and f the frequency (in GHz) [12]. The Fresnel zone at 169MHz is larger than that of

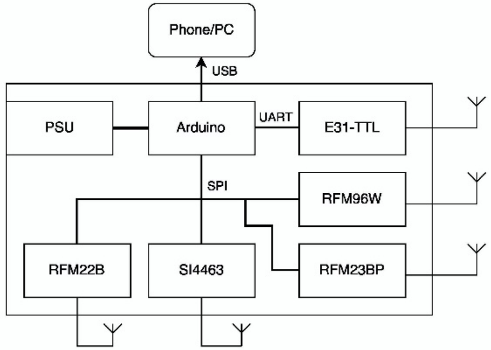


Fig. 3. A block diagram of the testing station.

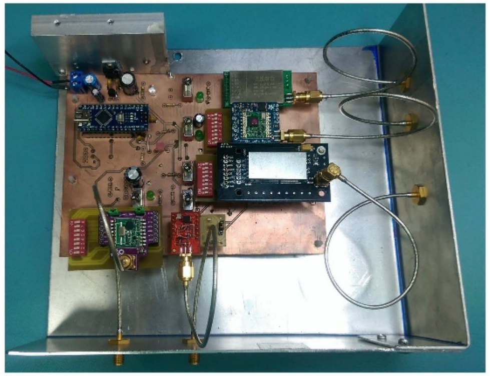


Fig. 4. A photograph of the testing station. A metallic box surrounds the PCB and short 50Ω cables connect the radios to the female SMA connectors grounded to the box. The metallic box acts as a ground plane, as well as ensuring that no torque is placed directly on the SMA port of the radio itself.

LoRa / NB Measurements

TABLE I
AVERAGE MEASURED RECEIVED SIGNAL STRENGTH FOR EACH FREQUENCY OVER ALL DISTANCES

Rx Height [m]	169MHz [dBm]	433MHz [dBm]	Difference [dBm]
0.63	-74.64	-78.11	3.47
1	-72.51	-76.36	3.85
2	-69.39	-72.61	3.22
3	-68.01	-70.48	2.47
3.5	-66.64	-68.48	1.85
Total Change	8	9.64	

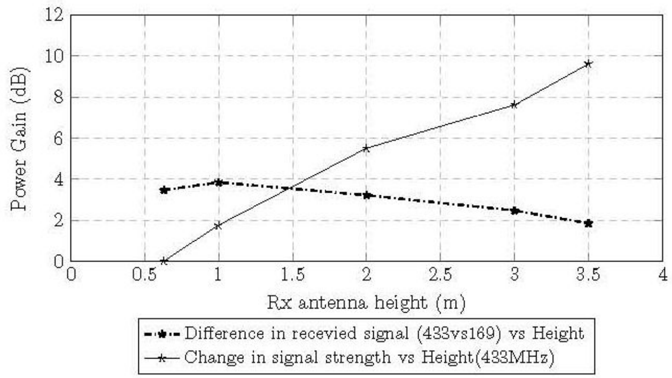


Fig. 1. Received signal strength difference between 169MHz and 433MHz vs antenna height as well as the change in received signal strength for 433MHz vs antenna height.

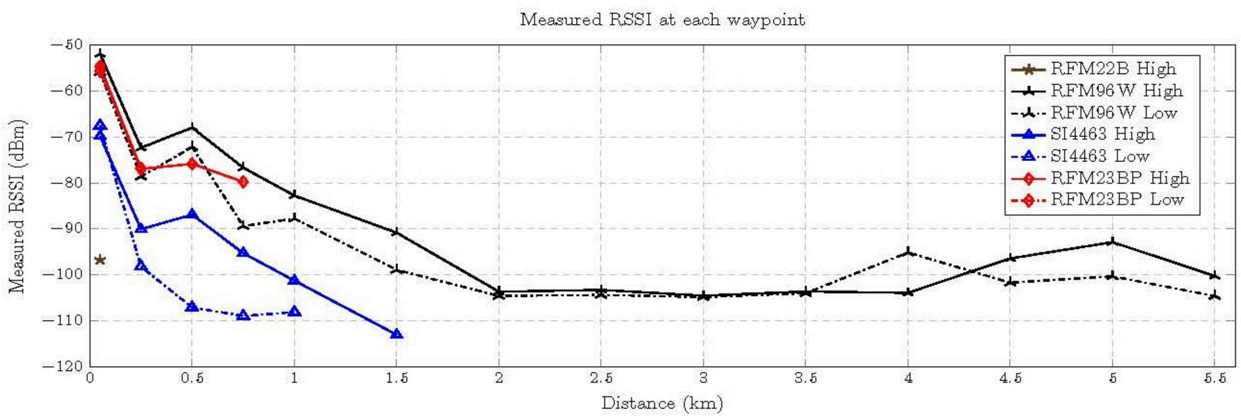
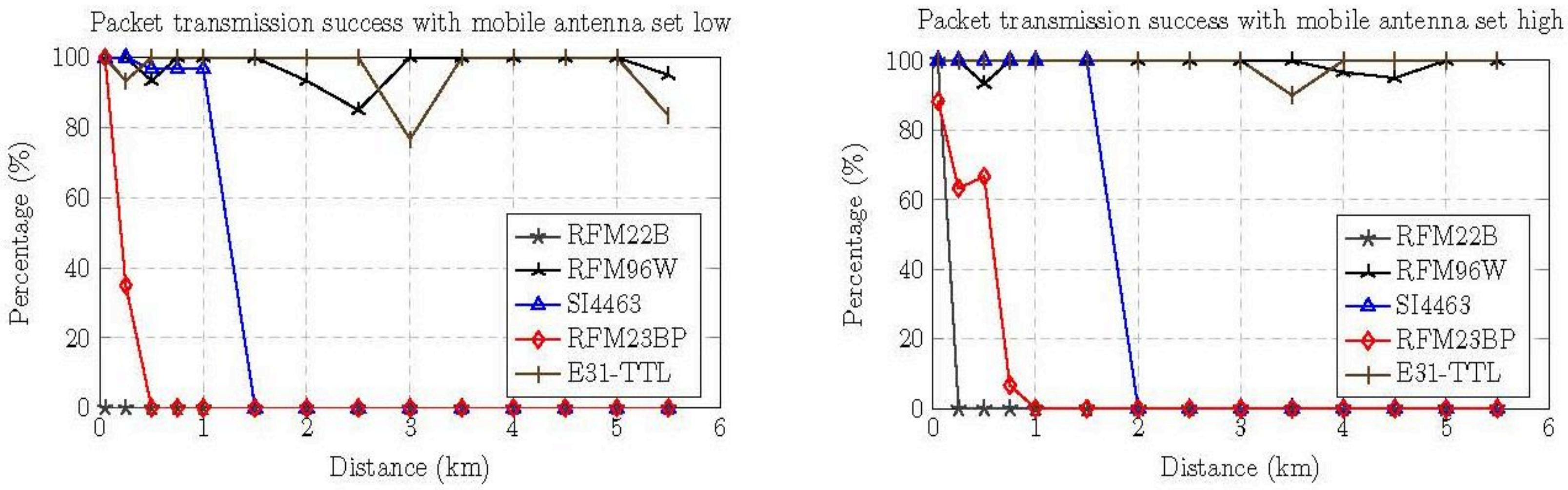


Fig. 5. The RSSI measurements at each waypoint (from 50m to 5500m) from each radio when the mobile antenna was set to 4m (high) as well when the antenna was set to 0.1m (low).

LoRa / NB Measurements (cont)



(a) (b)

Fig. 6. The percentage of packets which were successfully transmitted between stations for (a) antenna low and (b) antenna high positions. Each marker indicates the percentage at a specific distance, where 100% corresponds to no packet loss, while 0% indicates that no packets were successfully transmitted.

the distance at which a particular radio was no longer able to establish communication as the point at which its plot terminates. We see that, the further the radios are from one another, the lower the RSSI. This is expected as the signals between the radios experience increased free space losses as the distance between the stations increases [21]. The signals are also progressively disrupted and deflected by objects in the

TABLE III
PERCENTAGE OF SUCCESSFUL PACKET TRANSFERS BETWEEN STATIONS AVERAGED OVER ALL CONSIDERED DISTANCES.

Packets Received	RFM22B	RFM23BP	SI4463	RFM96W	E31-TTL
Low [%]	0	9.64	35	97.62	96.67
High [%]	7.14	16.07	42.86	98.93	99.29
Average [%]	3.57	12.86	38.93	98.28	97.98

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Planning and Summary

- Understanding and applying real hardware performance figures
- Verification in the vineyard
- BER tests have been implemented on two Arduino Mega boards. Final tests to be concluded
- Actual WSN PCB design
- More extended field trials
- More advanced predictive algorithms still to be developed, but initial results are promising
- At this stage, no results have been found to indicate that the initial concept is not sound

Stellenbosch & Surroundings

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Discussions & Questions