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5G Independent Smart Pole

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Abstract—This paper presents a model of an energy independent smart pole operating under the 5G technological umbrella. Types of sensors necessary for the smart cities operation are described. Suitable Sustainable energy sources for the pole operation are presented.

Keywords—sustainable smart city, independent smart pole.

I. INTRODUCTION

It is expected that there'll be 20 million electric vehicles in cities by 2020 and more than two thirds of the world's population will live in cities [1]. Cities will consume 80% of energy, emit 75% of CO₂ and consume 75% of raw materials by 2050 [2]. Smarter cities concept is a must according to the previous expectations. More efficient services and resources sustainability are not much more required than this era. To provide the required services, there is a need to rely on robust wireless network connectivity. Cities are seeking for smart governance, smart education, smart healthcare, smart buildings, smart mobility, smart infrastructure, smart energy and of course smart citizen [3]. To achieve what cities are seeking for, there is a need for applications such that blending wireless equipment in the urban environment. Frost and Sullivan research predicts a market potential of about \$ 1.5 trillion for the smart city market [4]. The trend of smart cities is set to drive urban developments of the incoming decades and will drive demand of storage, multi-energy networks, smart devices and new business models.

The excellence of 5G wireless communications lies in providing higher data rates, increase in base station capacity, and improvement in users' quality of service (QoS), compared to 4G LTE networks. 5G wireless systems, with previously listed improvements are expected to be an excellent smart cities technological umbrella. 5G will offer services such as high mobility, extreme network densification, reduced radiation, reduced signal dropouts, massive MIMO and massive support to Internet of Things IoT. Offering these services will help city planners to envision long term goals for smart cities [5].

Smart poles could be considered as remotely managed poles that house technology to improve mobile network performance across the smart city [6]. They also could be considered as digital real estate of the IoT. Having all suitable services on a single pole, will reduce maintenance costs because of remote management, and will help cities to be more energy sustainable. Having these multifunctional poles creates space and improves the environment visually and operationally. From the sustainability point of view, these poles are preferred to be 100% recyclable and to operate with renewable energy [7]. It is expected to have 73 million installed smart poles around the world. From the architecture point of view, smart poles should also beautify city streets. Poles manufacturing companies such as Continental Pole and Lighting fabricate smart pole with beauty standards. Figure 1 shows a model of smart poles [8].

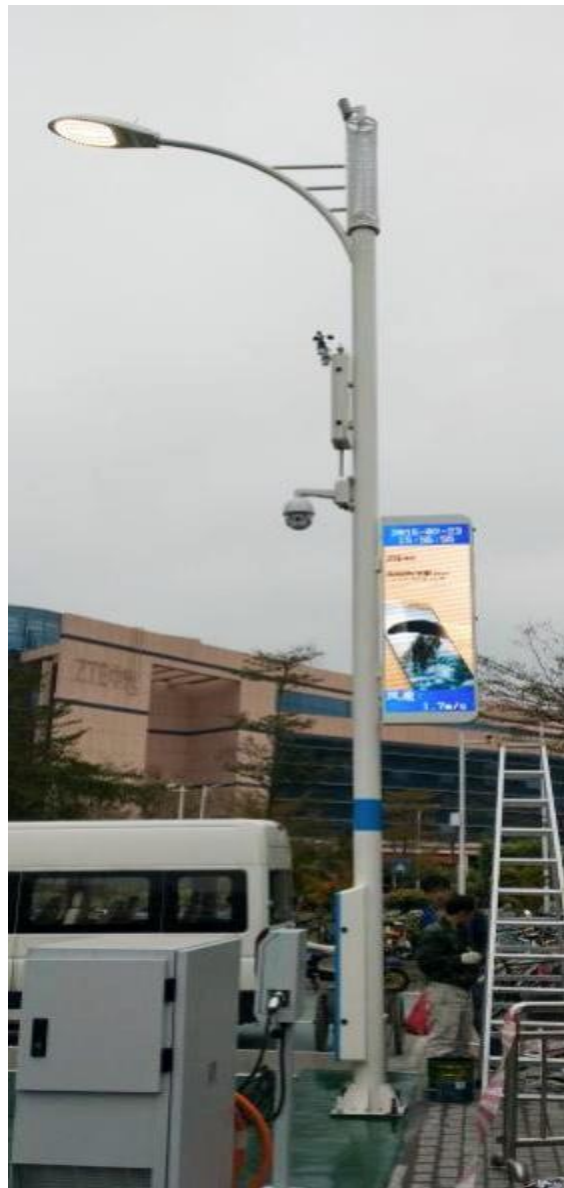


Fig. 1. A smart pole fabricated by Continental Pole and Lighting Company [8].

In this paper, we present a model of an 5G independent smart pole generating its own energy, providing a wireless infrastructure to support the digital transformation of cities. The specifications of the sensors expected to be necessary for smart cities operation are presented. Solar panels and wind turbines are the sustainable sources of power used of smart poles.

In section II the concept of 5G smart pole is presented. Section III gives a description of the required sensors to be attached to the smart pole. Their available physical dimensions and electrical requirements are listed to check the possibility of using them in building smart poles. In section IV, the solar panels and wind turbines as sustainable energy sources are shown. The proposed connections of the smart pole are shown in section V.

II. 5G SMART POLE.

The smart pole is a sustainable energy smart subsystem of the sustainable smart city system. Our vision for the smart pole is that it is a 5G access point. 5G will provide services of high mobility, highest network densification and good support to Internet of Things (IoT). Offering services with these features helps city planners to plan for smart cities. 5G smart city solutions could produce \$160 billion in savings through reduction in energy usage, traffic congestion and fuel cost. 5G can fulfill many important requirements for the growing demands of smart cities [5] such as the ability to connect many more sensors and devices, the high speed connectivity, ultra-low power consumption, and greater reliability.

The network deployment of 5G involves 10 to 100 times small cells locations more than 4G. It will not be efficient to build separate poles for this huge number of small cells required. The multifunction smart poles could carry these cells beside other sensors. Nowadays, we can find flexible and robust integrated outdoor Small Cells with a weight less than 2.8 Kgs and dimensions of 27, 20, 6.5 cm making it easy to attach one or more small cells to the smart pole [9].

To get the best possible quality of service and battery life, users need to be as close as possible to the cells. Also, radiation from the mobile phone will reduce as its distance to the cell decreases. According to the requirements of the 5G standards, the cell to cell distance is expected to be in the range 100- 300 m at heights from 9 to 15 meters. The proximity of citizens smart phones to smart poles could be sensed by the Smart City control system providing location based services and density of users estimation.

An 5G access point, a solar panel and a wind turbine system as an electric energy source, a variety of sensors, a battery and an optical fiber carrying the data generated are the basic components of the smart pole. The 5G small cell should be put inside the smart pole and the battery should be placed underground in a maintenance friendly cabinet. A camouflaging material could be used for covering the 5G access point. This material should be of long life with suitable RF transparency.

III. SMART POLE SENSORS

III.I Air quality sensor:

Since sustainable smart cities should be as clean as possible, environmental sensors such as air sensors are very important to measure pollution levels. A complete air quality monitoring system

could be found with a weight less than 12.5 kg and maximum dimensions of 62 x 32 x 55 cm. Figure 2 shows an Aeroqual AQS1 air quality monitoring system. It can measure percentages of: Volatile Organic compounds (VOC), Ambient Ozone (O₃) and Nitrogen Dioxide (NO₂). It can run on a regulated 12 VDC (21W / 30W) [10].



Fig. 2. Aeroqual AQS1 air quality monitoring system

III.II Security Camera:

Security is a crucial challenge in both public and private places. With a camera attached to the smart pole, we can draw many security benefits and improvements in traffic analysis which can help us in making cities truly smart. There are a variety of cameras with different specifications. The most important properties of the smart pole cameras are the light weight, high resolution and low power consumption. Figure 3 shows the Reolink camera [11]. It is small (7.1 x 7.1x 3.4 cm) Wi-Fi wireless camera with the capability to be connected to the solar panels for non-stopping operation.



Fig. 3. Reolink wireless camera.

III.III Audio speakers:

Audio speakers for public announcements could also be embedded in smart poles. There are a variety of speakers that could be hidden inside the poles. Feonic [12] is from the leading

manufacturers in this field. A speaker with dimensions 14.1 x 5.7 x 5.6 cm and frequency band from 60 Hz to 20KHz will be very suitable. Figure 4 shows an audio speaker fabricated by Feonic.

There could be an Intercom based Connection in Each Pole connected to Control Room. One speaker and one Microphone on each pole could help in emergency conditions. One touch button could be used to connect to control room in dangerous circumstances.

III.IV. LED Light sources:

Light emitting diodes (LEDs) have been used for years, primarily in the electronics industry for circuit board mounted indicator lights. Increased brightness, lower production costs, and the availability of a variety of colors have led to the successful use of LEDs in replacing old lamps in architectural, commercial and industrial applications [13]. LED lights save about 50% of electrical energy consumed. LED streetlights degrade slowly over time. Life is calculated based on the projected amount of time for the light to reach 70% of its original brightness, called the L70. Typically this is 50,000 hours or 13.7 years if on for 10 hours per day. Multiple light distribution types are available with power requirements from 30 watt to be compatible with solar panels [14]. Figure 5 shows an example of LED lights. As a result, the level of lighting pollution is minimized and suitable lighting levels are provided. Good public lighting solutions could provide the essential safety in the city. The type of LED lights selected will vary according to the road width and type.

LED display billboards could be used as Payment based advertisement. This could have a great economic benefits for the city management systems.



Fig. 4. Feonic audio-speaker.



Fig. 5. LED light.

1KW Electric AC /Solar Charging units could be used especially in parking areas. Working Voltage of 220VAC and Output Current of 10 to 30 A are required. Also economic benefits are expected with charging voltage Payment Card Compatibility.

IV. SOLAR PANEL SYSTEM AND WIND TURBINES

The solar panel system is a renewable power source uses photovoltaic PV panels to generate electricity from sunlight. The electric energy generated could be directly used by the connected loads or stored for future use [15]. We have to use the solar panel generating the sufficient amount of electric power for the connected sensors to work properly. The smart pole solar system should include these main parts; Solar PV panels, Solar charge controller to regulate the voltage and current going to the battery, Battery to store energy for supplying connected loads and the connected sensors. Fig. 6 shows the solar panel system.

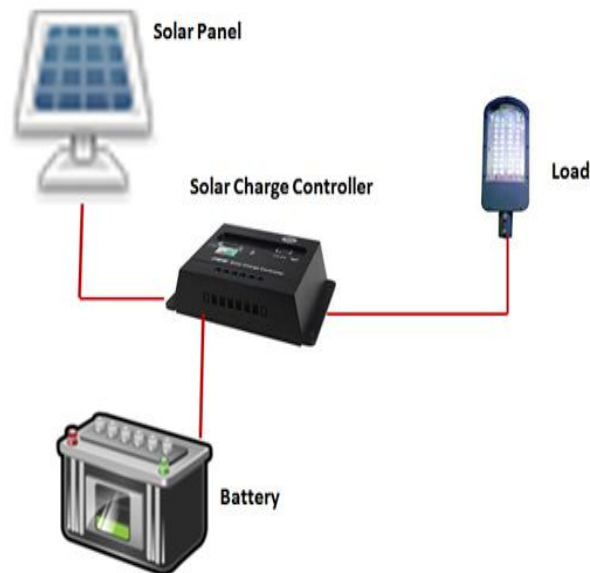


Fig. 6. The solar panel system [15].

Solar panels can be made from different materials. Gallium arsenide [16] solar panels are the most preferred because they are less sensitive to heat. Keeping their temperature below the maximum allowable temperature can increase their lives from 30 to 50 years. The total electrical power per day needed from the PV panel (P_t) will equal approximately 1.3 times (to consider the energy losses) the total power per day that must be delivered to all connected sensors. The size required for the PV solar panel will depend on P_t and on the panel generation factor PGF. The PGF differs from a city to another depending on the average sun shine hours per day. For Cairo, Egypt, the PGF is between 7 and 8. Dividing P_t by PGF will give the total Watt peak rating needed for the PV panels. Then, according to the datasheets of the commercially available panels, the required size could be estimated. These panels could be on the top of the pole and/or surrounding its outer area. Figure 7. Shows the possible orientations of the solar panels.

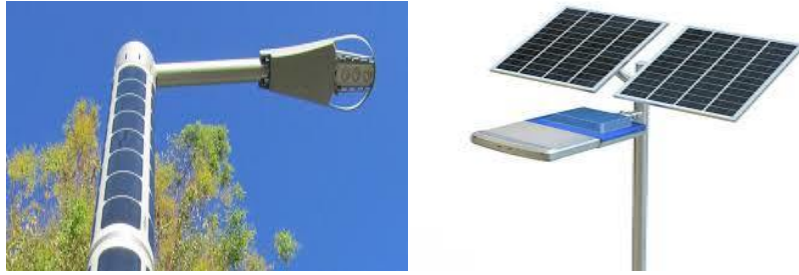


Figure 7. Solar panels possible orientations [17].

The battery recommended for using in our system is deep cycle battery [17]. This type of battery could discharge to very low energy levels and rapidly recharge. It should be large enough to store efficient energy for night and cloudy days. This battery is put under ground beside the pole. The ampere-hour capacity of the battery depends on the Pt, number of days expected for the system to work without PV production of electricity and the nominal battery voltage. The solar charge controller should have enough capacity to handle the current from the PV panel.

Also, wind turbines are other source of electrical energy that can be embedded to smart poles. The vertical axis wind turbines VAWTs are relatively compact and visually appealing [18], see Fig. 8. They are designed to allow wind to be caught at any angle or direction. Unlike horizontal axis wind turbines, VAWTs do not need to be placed as high in the air. This makes them a good choice for rooftop installations also. The vertical axis wind turbine is also nearly silent, which further adds to its appeal in urban settings. Available in 300W, 1.5 KW and 3 KW systems. VAWTs with solar panels provide a sufficient power source for the smart pole. Any excess power could be fed to the utility grid via smart grid technology. Smart grids are particularly important for the sustainable management of energy in urban areas. They require all of the electricity market's components to communicate with one another, and they incorporate large as well as small decentralized power generation units and consumers into an overall structure. Smart grids regulate power generation and prevent network overloads by ensuring that only as much electricity is produced as is actually needed [19]. In addition, demand management processes can be used to minimize peaks and balance energy supply. Smart grid is among the most important components of a smart city and there must be a plan for the role it will play to have a real smart city.

V. THE PROPOSED INTERNAL CONNECTIONS IN THE SMART POLE

The internal construction of the smart pole should be suitable for the electrical connections of the embedded sensors, adaptors, converters and battery. The majority of the standard dimensions of smart poles are suitable for housing the sensors and their electrical connections. The pole also has to provide a suitable housing for the optical fiber cables. Optical fiber network across the city ensures robust connectivity and enable the city to accommodate future technologies. It will also help to establish connectivity between Government departments, City infrastructure and Command & Control Center. Figure 9 shows the proposed connections in the smart pole.



Fig. 8. The VAWT.

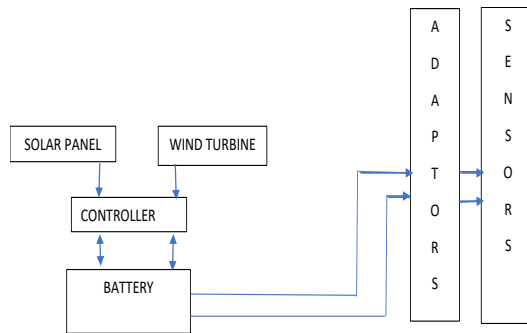


Fig. 9 The proposed electrical connections in the smart pole.

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