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SOLAR POWERED WIRELESS MONITORING SYSTEM OF ENVIRONMENTAL CONDITIONS FOR EARLY FLOOD PREDICTION OR OPTIMIZED IRRIGATION IN AGRICULTURE

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ABSTRACT

This paper describes the design and realization of a smart electronic system, based on a Wireless Sensor Network, for wide-area monitoring of availability level and rapid changes of the water presence in the monitored soil, in order to guarantee, depending on application, early flood prediction, water savings in the optimized farmland irrigation as well as waste reduction and optimal use of water resources where its availability is low. The designed sensor node, equipped with a small PV panel to recharge the Li-Ion battery for feeding the entire system, by means of the different embedded sensors, is capable of detecting environmental parameters, the solar radiation level and soil temperature and moisture (i.e. water volume content) values. The sensors communicate with a central processing unit located on board, the ESP8266 SoC module, used both as data processing unit and as Wi-Fi transceiver to receive/transmit sensors data; the user near a sensor node, by a tablet or smartphone with an appropriate app, can collect information provided from sensors and share them with all users who use the same app, through peer to peer Wi-Fi or other internet connection.

Keywords: wireless sensor network, environmental data monitoring, electronic equipment, signal processing.

INTRODUCTION

Water is a common good essential to life; the effects of climate changes, water's wastes and its non-uniform distribution in the area make it a resource hardly available and findable, often at the center of social tensions particularly in the developing countries. Water's distribution and dispensing are often obtained with conventional outdated systems; also it lacks a feedback system of presence on the territory of water resources, in order to detect any waste. In addition, it would be really fundamental the availability of a method or technology to monitor real-time the changes of water content or levels into the ground (useful in farming activities or similar) and to recognize the effects of climate changes, which often cause soil instability such as landslides and floods.

Figure-1. (a) Climate change's effects which often result in instability of the territory as landslides and floods and (b) monitoring of water resources where the availability is low especially in the developing countries.

With reference to water monitoring and management for irrigation or to water level's measuring for disaster prevention, the soil water content (or moisture) is an essential information for best management practices, for example to improve the agriculture sustainability. Irrigation management by means of continuous monitoring of soil moisture with dedicated environmental sensors is becoming widespread among agricultural growers.

Thanks to the availability of low cost/power and high performance transceivers for the modern wireless technologies, the operation capability and flexibility of wide area Wireless Sensor Networks (WSNs) is increasing more and more, with lower operation cost but greater robustness compared to traditional wired systems (Corke *et al.*, 2010). Thereby, the environmental physical parameters can be effectively collected and monitored for ensuring early flood prediction or optimized irrigation in agriculture. In the recent years, with the development of innovative Soil Moisture Sensors (SMS), the interest for research in these fields and practical applications is highly increased. A SMS-based system is the combination of soil moisture sensor and its controller; the buried sensor carries out the measurement of soil water content and communicates it to the irrigation controller.

The simplest and common control methodology is the "bypass" one with a smart device that bypasses the automatic irrigation, otherwise activated by using a programmed timer, when the soil moisture content is adequate for plant needs. A research work on water savings resulting from SMS-based irrigation controllers has shown a saving on water consumptions high up to 72% compared to an irrigation schedule typical or recommended for that region (Cardenas-Lailhacar *et al.*, 2010). Several works reported the benefits of using a SMS-based system for water savings effectively bypassing unnecessary as well as superfluous irrigation events (Haley *et al.*, 2012).

The need for monitoring the agricultural environment has been studied (Patil *et al.*, 2014), with the development of a smart system to monitor various ambient parameters like temperature, humidity, soil moisture and water level using a wireless sensor network (WSN) based on Zigbee/IEEE802.15.4 standard. A new architecture for decision support in the flood prediction using heterogeneous WSNs has been proposed, providing new opportunities for many innovative applications (Andersson *et al.*, 2015). Early warning flood detection also has been treated in Basha *et al*, with proper system architecture and deployment to meet the design requirements and to allow model-driven control, thereby optimizing the prediction capability. A multi-channel water level telemetry and low power automatically warning system based on WSN was developed (Chen *et al.*, 2013); in the proposed system, sensor nodes monitor water levels and transmit detected data to sink node periodically. The host server analyzed the sensing data received from the sink node to take decisions according to comparison algorithm, thus improving the alarm accuracy.

Power consumption is a key point for sensor node life time in WSNs located in remote and uninhabited places. Sensor nodes are battery driven devices and often operate on an extremely frugal energy budget; an energy harvesting system based on one of different developed techniques can be used as alternative power source of wireless sensor nodes in conjunction with the battery (Fayeez, *et al.*, 2015) (Amruta *et al.*, 2013).

Regarding long-duration and large-scale environmental monitoring with the aim of flood prediction or water savings in the farmland irrigation, several techniques can be used to measure soil parameters such as water quality,volumetric water content or moisture level, temperature and presence of harmful or polluting substances on the soil surface or below it, as discussed in detail in a paragraph of this paper.

This research work outlines a smart system, based on a WSN, useful to control the availability level and rapid changes related to water presence in the area through a real-time monitoring of the water flows into the ground resulting from climate calamities which often generate instability events, such as landslides and floods. By using the latest information and communication technologies, the designed sensor node, equipped with a wireless WiFi radio module, monitors the status/level of the water into the ground, its changes and detects information of different nature (such as temperature and humidity on the soil surface or below it and solar radiation level). Then different algorithms process these detected data for optimized water management in farmland irrigation or monitoring point by point of water resources where its availability is low, especially in developing countries.

ARCHITECTURE AND OPERATION MODE OF DESIGNED MONITORING ELECTRONIC SYSTEM

It was developed and realized a smart electronic system that, using modern “Internet of Things” (IoT) technologies today available, detects information about presence and real-time availability of water resources in the area where WSN-based monitoring system is installed and sends the detected data, also relative to environmental parameters, to the nearby tablets and smartphones that use an ad-hoc developed application. By means of a tablet or smartphone, moreover it’s possible to share information read from each sensor with all users who use the same app, through peer to peer Wi-Fi connection or any other Internet connection.

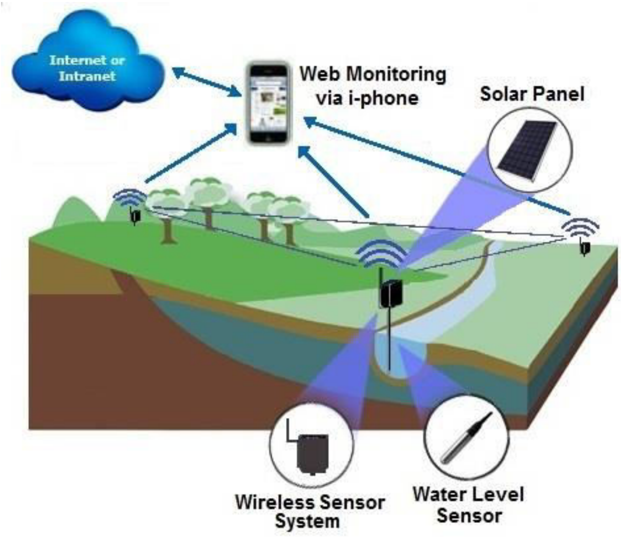
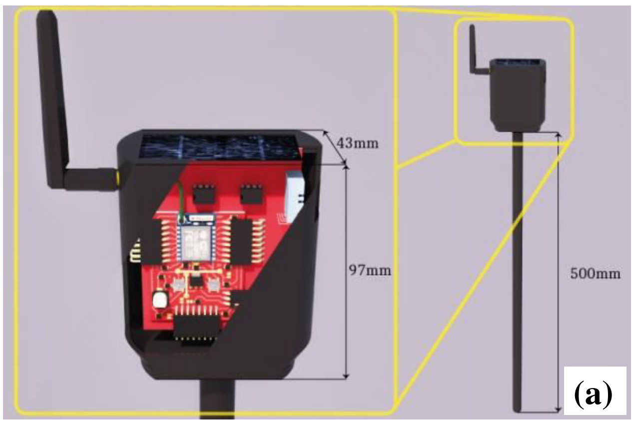


Figure-2. WSN for land monitoring and data processing/ transmission about presence and real time availability of water resources and prediction of environmental disasters.

The realized sensor node, shown in Figure-3(a) assembled and 3b disassembled, is provided inside of different sensor types such as ambient humidity and temperature sensors, solar radiation and soil moisture sensors, this last installed within the soil. The sensors communicate with a central processing unit located on board that sends the detected information, through Wi-Fi radio module, on cloud to be collected by tablet or smartphone using the appropriate app.



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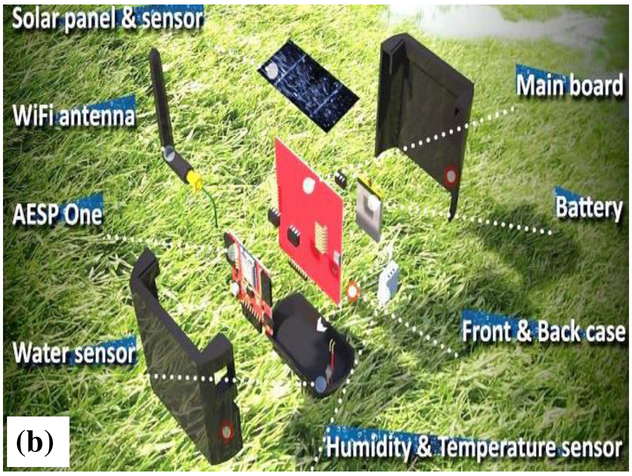

Figure-3. Viewing of realized wireless sensor node (a) complete of humidity, temperature, solar radiation and soil moisture sensors and its exploded depiction (b) with indication of all embedded components.

As shown in Figure-3, the designed sensor node includes other components as a small photovoltaic (PV) panel on top side that allows to recharge the lithium battery in order to supply the entire electronic system also during daylight hours (Fayeez *et al.*, 2015). In the block diagram of Figure-4a, the typical connection between PV panel and rechargeable battery (DC output voltage=3.3V) by means of a battery charger is reported whereas the internal circuital scheme of battery charger, with LTC3105 IC device of Linear Technology, is shown in Figure-4b.

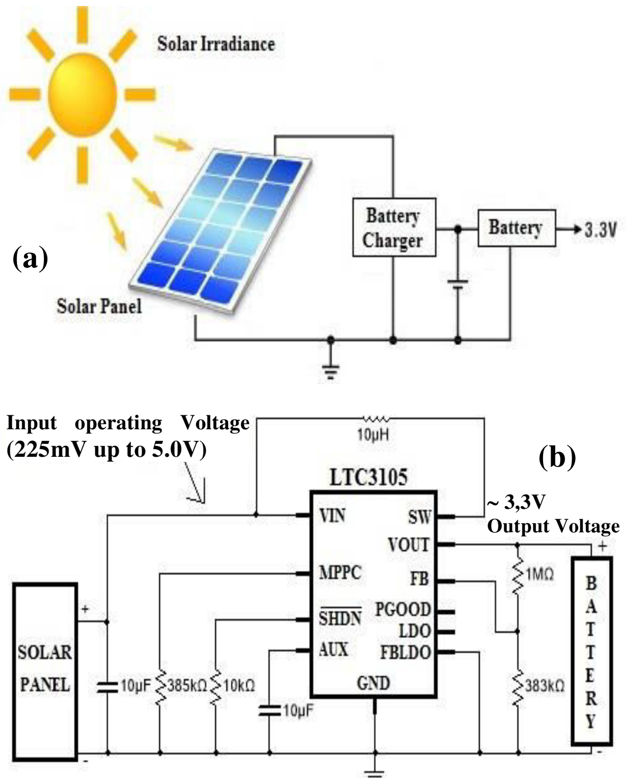

Figure-4. Connection between PV panel and rechargeable battery (a) and internal circuital scheme of battery charger with LTC3105 IC device (b).

The integrated circuit LTC3105, used for the battery charger, is a high efficiency step-up DC/DC converter that can operate with input voltages as low as 225mV. A 250mV start-up capability and integrated maximum power point controller (MPPC) enable operation directly from low voltage, high impedance alternative power sources such as photovoltaic cells, TEGs (thermoelectric generators) and fuel cells. A user-programmable MPPC set point maximizes the energy that can be extracted from any used power source. Thanks to its excellent performances which allow to perform optimally the charging of Li-Ion battery, a 3.3V output voltage, provided by the battery, is available to feed, at any time, the realized sensor node.

The main block of designed system, on which is based the entire operation of the sensor node, is the AESP One fully compatible development board, shown in the Figure-5, based on ESP8266 Wi-Fi radio module after described in detail. The AESP One board collects information from connected sensors and, through a Wi-Fi radio module, sends data on cloud. It's a project developed to be suitable with the most software and USB UART hardware (used to program the device) available on the market. Although an antenna is embedded in ESP8266 device, an external antenna was added to obtain greater network coverage when using the sensor node outdoors.

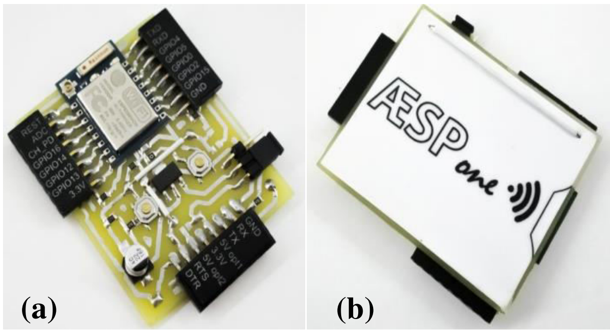

Figure-5. (a) Realized AESP One fully compatible development board based on ESP8266 module with pinout connections (b) and its bottom view with printed label.

AESP ONE BOARD BASED ON ESP8266 MODULE TO DETECT DATA FROM SENSORS AND SEND THEM ON CLOUD

The main characteristics of the AESP One board are a single PCB face that makes simple the PCB printing, fully configurable jumpers for further devices integration and easy to use combined with a small form factor (useful for mobile applications).

AESP One board, whose circuital scheme is shown in Figure-6, can be programmed in function of specific desired application and it is compatible with most commercial USB UART adaptors. There is no need of external power supply, during programming operations, due to presence of voltage regulator AMS1117 which receives 5Volt as input, characteristic of USB UART adaptors, and supplies 3.3Volt to the output suitable for supplying the entire electronic board.

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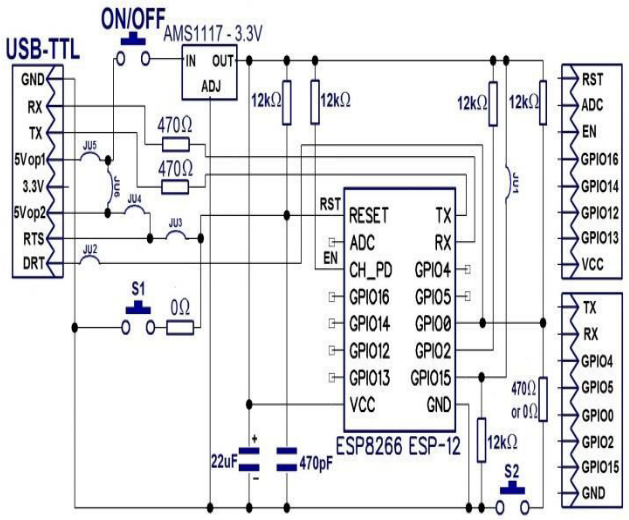

Figure-6. AESP One circuital scheme designed with ESP8266 Wi-Fi Radio Module embedded.

Due to presence of a CPU (with maximum clock frequency of 160MHz) embedded into the ESP8266 Wi-Fi radio module, various network protocols and dedicated pins for communication are available. By using I^2C or SPI serial communication protocols, the AESP One board can be interfaced with other devices through GPIO pins, useful these last also to use other functions provided by the ESP8266 embedded module.

The board layout, shown in Figure-7, has been designed by using Eagle software with particular attention for obtaining a simple PCB, with a small size and fully configurable thanks to the presence of several jumpers. All GPIO pins of ESP8266 Wi-Fi module are externally accessible (see the Figure-8 with presence of connectors to interface the board with other external devices). There are two push buttons on the realized board, one on the left in Figure-8 for resetting the board before (or after) to run the loaded program and the second one, on the right, to put the board in flash mode. It's available a jumper plug, on the right side, to disconnect the board from power source or to power on the designed device itself.

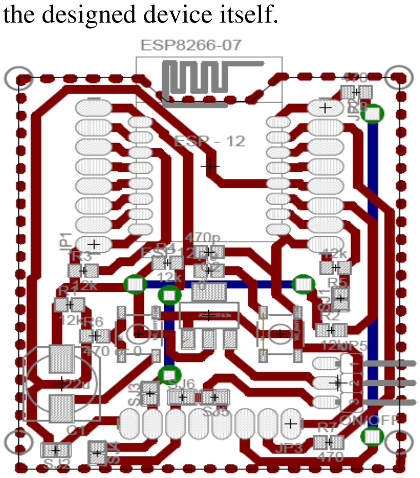

Figure-7. Layout view of AESP One board designed using EAGLE Software PCB design.

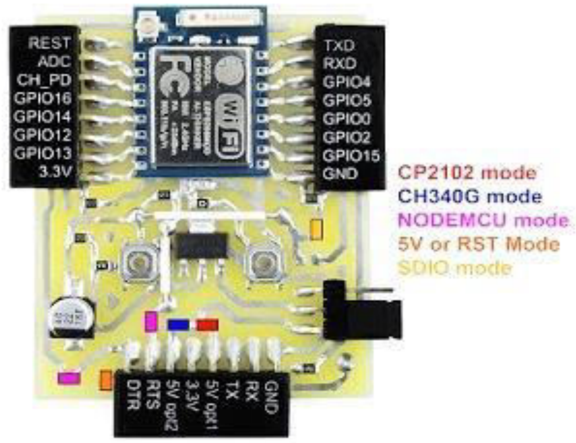

Figure-8. View of realized board with fully configurable jumper and indication of GPIO pins' functionality.

The AESP One module is installed on a mother-board or main board shown in Figure-3 to which the different used sensors are connected; the rechargeable battery, using energy from the solar panel, feeds the entire designed system. Also an external antenna is used in order to provide greater network coverage in case of use of the sensor nodes in outdoor environment. The electronic board is equipped with a DHT11 Humidity and Temperature sensor to measure them in the environment where is located, with a solar radiation sensor to control the weather as well as PV panel's performance and with a SMS device based on Frequency Domain Reflectometry (FDR) method to measure the volumetric amount of water present in the surrounding soil by detected relative dielectric constant. Before making a detailed analysis of the technical specifications and operation of used sensors, in the following section there is a description of ESP8266 Wi-Fi module, used both as processing unit of detected data from sensors and as Wi-Fi transceiver module to receive/transmit the data to/from the cloud.

ESP8266 PROGRAMMABLE WIFI RADIO MODULE TO PROCESS AND SEND DATA TO SMARTPHONE OR TABLET

The designed sensor node is based on the Wi-Fi System-on-Chip (SoC) module called ESP8266 (Espressif Smart Connectivity Platform) shown in Figure-9. It is a 2.4GHz Wi-Fi transceiver produced by Espressif Systems (*http://espressif.com*) with embedded not only the RF stage but also a fully programmable 32bit microcontroller, registers for the management of I/O pins and the SPI/I^2C serial communication protocols. Moreover, the possibility to execute a pre-loaded firmware and to manage some digital and analog GPIO pins allows to interface it with peripherals or external devices of different typologies (in our case, the used sensors). By means of ESP8266 module, wireless internet access can be added to any microcontroller-based design with simple connectivity through the available UART interface. There are up to 16 GPIO pins, each assignable to various functions by the firmware (e.g. interrupt input), with internal pull-up/down resistor and a multiplexing of analog inputs for connection to sigma-delta analog/digital converter. In Figure-10 is shown the block diagram of ESP8266 SoC Wi-Fi module.

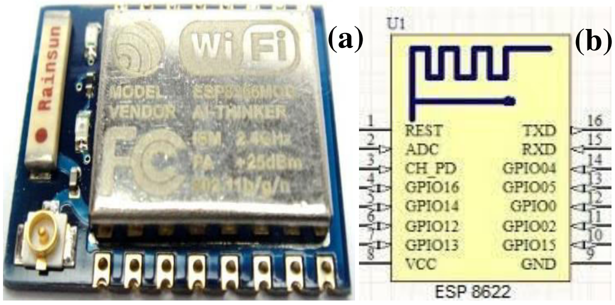

Figure-9. (a)Viewing of ESP8266 Wi-Fi Radio Module (b) and its pinout description.

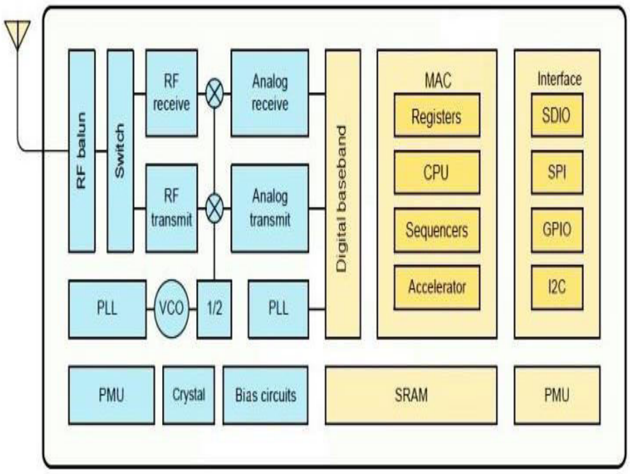

Figure-10. ESP8266 block diagram with its main internal functional blocks.

The ESP8266 chip was designed to operate with a supply voltage of 3.3V with a maximum allowable value of 3.6V; each digital input is provided with a proper circuit of overvoltage protection in order to secure the integrated circuit from input voltages exceeding 6V. Finally, it allows the use of all the most modern encryption protocols, as well as, WEP (RC4), CCMP (CBC-MAC, counting mode), TKIP (MIC, RC4) or WAPI (SMS4), WEP (RC4), CRC, WPA, WPA2 e WPS.

ESP8266 on-board processing and storage capabilities allow it to be integrated with the sensors and other devices for specific applications through its GPIO pins with minimal required development and very small loading during the runtime. With its high degree of on-chip integration, including a WiFi antenna with switch balun device, power management converters and a front-end module, it requires minimal external circuitry so that the entire solution occupies a minimal PCB area. Other sophisticated system-level features include fast sleep/wake context switching for energy-efficient VoIP, adaptive radio biasing for low-power operation, advance signal processing, bluetooth and LCD interference mitigation.

ESP8266 module can be programmed to wake up when a specified condition is detected; this minimal wake-up time feature can be utilized by mobile devices, allowing them to remain in low-power standby mode until Wi-Fi is needed. In particular, the ESP8266 chip implements three different operation modes with regard to power consumption; *active mode, sleep mode and deep sleep mode*, each one requiring the activation of a number of embedded devices and peripherals. In sleep mode, the radio module is turned off whereas the watchdog timer remains active and the current consumption is only 12µA; in this operation mode, it is possible to program the internal timer to turn on the radio module at regular time intervals to send or receive data. If necessary, it is possible to turn on the Wi-Fi radio module and thus to enable data transmission using external signals. The CH_PD line, available on the external connector, allows to bring the ESP8266 module in deep sleep state with analmost zero current consumption. The current absorption from ESP8266 powered device during active mode reaches a maximum of 215mA at maximum power transmission with 802.11b protocol (data rate equal to 11Mb/s) and it drops to 145mA with 802.11g protocol (data rate equal to 54Mb/s).

The realized AESP One board is fully compatible with commercial USB-UART adaptors such as CP2102 and CH340G models, both shown in Figure-11. At last, a programming option is provided to flashing the System-on-Chip Wi-Fi ESP8266 module through the push buttons on board or the RTS/DTR pins of UART USB adaptor.

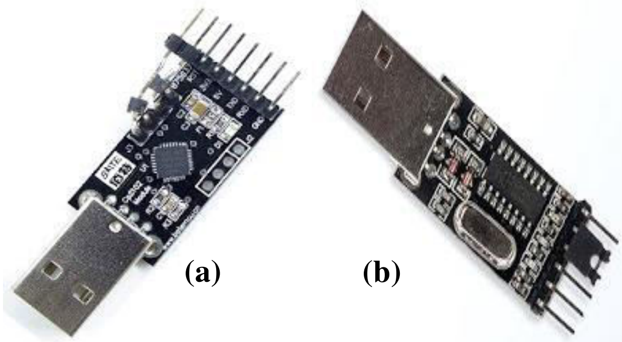

Figure-11. (a) UART-USB adaptors: CP2102 adaptor's model and (b) CH340G model

MONITORING OF WATER PRESENCE: DESCRIPTION OF THE COMMON SOIL MOISTURE SENSING TECHNOLOGIES

Several methods are usable for measuring and monitoring the soil water content on the ground surface or below it; following a description of the main measurement techniques is reported distinguishing between the direct and indirect ones.

The water content in the soil can be directly determined using the difference in weight before and after drying a soil sample; this direct technique, usually referred to thermo-gravimetric method or simply gravimetric, determines the water content as weight of water over weight of dry soil (i.e. the ratio of the mass of water present in a sample to the mass of the soil sample after it has been oven-dried). Although the direct methods are accurate and inexpensive, they are destructive, slow, time-consuming and do not allow to make repetitions in the same location.

Anyway, the most practical techniques for soil water monitoring are indirect, mainly classified in *volumetric* or *tensiometric* methods. While the first gives the volumetric soil moisture, the latter yields the soil suction or water potential (i.e., the tension exerted by capillarity); both quantities are related through the soil water characteristic curve, specific to a given soil.

In this research work, a sensor based on volumetric method was used, in particular on method known as dielectric technique, widely adopted for the good response time (almost instantaneous) and because it doesn't require maintenance and provides continuous readings through an automatic operation. There are different dielectric methods such as *Time Domain Reflectometry* (TDR), *Frequency Domain* (FD) and *Capacitance and Frequency Domain Reflectometry* (FDR).

In the TDR method, the soil bulk dielectric constant (Ka_b) is determined by measuring the time it takes for an electromagnetic pulse to propagate along a transmission line (TL) that is surrounded by the soil. A TDR instrument requires a device capable of producing a series of precisely timed electrical pulses, with a wide range of high frequencies to be used by different devices (e.g., 0.02-3 GHz), which travel along a TL that is built with a coaxial cable and a probe (Figure-12). This high frequency provides a response less dependent on soil specific properties like texture, salinity or temperature.

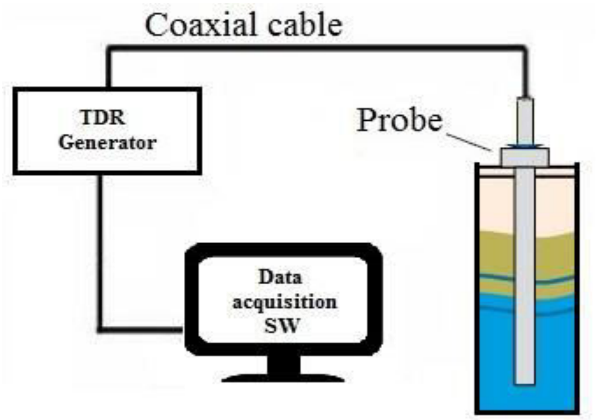

Figure-12. TDR instrument for measuring the propagation time of an electromagnetic pulse along a transmission line (coaxial cable and a probe) surrounded by the soil.

The TDR probe usually consists of 2-3 parallel metal rods that are inserted into the soil acting as waveguides, in a similar way as an antenna used for television reception. At the same time, TDR instrument uses a device for measuring and digitizing the energy (voltage) level of the TL at time intervals down to around 100 picoseconds. When electromagnetic pulse, traveling along the TL, finds a discontinuity (i.e., probe-waveguides surrounded by soil) part of the pulse is reflected, producing a change in the energy level of the TL. Thereby, the travel time (Δt) is determined by analyzing the digitized energy levels. Soil salinity or highly conductive heavy clay contents may affect TDR measurements due to attenuation of reflected pulses. In soils with highly saline conditions, the use of epoxy-coated probe rods can solve the problem but with a loss of sensitivity and changes in calibration. In addition to travel time, another feature of pulse travelling through the soil can be related to the soil electrical conductivity, the pulse's size or attenuation. Thus some commercial devices are capable of measuring the water content and soil salinity simultaneously.

The FD method uses the capacitance of a capacitor, with the soil as dielectric, varying with the soil water content. When the capacitor (made of metal plates or rods embedded in the soil) is connected to an oscillator getting an electrical circuit, the changes in soil moisture produce variations of the circuit operating frequency. In FDR method, the oscillator frequency is swept under control within a certain frequency range to find the resonant frequency (at which the amplitude is greatest), which gives a measure of water content in the soil.

The probes consist of two or more electrodes (plates, rods or metal rings around a cylinder) inserted into the soil (Figure-13). When an electrical field is applied, the soil around the electrodes forms the capacitor's dielectric completing the oscillating circuit.

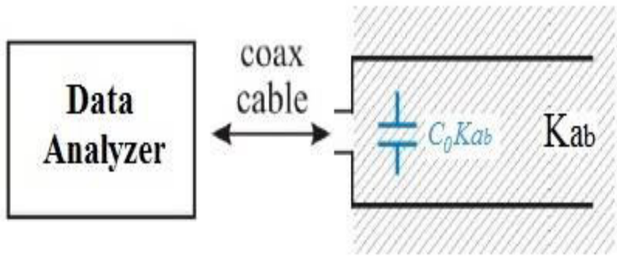

Figure-13. FD method uses a capacitance with the soil as dielectric whose permittivity varies with soil water content.

A common approach to establish the relationship between the soil bulk permittivity (or dielectric constant), Ka_b and the volumetric soil moisture or Water Volume Content (WVC) is the following empirical equation:

$$WVC = -5.3 \bullet 10^{-2} + 2.29 \bullet 10^{-2} Ka_b - 5.5 \bullet 10^{-4} Ka_b^2 + 4.3 \bullet 10^{-6} Ka_b^3$$

Since the dielectric constant of liquid water (Ka_w = 81) is much higher than that of the other soil constituents (Ka_s = 2–5 for soil minerals and 1 for air), the soil bulk permittivity is mainly determined by liquid water presence.

Before analyzing in detail the Soil Moisture Sensor used in this work, following it is reported a description of commercial sensors to measure the volumetric water content within the soil, analyzing the

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operating principle and the relevant technical specifications.

The Granular Matrix Sensor (GMS), shown in Figure-14a, is made of a porous ceramic external shell with an internal matrix structure containing two electrodes.

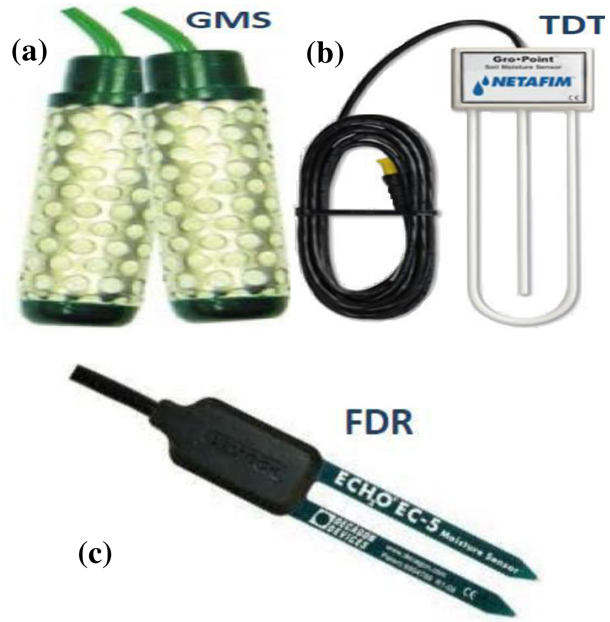

Figure-14. Commercial SMS devices: Granular matrix sensor model (a), TDR sensor (b) and FDR sensor (c).

An internal gypsum cylindrical tablet buffers against the high salinity levels of irrigated soils; the GMS calibration depends on temperature and soil type whereas the reaction time is slower than other modern sensor types.

The Time Domain Transmissometry (TDT) and its precursor TDR sensors (Figure-14b) measure the time required for an electromagnetic pulse to travel a finite distance along a rod or wire. TDR sensor measures the travel time based on reflected waveforms while TDT is an equivalent technique that measures the transmitted (rather than reflected) pulse. The travel time is then converted into the soil's WVC value. These sensors provide high accuracy, not affected by low/moderate soil salinity levels. FDR sensor, shown in Figure-14c, operating at a high frequency are relatively unaffected by soil salinity levels. The increasing use of the dielectric methods (TDT/TDR and FDR) are due to the following advantages:

- No need for calibration
- Minimal or no maintenance
- Installation and use is non-destructive
- Measurements may be made near the surface
- Provide instantaneous and accurate measurements
- Can be used for automatic control of irrigation systems

The SMS device used in the designed sensor node, manufactured and marketed by Netsens company, adopts the FDR method; as previously reported, it determines the volumetric amount of water present in the soil surrounding by measuring the relative dielectric constant. Each measurement is done after a calibration of the internal sensor, carried out automatically, aiming at removing any error or inaccuracy due to temperature changes or to natural decay of the components. The innovative 4-fork design (as shown in Figure-15a) is specially designed to obtain more accurate measurements. A special manufacturing technique covers the sensor with a protective layer, to make it immune to effects of ions and dissolved salts in the soil. The analog voltage output has two channels for soil moisture and temperature detection, with a power supply voltage required in the range [4.5V ÷ 18V]. The sensor performs a self-calibration before each new measure to minimize reading errors and its output is also corrected for temperature variations of the soil.

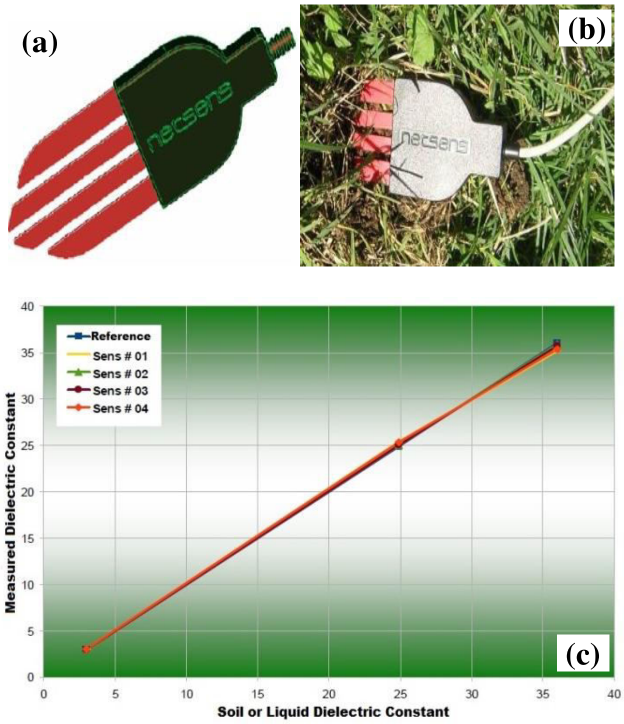

Figure-15. Soil moisture and temperature sensor: 4-fork design to obtain accurate measurements (a); sensor covered with a protective layer to make it immune to effects of ions and dissolved salts in the soil (b); graph with solid or liquid dielectric constant (known) vs measured soil's dielectric constant (c) (four sensors sample tested materials whose dielectric constant is known).

With regard to FDR-based SMS device described above, the formulas for WVC and T calculation as a function of V_{OUT} output voltage are the following:

WVC (%) = 80 x (V_{OUT} - 0.5) / 2.5
T (°C) = (100 x V_{OUT} / 3) - 50

If the measured V_{OUT} is equal to 1.35Volt then the WVC value is 27.2%; if measured V_{OUT} is equal to 2.15V, the corresponding value of temperature is 21.6 °C.

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ENVIRONMENT HUMIDITY AND AIR TEMPERATURE SENSOR: OPERATION MODE AND TECHNICAL FEATURES

In order to measure the environment humidity and air temperature, it was chosen the DHT11 sensor which provides a digital output varying as function of detected air temperature and humidity. For this purpose, the sensor includes a resistive-type humidity sensing component and a negative temperature coefficient (NTC) thermistor (its resistance decreases with increasing the detected temperature). The used technology fabrication of the DHT11 sensor guarantees high reliability, excellent long-term stability and a very fast response time.

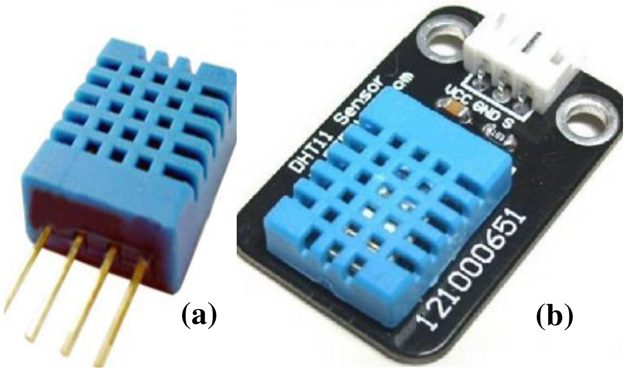

Figure-16. (a) DHT11 Humidity and Temperature Sensor with embedded a resistive humidity sensing device and a NTC thermistor (b) and the breakout board for DHT11 sensor which gives a digital output according to temperature and humidity measured values.

DHT11 sensing device is accurately calibrated before marketing; the calibration coefficients are stored in the internal memory and used by the embedded detecting/processing unit. The single-wire serial interface makes the integration of this sensor in digital systems quick and easy. Sensor physical interfacing is realized through a 0.1pitch 3-pin connector (+5V, GND and DATA pin); the first two pins, power supply voltage and ground, are used to power the sensor, the third one is the digital serial output signal. Its small physical size (26.7mm x 17.8mm) and its very light weight (just 2.7g) make this board an ideal choice to be used in environmental monitoring systems. The single-wire bus needs a 5KOhm pull-up resistor and the connection to a data acquisition/processing unit (MCU) is realized as shown in Figure-17.

A single-wire data bus is used for communication and synchronization between the PIC embedded into the ESP8266 WiFi radio/data processing module (as shown in Figure-6) and the DHT11 sensor. The DHT11 serial output, for both temperature and humidity measurement, has a 16-bit resolution, with a humidity and temperature accuracies respectively equal to ±3-5% and ±2% at 25°C.

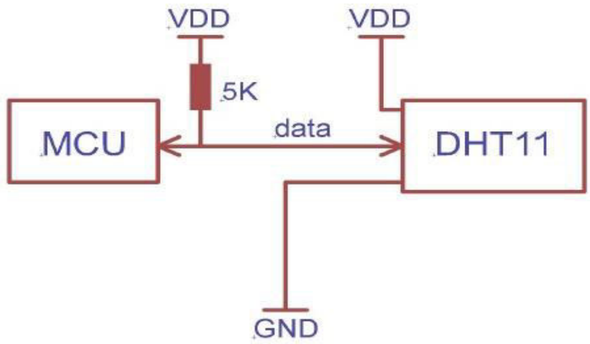

Figure-17. DHT11 sensor connected to Micro-Controller-Unit (MCU) or CPU embedded into the ESP8266 module by a single-wire bus which needs a 5KΩ pull-up resistor for cable shorter than 20 meters.

Therefore the complete serial digital data consists of 40 bit, detailed as follows: 8bit integral humidity data + 8bit decimal humidity data + 8bit integral Temp. data + 8bit decimal Temp. data + 8bit check-sum (which is the sum of preceding four bytes); overall the time duration of a communication process is about 4ms.

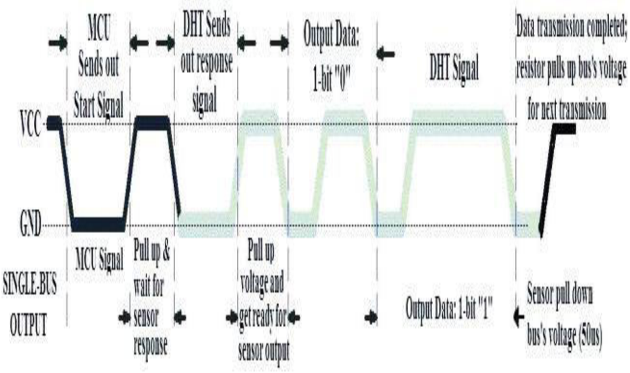

Figure-18. Serial communication process between the DHT11 sensor and the data acquisition/processing unit.

When MCU sends a start signal, DHT11 sensor changes from low-power-consumption mode to running-mode, waiting for MCU complete sending of start signal. Once it is completed, DHT11 sends the 40-bit response digital signal, relative to humidity/temperature information, to MCU. Without the start signal from MCU, DHT11 will not give the response signal to MCU. Once data are revecived, DHT11 changes to low-power-consumption mode until it receives a start signal from MCU again.

CONCLUSIONS

Thanks to the use of designed sensor node, the user, through a tablet/smartphone with a specific application, will connect to the developed WiFi WSN, sharing the detected environmental data relative to the monitored area with other users, even far, that use the same app.

Figure-19. Wireless communication between the realized monitoring nodes and a screen of developed application on tablet/smartphone for remote control by internet network.

In this way, the users group will monitor in real-time the changes of soil water content and the detected environmental parameters in order to predict quickly some soil instability events such as landslides or floods. The designed sensor node, equipped with the WiFi ESP8266 radio module, has a lower manufacturing cost compared to other solutions available on the market; it monitors the status/level of the water into the ground, its changes and detects other information of different nature (such as solar radiation level, temperature and humidity in the surrounding environment, on the soil surface or below it). Then the ESP8266 Wi-Fi module, used both as processing unit and as Wi-Fi transceiver to receive/transmit the data to/from the cloud, will process the signals detected from the sensors for optimized water management in farmland irrigation or point by point water presence's control in order to detect any wast especially where the water's availability is low. Finally, a small PV panel allows to recharge the lithium battery in order to feed the entire designed system also during the daylight hours, thereby making the sensor node independent of a DC conventional battery.

REFERENCES

P. Corke, T. Wark, R. Jurdak, W. Hu, P. Valencia, D. Moore. 2010. Environmental Wireless Sensor Networks. Proceedings of the IEEE. 98(11), DOI: 10.1109/JPROC.2010.2068530.

B. Cardenas-Lailhacar M.D., Dukes, G.L. Miller. 2010. Sensor-based automation of irrigation on Bermudagrass during dry weather conditions. Journal of Irrigation and Drainage Engineering. 136(3): 161-223.

Melissa B. Haley, Michael D. Dukes. 2012. Validation of Landscape Irrigation Reduction with Soil Moisture Sensor Irrigation Controllers. Journal of Irrigation and Drainage Engineering. 137(2): 135-144.

S.S. Patil, V. M. Davande, J. J. Mulani. 2014. Smart Wireless Sensor Network for Monitoring an Agricultural Environment. IJCSIT - Int. J. of Computer Science and Information Technologies. 5(3): 3487-3490.

K. Andersson, M.S. Hossain. 2015. Heterogeneous wireless sensor networks for flood prediction decision support systems. IEEE Proc. of Conference on Computer Communications Workshops (INFOCOM WKSHPS), pp. 133-137, DOI:10.1109/INFCOMW.2015.7179373.

E. A. Basha, S. Ravela, D. Rus. 2008. Model-based monitoring for early warning flood detection. (SenSys '08) Proceedings of the 6th ACM conference on Embedded network sensor systems, pp. 295-308, ISBN: 978-1-59593-990-6, DOI: 10.1145/1460412.1460442.

Xiangnan Chen, Y. Li. 2013. A Low Power Automatically Warning System Based on Wireless Sensor Network. Journal of Communications. 8(8): 512-520, doi:10.12720/jcm.8.8.512-520.

A.T.I. Fayeez, V. R. Gannapathy, Ida S. Md Isa, M. K. Nor, N. L. Azyze. 2015. Literature review of battery-powered and solar-powered wireless sensor node. Asian Research Publishing Network - Journal of Engineering and Applied Sciences. 10(2): 671-677, ISSN 1819-6608.

M.K. Amruta, M.T. Satish. 2013. Solar powered water quality monitoring system using wireless sensor network. IEEE Proc. of Int. Multi-Conf. on Automation, Computing, Communication, Control and Compressed Sensing. pp. 281-285, DOI: 10.1109/iMac4s.2013.6526423.

D. Di Palma, L. Bencini, G. Collodi, G. Manes, F. Chiti, R. Fantacci, A. Manes. 2012. Distributed Monitoring Systems for Agriculture based on Wireless Sensor Network Technology. International Journal on Advances in Networks and Services. 3(1 and 2): 18-28.

S.M. Khaled Reza, Shah A. Tariq, S.M. Mohsin Reza. 2010. Microcontroller Based Automated Water Level Sensing and Controlling: Design and Implementation Issue. Proc. of World Congress on Engineering and Computer Science. Vol I, ISBN: 978-988-17012-06.

Xiaoqing Yu, Wengting Han, Zenglin Zhang. 2015. Remote Monitoring System for Intelligent Irrigation in Hybrid Wireless Sensor networks. International Journal of Control and Automation. 8(3): 185-196, http://dx.doi.org/10.14257/ijca.2015.8.3.20.

P. Jiang, H. Xia, Zhiye He, Z. Wang. 2009. Design of a Water Environment Monitoring System Based on Wireless Sensor Networks. Sensors, Vol. 9, pp 6411-6434; ISSN 1424-8220, DOI:10.3390/s90806411.009).

S.Viswanath, M. Belcastro, J. Barton, N. Holmes, P. Dixon. 2015. Low-power wireless liquid monitoring system using ultrasonic sensors. Int. J. on Smart Sensing and Intelligent Systems. 8(1): 26-44.

G. V. Satyanarayana, SD. Mazaruddin. 2013. Wireless Sensor Based Remote Monitoring System for Agriculture

Using ZigBee and GPS. Proc. of Conf. on Advances in Communication and Control Systems.

C. Arun, K. Lakshmi Sudha. 2012. Agricultural Management using Wireless Sensor Networks - A Survey. 2nd International Conference on Environment Science and Biotechnology IPCBEE, 48: 76-80, IACSIT Press, DOI: 10.7763/IPCBEE. 2012. V. 48. 15.

E. Prem K. Gilbert, B. Kaliaperumal, E. Blessing Rajsingh. 2012. Research Issues in Wireless Sensor Network Applications: A Survey. Int. Journal of Information and Electronics Engineering. 2(5), DOI: 10.7763/IJIEE.2012.V2.191.

Retno Tri Wahyuni, Yusmar Palapa Wijaya, Dini Nurmalasari. 2014. Design of Wireless Sensor Network for Drainage Monitoring System. Innovative Systems Design and Engineering (IISTE). 5(5).

J. Valverde, V. Rosello, G.Mujica, J. Portilla, A. Uriarte, T. Riesgo. 2012. Wireless Sensor Network for Environmental Monitoring: Application in a Coffee Factory. International Journal of Distributed Sensor Networks, Volume 2012, Article ID 638067, DOI:10.1155/2012/638067.

A. Al-Mamun, N. Ahmed, N. Uddin Ahamed, S. A. M. Matiur Rahman, B.Ahmad, K. Sundaraj. 2014. Use of Wireless Sensor and Microcontroller to Develop Water-level Monitoring System. Indian Journal of Science and Technology. 7(9): 1325-1330.

Ka-Heng Chan, Chi-Seng Cheang, Wai-Wa Choi. 2014. ZigBee Wireless Sensor Network for Surface Drainage Monitoring and Flood Prediction. IEEE Proc. of International Symposium on Antennas and Propagation (ISAP 2014), pp. 391-392, DOI: 10.1109/ISANP.2014.7026695.

Iqbal Singh, Meenakshi Bansal. 2011. Monitoring Water Level in Agriculture Using Sensor Networks. IJSCE International Journal of Soft Computing and Engineering. 1(5): 202-204, ISSN: 2231-2307.

Rashid Hussain, Purvi Mishra, Babita Sharma. 2013. Use of Wireless Sensor Network for Human and Animal Health Care during Flood. (IJAIEM) International Journal of Application or Innovation in Engineering and Management. 2(3): 29-33, ISSN 2319-4847.

A. Reddy, J. Nagaraju. 2015. Fabrication of Solar Augmented Automatic Water Level Sensing and Water Pumping System for Irrigation. (IJMETMR) Int. Journal and Magazine of Engineering, Technology, Management and Research. 2(7): 569-573, ISSN: 2348-4845.