

WSN Lab 2019, Group 1: Solar Pro

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Abstract—The source of future energy production has to be and is undoubtedly renewable and environmentally friendly. Solar power is one of the most readily available energy sources in almost all parts of the world. Although solar power is ubiquitous, certain physical and technological limitations allow for a maximum efficiency factor of 37% (and that's for commercially available high end solar cells). This implies that only 37% of the sun's energy that is captured by the solar cell can be converted to useful electrical energy. This paper focuses on using Wireless Sensor Networks (WSN) to utilise the maximum possible energy of the solar cells without any further losses by aligning the solar panel orthogonal to the sunrays depending on the daytime.

I. INTRODUCTION

The energy generated by the solar panels is highly dependent on the angle of incidence of the sunrays on the panel.

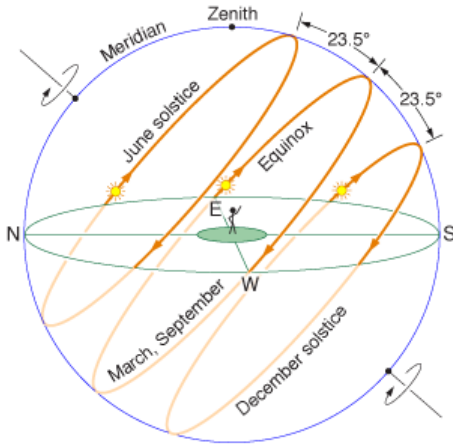


Fig. 1: Sun's path in Winter and Summer. Source: [?]

The sun's path in the horizon is dynamic and dependent on the time of the year. In the northern hemisphere, the sun is higher in the sky during summer and lower in the winter. In the summer the sun rises in the north east and sets in the north west. Whereas in winter, the sun rises in the south east and sets in the south west as it can be seen in Fig. 1

As we can see from Fig. 2, consequent of the sun's path in the sky the angle of incidence of the sun's rays on the panel changes not only during the day but as well as during the different months of the year.

In order to track the sun's rays, so that the solar panel is always perpendicular to it, we need a dynamic system that

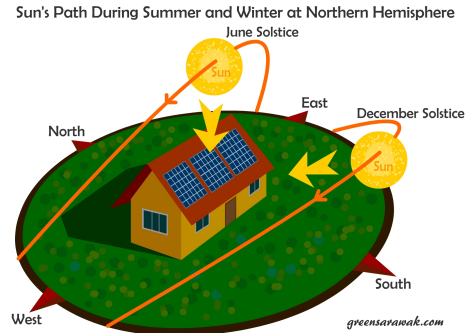


Fig. 2: Angle of incidence of the sun's rays on the panel
Source: [?]

adjusts to the E-W changes in the sun's angle during the different times of the day as well as the N-S tracking during the changes in the months.

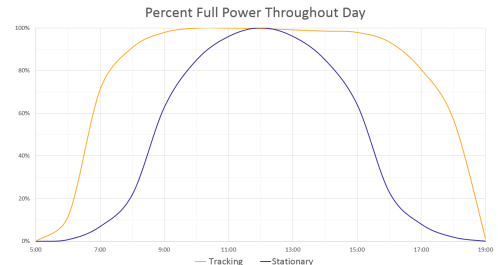


Fig. 3: Comparison of energy produced by a tracking vs non tracking system Source: [?]

II. APPLICATION SET UP

Our proof of concept showcases the potential to utilising a wireless sensor network to not only control the tracking of the panel but also log panel data. In order to achieve this we employ three different kinds of sensors, eight wireless motes, of which one is set up as the base station connected to a desktop computer and the seven others deployed around the basestation to function as sensor and panel control motes. Since only four digital servo motors are available, not every mote in the field is able to align the solar panel according to the sun's rays. Nevertheless we can still measure and transmit sensor values. A possible setup with a multihop communication towards the base station is depicted in Fig 4.

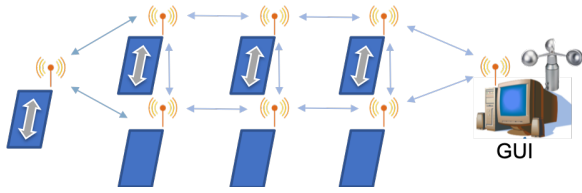


Fig. 4: Possible application setup with seven sensor motes and a base station ensuring multihop communication.

A. Sensors

Described below are the different types of sensors used in our application along and their uses:

- **Digital Servo Motor - HS-422 [1]**
A servo motor is a cheap rotary actuator which is connected to the mote via three wires: Ground (GND), Voltage (VDD) and Signal. The servo angle can be set via the signal wire by using a PWM-Signal. Most servos expect to see a pulse every 20ms. The correspondence between pulsewidth and servo angle is as in formula The servos will be used to change the angle of solar panels.

$$pw = 1.0ms + 1.0ms \cdot \left(\frac{\alpha}{\alpha_{max}}\right) \quad (1)$$

- **Light Sensors [?]**
The light sensors are used in this proof of concept to simulate the power output of the solar panel.
- **Wind Speed Sensor [?]**
This monitors the windspeed at all times and is connected directly to the base station. In the case of excessive wind speeds, the panels will have to be stowed at a safe angle.
The Windspeed sensor interfaces with the base station by sending a digital signal, which is processed by the base station using interrupts and the interrupt trigger interval gives us the windspeed.

$$ws = 0ms \cdot \left(\frac{\alpha}{\alpha_{max}}\right) \quad (2)$$

- **Zolertia RE-mote platform [2]**
This is the brain of the Wireless sensor network which will be used together with the Contiki OS

B. Motes

We are using 8 motes in total out of which

- 7x Zolertia REMotes are used as nodes attached to solar panels
- 1x Zolertia REMote is used as a base station

1) *Base station*: The base station is connected to a computer which displays the GUI (current state of the network). It runs a different code compared to the panel motes as it has to account for interfacing with the computer and collect data from the wind speed sensor at the same time.

2) *Panel Motes*: The panel Motes runs a subset of the base station code.

III. NETWORK DESCRIPTION AND ROUTING TECHNIQUES

In this proof of concept we are demonstrating an energy harvesting WSN which provides information on the status of the solar panel along with the ability to control the angle of the panel in 1 axis. In a real world scenario it is intended that the mote [2] will be connected to the solar panel and be able to draw minimal power required for the functioning of the mote.

A. Network

Considering our application and the reliability as one of the factors, we decided that a centralised base station polling based querying scheme suits our application the most. The routes are first discovered during the network discovery phase and the routing tables are exchanged as described in III-D

B. Modes of Operation

In our application we have 5 modes of operation, which are

- IDLE
- NETWORKDISCOVERY
- PATHMODE
- UNICASTMODE
- EMERGENCY

1) *IDLE*: When the device comes out of reset this is mode, the mote gets into.

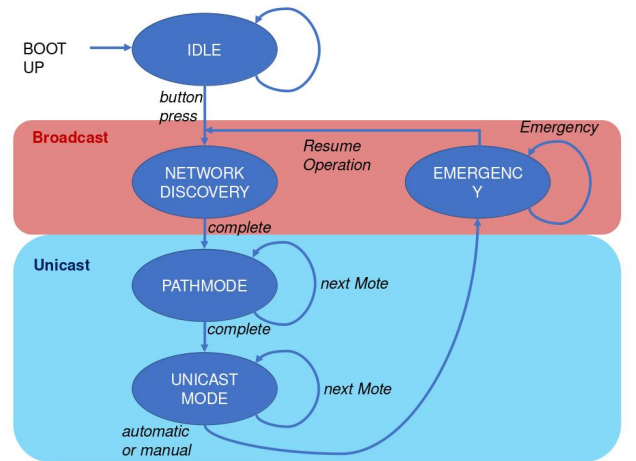


Fig. 5: Angle of incidence of the suns rays on the panel
Source: [?]

C. Routes

D. Network Discovery

IV. GRAPHICAL USER INTERFACE (GUI)

The graphical user interface (GUI) is a desktop application programmed with the aid of the QT Creator and focuses on displaying information about the motes operating in the field and allows the user to interact with a desired mote .The computer running the GUI is directly connected to the base

station mote via a serial link.

The GUI basically consists of the two tabs "General" and "Connections" as shown in Fig. 6a and Fig. 6b.

The "General" tab shows a network graph of the wireless sensor network and the system time. Communicating sensor motes are depicted with a yellow circle and a number inside, whereas the base station is shown centered as green circle. The doublesided arrows depict the wireless communication route and therefore the network topology. It does not show possible wireless communication between sensor motes, because only the shortest paths towards the base station as sink in the network is of importance. The two buttons "Network Discovery" and "Emergency" in the bottom left corner enable the user to trigger these two operational states manually.

Two info boxes aligned to the right side of the window show the sensor information of the motes. The upper info box shows the values of the anemometer connected to the base station, such as the actual wind speed, the average windspeed, the maximum windspeed and the emergency threshold, at which the solar panels are aligned to a predefined safety angle. The GUI also allows to choose a user defined emergency threshold, which is set by pressing the "Set" button next to the number field. The default value is 16 km/h.

The lower info box shows the sensor information of the selected mote. A mote is selected by clicking on a mote in the network graph. The particular information such as the Node ID, the temperature, voltage, luminosity and panel angle are presented. For maintenance reasons it is also possible to operate the selected mote by clicking on the "Manual" button. It is then possible to enter an angle between 0 and 180 degrees to manually align the selected solar panel by clicking the "Set" button next to the number field.

The second tab of the GUI allows the user to connect and disconnect the serial link to the base station via selecting the respective port and clicking the buttons "Open" to connect or "Close" to disconnect. The textbox aligned to the bottom of the tab shows possible debug information from the base station.

V. FUTURE WORK AND OPTIMISATIONS

VI. APPLICATION SPECIFIC FEATURES

The MAC layer is not modified and runs the Contiki standard configuration "ContikiMAC" according to [3].

VII. CONCLUSION

The power efficiency of solar panels highly depends on the inclination angle of the sunrays. By aligning the solar panel orthogonally to the sunrays depending on the daytime it is possible to increase its energy efficiency. In this application a wireless sensor network has been employed to control the solar panel angle via a digital servo and measure amount of light hitting the panel with a light sensor. Furthermore the temperature of the controlling mote and its battery voltage is read out.

The application setup consists of seven sensor motes, of which four motes operate a digital servo. One mote functions as base station and delivers the sensor information to a desktop application with a GUI.

The network is set up by first initialising a network discovery routine. All motes broadcast and collect information about their neighbors to set up their very own distance vector table.

After completion, the base station reaches out to each mote with a unicast request to collect the shortest path through their respective acknowledge.

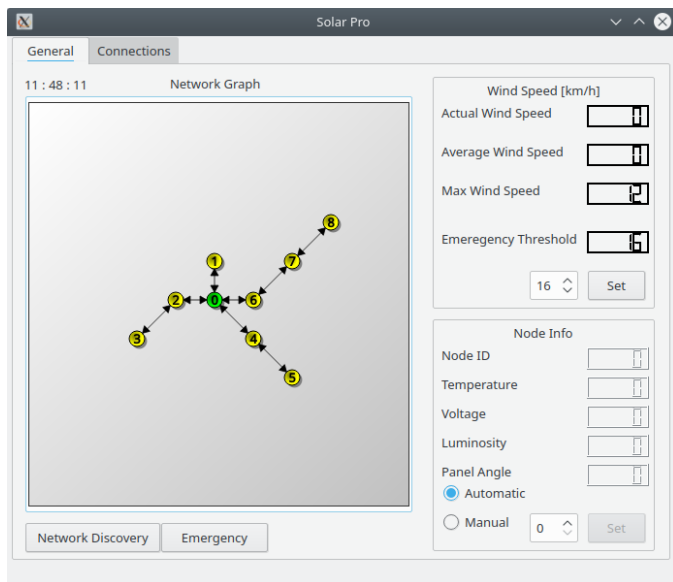
With this information the base station is able to poll the sensor informations of each node by cycling through the network.

The network graph and sensor information are visually presented in the graphical user interface, which also allows to operate the servo position manually, set a wind speed emergency threshold or simply trigger an emergency case manually. It is also possible to manually restart the network discovery. Further ideas to advance the application are a sun tracking algorithm which steers the solar panel according to sensor values. Another useful feature would be to integrate data visualization of the sensor values as a graph showing the history of e.g. the last 24 hours.

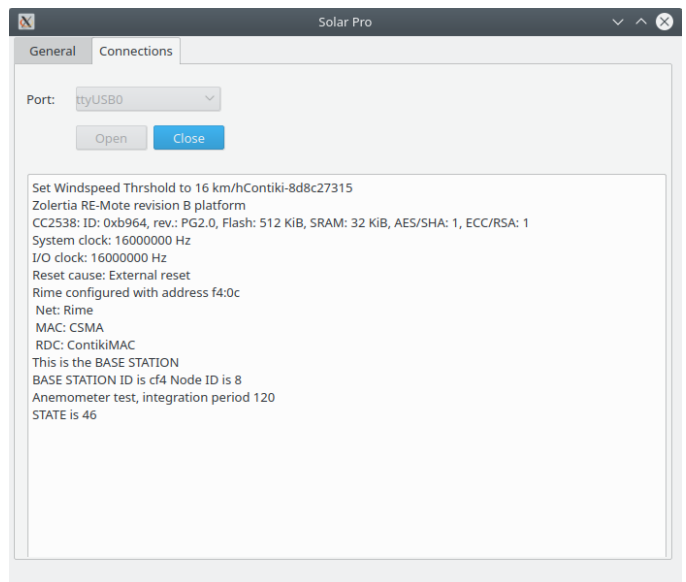
The conclusion goes here. [3]

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- [1] K. Sukumar, "Servo Motor HS-422," <https://www.multiplex-rc.de/produkte/112422-servo-hs-422>, 2008, [Online; accessed 19-July-2008].
- [2] —, "Zolertia Remote," <https://github.com/Zolertia/Resources/wiki/RE-Mote>, 2008, [Online; accessed 19-July-2008].
- [3] A. Dunkels, "The contikimac radio duty cycling protocol," 2011.



(a) GUI General Tab



(b) GUI Connections Tab

Fig. 6: Graphical User Interface of the Solar Pro Application