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Low-Cost Cloud Enabled Wireless Monitoring System for Linear Fresnel Solar Plants

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OUTLINE

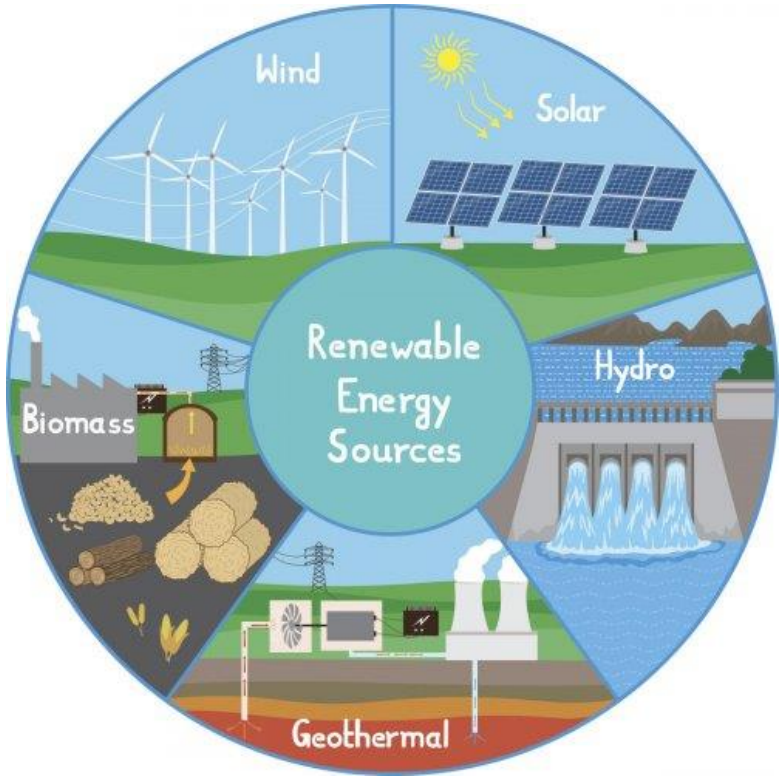
- Introduction
- Linear Fresnel Solar Plants
- Monitoring System Architecture
  - Hardware
  - Cloud-based Monitoring
- Discussion

1. Introduction

1. INTRODUCCTION

- **Renewable energy technologies** have gained tremendous attention globally stimulated by the need of replacing the fossil energy systems, in spite of the fact that they are **clean sources of energy derived from plentiful and unlimited sources** that have a much lesser negative impact on environment than conventional fossil energy technologies.
- **Energy from the solar radiation** has the largest potential for providing abundant, clean, safe, and reliable power.
- Solar energy techniques currently available:
  - PhotoVoltaic (PV) cells/panels. The most common technique. PVs are well-known electronic devices used to generate direct current electricity from solar radiation.
  - Concentrated Solar Power (CSP). CSP systems are employed to reflect and concentrate sunlight onto receivers that collect solar energy and convert it into heat. Then it can be used to produce electricity via a steam turbine or a heat engine driving a generator.

CSP systems are advantageous over the PV technology by having **higher conversion efficiencies**, **low investment cost** and **inherent thermal storage** to work during the off hours.



Source: www.deccanherald.com

1. INTRODUCCTION

- Monitoring and performance analysis of solar plants are crucial aspects to observe the stability and performance of the system.
  - Decrease of operation cost and maintenance.
  - Ensuring faults detection.
  - Increase of energy production efficiency.

- Monitoring of the status of solar plants can be implemented by:
  - Interface cables.
  - Wireless communications.
  - Both.

Security, speed and reliability for data transmission.

Technical limitations for installation.
Higher material cost: *wires, expenses for trenching, lightning protection and protection against rodents*.
Higher maintenance cost.

The successful application of wireless communication technologies in PV plants and the obtained cost reduction make it an **attractive technique for monitoring CSP plants**.

1. INTRODUCCTION

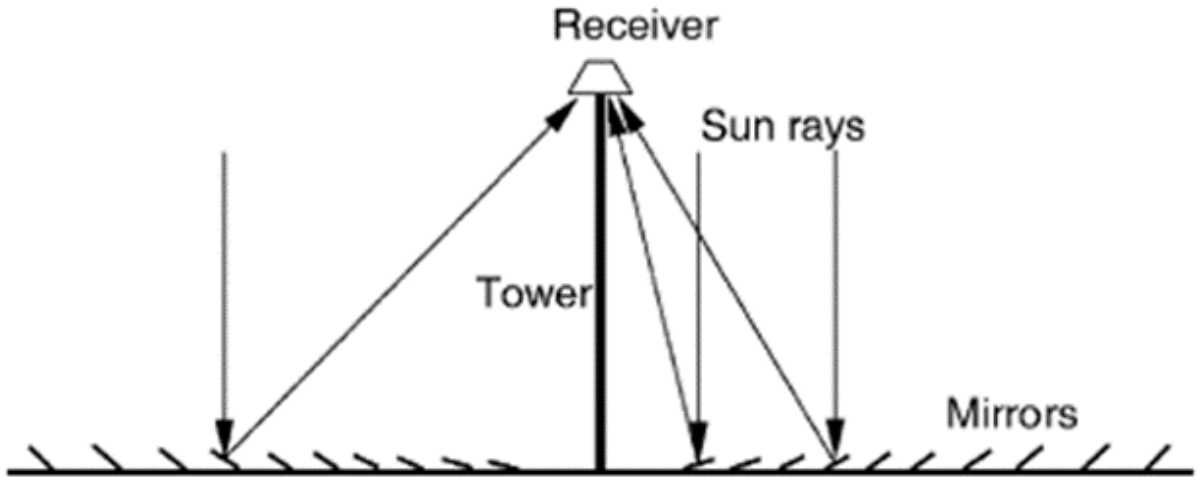
Aim of the work

- This work proposes a **low cost WSN-based monitoring system for LFR plants**.
- The designed wireless nodes are based on **ZigBee communication technology** and are **supplied by solar paneled power cells**.
- The employed **sensors** provide information regarding the **efficiency, stability, fault detection, safety and security** of the LFR plants.
- In order to monitor remotely the LRF plants, **the collected data is sent** through a Gateway node **to a specifically designed and developed Cloud and web-based monitoring system**.

2. Linear Fresnel Solar Plants

2. Linear Fresnel Solar Plants

- **LFR** is a recent entrance technology of CSP based usually on small scale projects.
- It composes of many long **rows segments of flat mirrors**, which focus the light onto a fixed **elevated tubular receiver** running parallel to the reflector rotational axis.
- Mirrors are aligned horizontally and track the sun position such that the tubular **receiver is illuminated (i.e. heated) without need to be moved**.



Source: S. A. Kalogirou, "Solar thermal collectors and applications," Progress in Energy and Combustion Science, vol. 30, pp. 231-295, 2004.

2. Linear Fresnel Solar Plants

- In a recent EU-funded project, Small scale Thermal Solar districts for Mediterranean communities (STS-MED), a **solar multi-generation approach** has been implemented in four different countries (Cyprus, Egypt, Jordan and Italy), each characterized by different collectors and different integration scenarios.

- In this work we consider two LFR plants (in Egypt and Italy) where PLC and SCADA systems are used for monitoring and control.

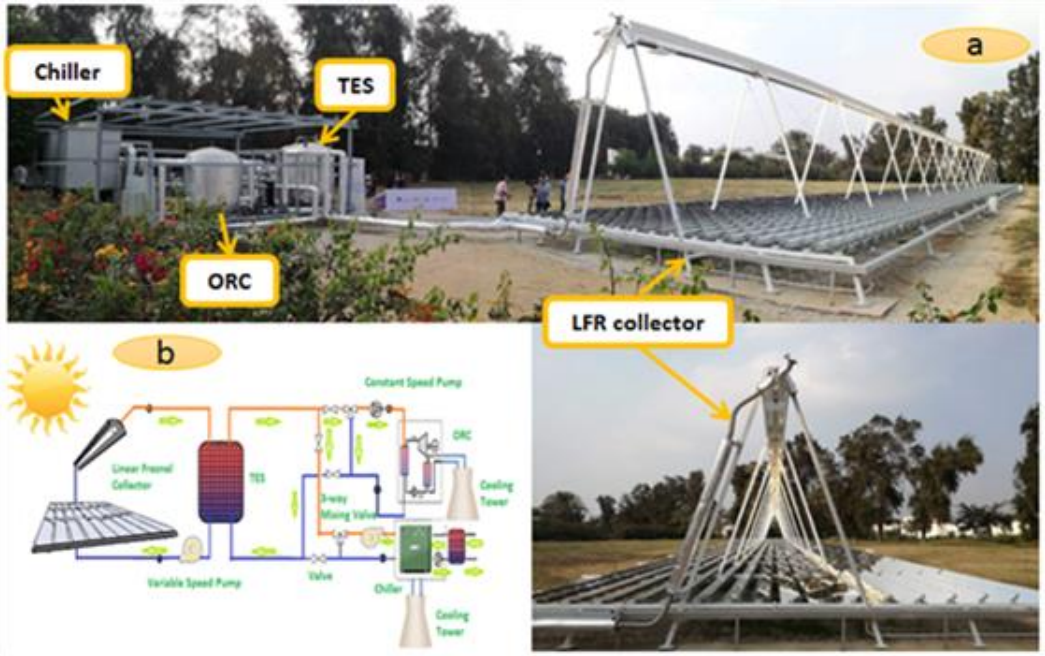
Table 1. Data specification of LFR plants.

Data	LFR Egypt	LFR Italy
Latitude	30°25'05.5"N	38°06'01.0"N
Longitude	31°38'07.8"E	13°20'37.3"E
Elevation	35 m	50 m
DNI per year	1958 kWh.m^{-2}	1703 kWh.m^{-2}
Aperture area	299.50 m^2	483.84 m^2
Thermal oil	Therminol 66	Paratherm NF
Peak power	115 kW	190 kW
Receiver length	52 m	84 m
Working temperature	140°C	270°C

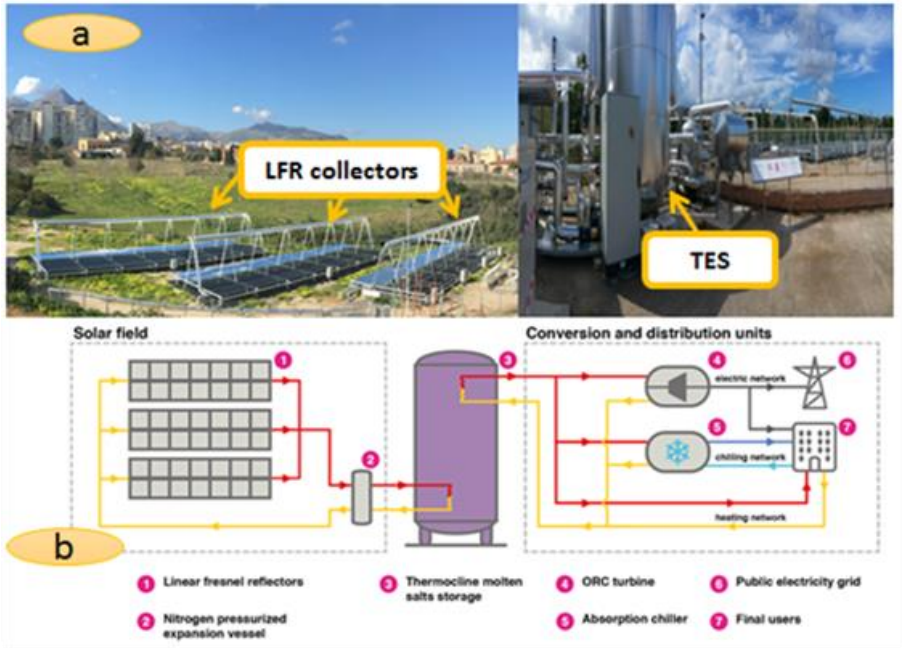
2. Linear Fresnel Solar Plants

- The plant in Egypt includes LFR collectors (model IDEA 1FC-1832). It consists of a single Linear Fresnel solar collector, thermocline storage tank, 4 kW organic Rankine cycle (ORC), and 35 kW thermally driven chiller.
- The plant in Italy has been commissioned in the campus of the University of Palermo. It consists of three identical LFRs, thermocline ternary molten salt tank, 10 kW ORC, and 23kW LiBr chiller.
- The subsystems of multi-generation LFR plants that require adequate monitoring and control are, mainly, the sun tracking system, Thermal Energy Storage (TES) System, outlet temperature of HTF along the solar collector, power generation and cooling generation.

Sekem LFR solar plant, in Egypt



Palermo LFR solar plant, in Italy

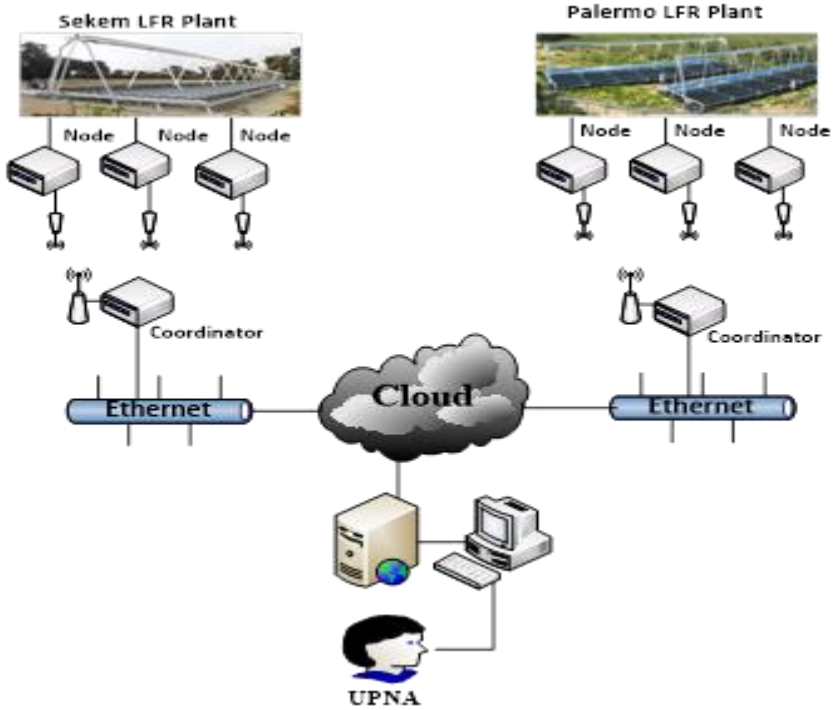


3. Monitoring System Architecture

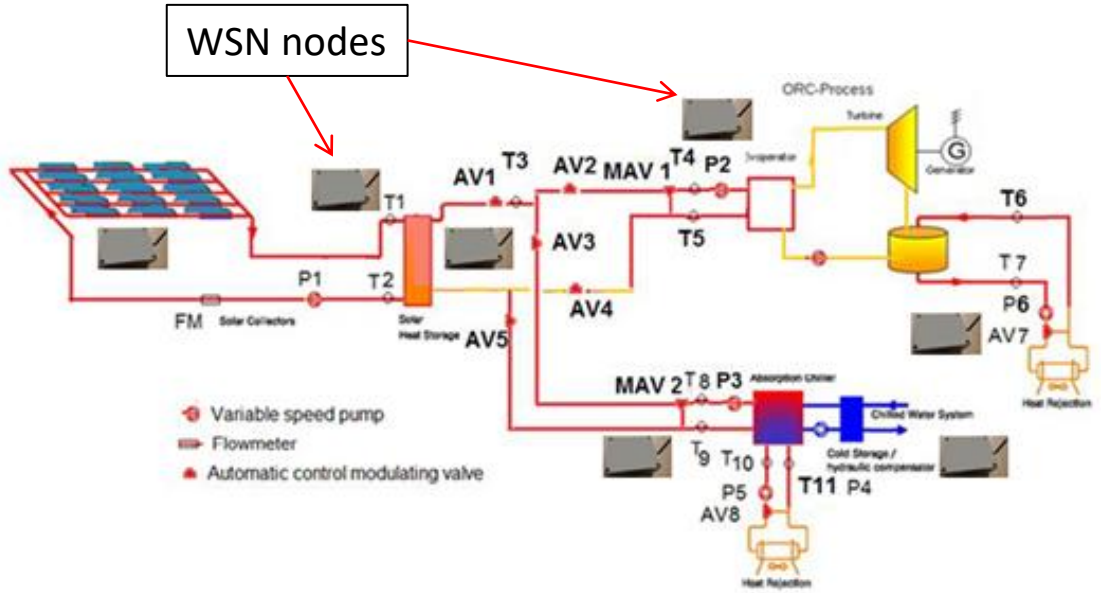
- ✓Hardware
- ✓Cloud-based Monitoring

3. Monitoring System Architecture

- **The proposed wireless monitoring system** of the LFR plants deployed in Egypt and Italy **is based on a ZigBee-based WSN** of many nodes distributed in different zones of the plant.
- The **mesh topology** provided by ZigBee **provides the full coverage of the area of interest** as well as **high degree of redundancy**.
- The **collected data** is sent to the wireless network coordinator, which will send the information **to the Cloud** via Ethernet connection, for its **control and monitoring in the Public University of Navarre** (UPNA), Spain (it could be also monitored from Egypt and Italy).



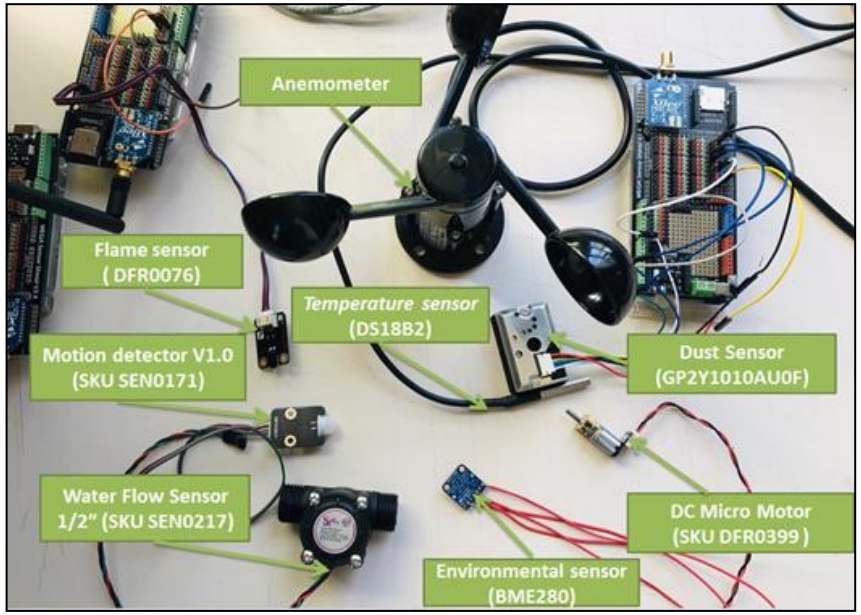
Communication architecture of the proposed monitoring system



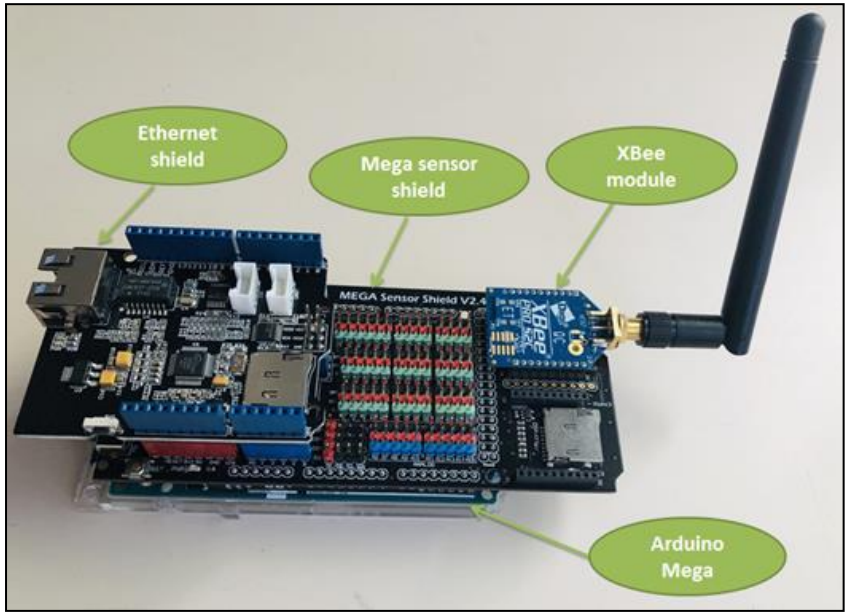
Proposed WSN for the LFR plant monitoring system

3. Monitoring System Architecture

- **Hardware**
- For the goal of monitoring fault detection, minimum time delay, safety and security, several **low-cost sensors** have been employed (based on Arduino or compatible boards).
- Digi's ZigBee s2c XBee-PRO operating at 2.4 GHz band have been employed as RF modules.
- Test-bed at UPNA prior a future deployment in the LFR plants



Sensor nodes



Coordinator node

WSN: 8 nodes + 1 coordinator (distributed in 3 buildings and gardens)

Test duration = 3 hours

99.7% of packets arrived successfully to the Cloud

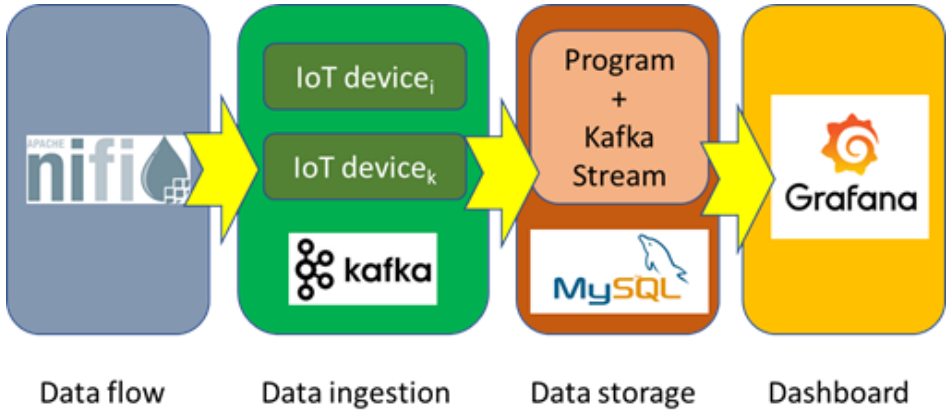
3. Monitoring System Architecture

- **Cloud-based monitoring**

- A specific cloud infrastructure has been developed, located at the campus of the Public University of Navarre (UPNA):
  - Six TTL Teknoslim computers, equipped with Intel i5-7500 quad core processors, with 16 GB of RAM and two hard disks (a 256 GB SSD, and a 1TB HDD).

- The proposed system is based on well-known and –proven open-source tools:
  - Apache NiFi component: in charge of data flow managing.
  - Apache Kafka component: in charge of handling real-time data.
  - MySQL relational database.
  - MongoDB no relational database.
  - Grafana platform for analytics and monitoring:

Collects the information from the MySQL database and provides structured and useful information over an interactive dashboard.



4. Discussion

4. Discussion

- **This work proposed a wireless cloud-based monitoring system for LFR plants in order to facilitate remote monitoring and control.**
  - ✓**ZigBee** wireless communication technology has been chosen (mesh topology)
  - ✓The WSN nodes are suited to measure various **key parameters** of LFR plants
  - ✓The system can be configured with different sampling times and it is **easily scalable** to any number of measurement points, which renders it highly versatile.
  - ✓The monitored parameters are displayed on a **web-based graphic interface for its analysis and processing.**
  - ✓The **test** of the system has been **successful**.
- **Future work:**
  - ✓The evaluation and deployment on the real plants will be reported in future works.
  - ✓Assessment of other wireless communication technologies, such as LoRaWAN, SigFox and NBIoT.

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THANKS!

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