Enabling the Internet of Things Using Visible Light

Avantika Gupta, K. Aditi, Mohd Toaha Umar

Abstract: The Internet of Things(IoT) is on the verge of transforming the world we live in. To facilitate the impending development of IoT, it is imperative that a sustainable framework for IoT is designed, which offers high speed connectivity, easy and secure access , and uses the energy available judiciously. The suggested framework in this paper utilizes visible light for its operation. Also, to increase the energy efficiency of an IoT framework, it is suggested to use light energy harvesting sensors, which will result in minimal maintenance, and use of visible light to power the IoT systems using a photo battery. To enhance the working of the photo battery, a methodology has been suggested.

Keywords—Internet Of Things; Li-Fi; Energy harvesting; Photo Battery; Power Over Fibres

1. INTRODUCTION

The Internet of things is the new buzzword these days. It can be defined as a concept in which the virtual world of information gets integrated with the real world technology [1]. It is expected that by 2020, there will be 50 billion devices connected to the internet [2].

The expansion of IoT faces a few hurdles right now: the important ones being that of connectivity and energy management. Wi-Fi is frequently the technology of choice for wireless connectivity in IoT. Wi-Fi operates over two frequency bands, usually at 2.4 GHz and 5 GHz [3]. With increasing devices offering Wi-Fi connectivity at 2.4 GHz, it is almost close to saturation, which leads to reduced speeds. And with the increase of devices, the energy issues that exist today are going to get even more acute in the future. Also, there is a need to provide backup to power IoT devices in places where power shortages occur.

This paper proposes a self sustaining system, as shown in Fig 2, for the Internet of Things which utilizes visible light. The system consists of three components: Light Fidelity (Li-Fi) (Fig 1) for internet connectivity [4], using visible light harvesting sensors [5], and a backup photo battery [6].

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At this point, internet connectivity using Li-Fi is limited to close range applications only, and hence, a method for propagating Li-Fi over large distances which utilizes power over fibre has been proposed. Furthermore, a hybrid energy harvesting structure utilizing Li-Ion and NiMH batteries, and a backup system using photo battery has been suggested.

Fig 1: IoT utilizing Li-Fi

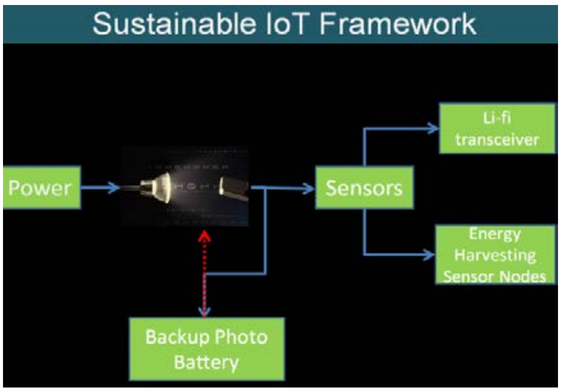

Fig 2: The proposed IoT Framework

The proposed infrastructure has many advantages. Li-Fi offers speeds **up to 100 Gbps,** whereas Wi-Fi offers a maximum speed of 7 Gbps **[7].** It also solves the problem of the spectrum congestion, as the visible light operates over a huge bandwidth, and can coexist along with Wi-Fi, as there is no interference with the radio frequency. It also enhances the security, as visible light cannot penetrate walls like radio waves, thus making it inaccessible to users outside the room where the Li-Fi transmission is taking place. It actually is of great benefit in industrial IoT systems, where a high level of security is desired. An additional benefit is the more environment friendly nature of Li-Fi, and its ability to be used in environments where Wi-Fi is not suitable, such as hospitals.

Furthermore, by utilizing ambient light for energy harvesting sensors, we are ensuring that the supply of energy is both controllable and predictable, and also requires minimal supervision [8].

2.LI-FI

2.1. Principle

Light Fidelity, or Li-Fi, utilizes intensity modulation for its operation, i.e. the continuous dimming and brightening of LEDs is used to transmit data [4], as shown in Fig 3. It can be considered analogous to Morse code, but at extremely high speeds. It is a bidirectional means of communication, in contrast with Visible Light Communications(VLC) which is unidirectional.

For receivers, an avalanche photodiode is used(Fig 4), which can be embedded in any device with which communication is to be maintained [4].

2.2. Propagation

There are several ways of propagating Li-Fi over wide distances. One method may include the installation of laser towers as transmitters, and use of solar panels as receivers [9]. This technique is however difficult to implement, as the installation of large number of light emitting towers will be a space consuming, and expensive task. Another method may be to integrate Li-Fi over transmission lines [10].

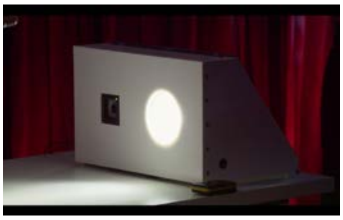

Fig 3: Li-Fi Transmission using LEDs

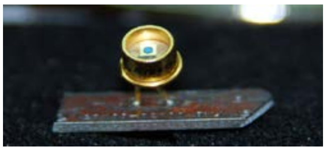

Fig 4: Avalanche Photodiode used as detector

Propagation using Power over Fibres (Fig 5)

- Li-Fi has only been tested for close range applications, and propagation over large distances is still in the developmental stage.
- One of the ways in which Li-Fi can be propagated over large distances is by utilizing power over fibres (PoF) [11]. In this method, a laser diode is used at the transmission end of the optical fibre, and a driver is used to modulate the light emitted. A photovoltaic converter is used at the receiver end to convert the light energy into electrical energy.
- The voltage and current generated are of the order of 24V and 20mA, which is sufficient to power the LED bulbs, which are used for Li-Fi propagation.
- An optical diffuser is then used to ensure that the light spreads throughout the room in which Li-Fi connectivity is required.

Advantages of using Power Over Fibres:

i. Optical fibres are not affected by electromagnetic interference, which may affect transmission lines.
ii. The tapping is much more difficult in optical fibres than in transmission lines and thus they are more secure.
iii. Presence of virtually unlimited bandwidth and access to unlicensed spectrum.

3. ENERGY HARVESTING SYSTEMS

3.1. Introduction

Energy Harvesting may be defined as a process of harnessing energy from the environment or other energy sources and converting it into electrical energy [8].

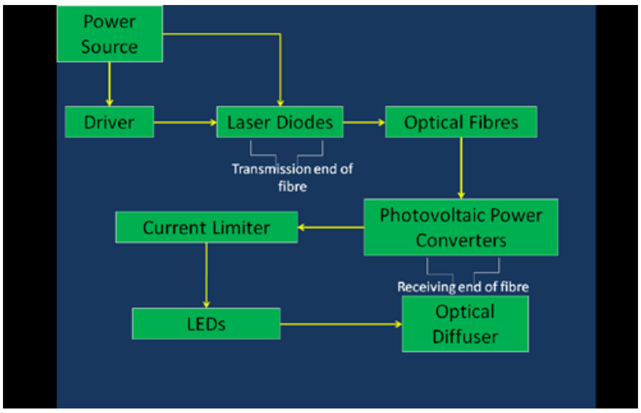

Fig 5: Block diagram of transmitting Li-Fi using PoF

3.2. Proposed Energy Harvesting Architecture

The proposed energy harvesting architecture is a triple storage energy device. It utilizes the following components:

i. Solar Panels fitted with converging mirrors, to increase the efficiency of the panel.

ii. Primary Storage: Super-capacitors, of the order of tens of Farads, are used as the primary storage element.

iii. Secondary Storage: Li-Ion Battery is used as a backup storage. Since Li-Ion battery has a pulse charging mechanism, the pulse charging is enabled by using an external hardware or software.

iv. Comparator: A comparator is then used to detect if the pulses are being generated for the charging of the Li-Ion battery. If the value of the current is less than the threshold current, the energy is diverted to the tertiary storage by using a switch.

v. Tertiary Storage: NiMH batteries are used as the tertiary storage of the batteries. NiMH batteries utilize trickle charging, and in case the mechanism for pulse charging fails, or there is not sufficient current being generated, the NiMH battery comes into play.

3.3. Advantages:

i. Availability at all times: With the inclusion of NiMH battery in the architecture, the energy is expected to be harvested at all times.

ii. Higher Charging Efficiency: As Li-ion batteries have less self discharging rate, the charging efficiency is expected to be higher

iii. Longer Durability: As super capacitors store energy for longer durations, the architecture will provide backup for longer durations.

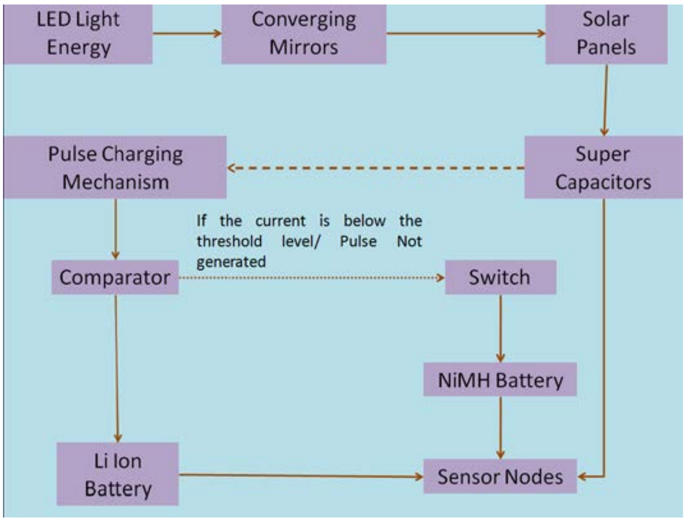

Fig 6: Block Diagram of the Energy Harvesting Architecture

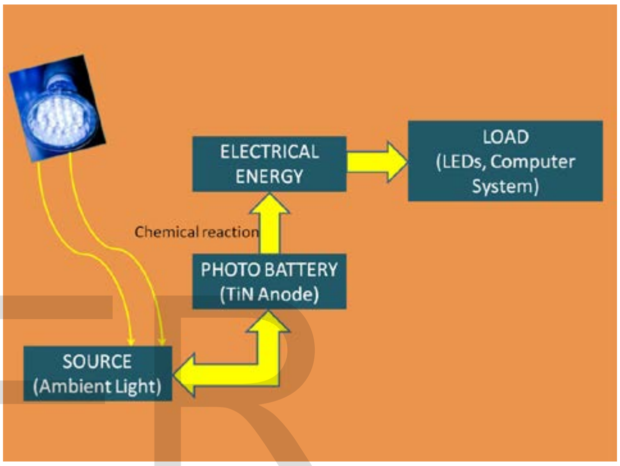

Fig 7: Block Diagram of Photo Battery

4. PHOTO BATTERY

4.1. Introduction

Two of the many components of Li-Fi are LEDs and LED driver. The function of the LED driver is to control the brightening and dimming of the Li-Fi LEDs. Basically, the encoded data containing information is transmitted using this driver. So, continuously powering these two components becomes important as any hindrance in connectivity due to power cut is undesirable in IoT systems. This purpose is served by photo battery, as shown in Fig 7.

In the photo battery, the anode is formed by titanium nitride (TiN) and iron(III) hexacyanoferrate(II) forms the cathode. Sodium persulfate ($Na_2S_2O_8$) acts as battery active species which aids in charging without external input. The low output of the battery is sufficient to light up LEDs which are the main components of the proposed system. The photo battery's output is imperceptible under dark surrounding but its

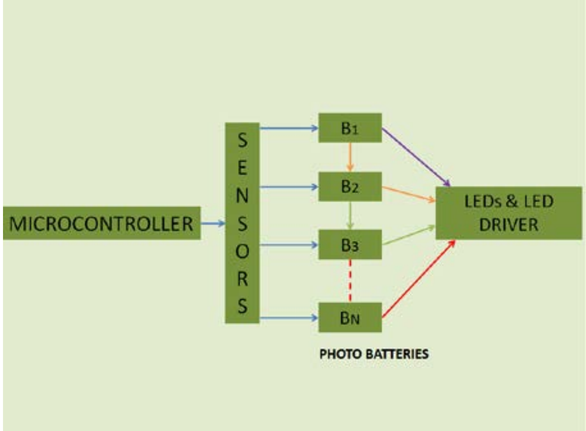

Fig 8: Implementing Photo Battery in the IoT Framework

performance gets enhanced when illuminated. This confirms its utilisation of artificial light to produce electric output.

4.2. Methodology of Implementation

As shown in Fig 8, a stack of photo batteries may be used in which only one battery at a time may be giving output to the LEDs and LED driver until it gets discharged and function of providing output is passed on to the next battery. This transfer of functionality can be made possible by using a voltage meter to measure the output of the battery. In case this voltage goes below a threshold value, the current battery is disconnected from the system and next fully charged battery comes to working. Till the time this process goes on, the previous batteries are replenished and are ready to be used again when the loop returns to its starting point to continue the same cycle. This way all the photo batteries may not die out simultaneously leading to backup failure. Sensors can be used to keep track of the level of $Na_2S_2O_8$ when it falls below a certain level, which is the point when batteries shall be replenished with the same to continue working. This is how the photo battery can be incorporated in the IoT framework.

5. Conclusions

The suggested framework in the paper can facilitate the ushering of the new era of the Internet of Things, by ensuring faster, more secure and more accessible connectivity to the internet, and efficient harvesting of the ambient energy sources. The implementation faces a few roadblocks though, as widespread implementation of Li-Fi will be quite cost and time consuming, and the runtime of the photo battery also needs to be increased significantly. But once implemented, the framework can ensure that our future is not just smart, but sustainable as well.

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