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A Novel Approach to Maximize Network Lifetime by Reducing Power Consumption in Routing using VLC-BR

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ABSTRACT

In context to maximize network lifetime by reducing power consumption in the Wireless Sensor Network (WSN) and to increase the span of the battery associated with the network many hardware and software based algorithms has been proposed. In a WSN, the battery power retaining and power drop management are prime matter of research during sending traffic. The maximum battery power of node invests in sending and receiving traffic. In this paper, we have proposed a novel way to manipulate and design the conventional method of receiving and transmitting information of node by replacing the traditional transceiver module with the Light Fidelity (Li-Fi) module having an LED as a transmitter and a photodiode as a receiver, eyeing to have a power aware routing. Li-Fi is a high-speed, bi-directional and fully networked wireless communication technology similar to Wi-Fi. By sending traffic using Visible Light Communication (VLC), we have found the total power consumption of the network could be minimized by having better data integrity and security and A higher bandwidth and efficient routing has been attained by outperformance of sending information packets as light signal over classical radio signal information trafficking in a WSN, that is why we termed our model as Visible Light Communication Based Routing (VLC-BR). We have simulated our proposed designed model in Matlab and able to increase the lifetime of the network by reducing per node power consumption among nodes and tried to analyze the pros and cons of using light fidelity technology in present time within a WSN.

Keywords: LI-FI, Power-aware routing, Transceiver, Bandwidth, VLC.

I. INTRODUCTION

The radio spectrum that already exists fails to the present time's need and faces various issues availability and scalability. To explore the potential of other spectrums available, a new medium has been proposed which able to serve best to our needs i.e. a visible data transmission system utilizing LED lights. This system of communication using Light Fidelity which can be used in the various field instead of radio wave communication where radio frequency (RF) based transmission are generally not allowed or to get rid of the interferences with critical systems[18]. That is way we have proposed and design a module of Light Fidelity in a WSN and compare the conventional power consumption with respect to the VLC-BR in context to Total Network Life Time (TNLT)[8][9][10][11].

A huge amount of unregulated bandwidth is available at visible light and infrared frequencies. The visible spectrum covers wavelength from 380 nm to 750 nm [18]. We are here intending to use visible light for communication which can bitterly explain as, the transmission of data in a way that human eye cannot detect is that in the form of LED light which create binary code received by sensitive photo sensor which decodes the data and it has been proved of communication of data with high, i.e. 90 percent accuracy.

When more traffic paths are connected to a single node to send traffic further, the performance and efficiency along with the power loss maximized due to less power and bandwidth availability in the

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conventional WSNs[18] [19]. Harald Hass proposed in the year of 2012, the notion of the high-intensity light source of solid state design which is called Li-Fi which serves clean lighting solution for communication. A Li-Fi is now an associated with VLC that implemented using white LED light bulbs, where the LED light changing the high-speed current which is not visible to our naked eyes. He had demonstrated transmission of data more than 10 Mbps speed initially, now it has been reached to 200Gbps. Today the bulb is available 10,000 times, which can solve the issue of radio frequency shortage and can create a new communication channel with the pre-existing network equipment. So here in this paper, we have tried to implement the model logically to show an alternative and best approach model in terms of efficiency and less power consumed wireless communication technology for which has been using radio spectrum life WSNs[19].

(A) Benefits of VLC Technology

- Capacity: by comparing the VLC spectrum all existing spectrum seems to be dwarfed, it has immense potential in context to capacity.
- Security: the radio wave use in conventional network models are can be easily intercepted and misused which has been connected through walls, whereas in Li-Fi based VLC-BR this is almost avoidable because the light waves use over here are not connected through walls.
- Efficiency: The present radio wave base station the efficiency is about five percent,in our VLC-BR it is much higher because the light source LED uses less energy.
- Availability: generally radio waves are not working in every place and in some place this type of signal are prohibited, but comparing that light can be available anywhere, which enhanced its availability.

(B) Advantageous Features of Li-Fi

- In context to Green Information Technology(GIT): li-fi technology use not effect on the living organisms including humans whereas talking about the radio wave it has been a threat to the living body though the impact is too less.
- In context to Frequency Bandwidth problem: lifi is working on VLC medium and we do not require any pay for communication and licensing purpose.
- In context to Smart Network: lifi can work at any sensitive area and save consumption of memory.
- In context to Traffic packets security: as light waves are not connected with the wall so the security is higher than other competent medium of it. Here the risk of data leaking is too less.
- In context to WSN: it can replace the conventional technology which uses apparently more power which limits the network lifetime. By use of lifi technology, in many cases it will reduce the power consumption up to 20 percent in sending data, storing and manipulating data.

II. NODE’S ARCHITECTURE DESIGN

Every wireless sensor network is consisting of many nodes distributed in either uniformly or following non-uniform node distribution. These sensor nodes are the main structural and functional unit of any network [11][10], which performance and power consumption limits the network efficiency and networks lifetime, which are an embedded system consisting of many elements within, like GPS, a small memory element, sensor based on application, an ADC unit convert the sensed data by sensor to digital form and a fixed value battery as shown in the fig. 1[11]. Apart from all these for transmitting and receiving the traffic we have here used a li-fi module , which consists a low power LED and a low power photodiode that consume the very little power of the battery.

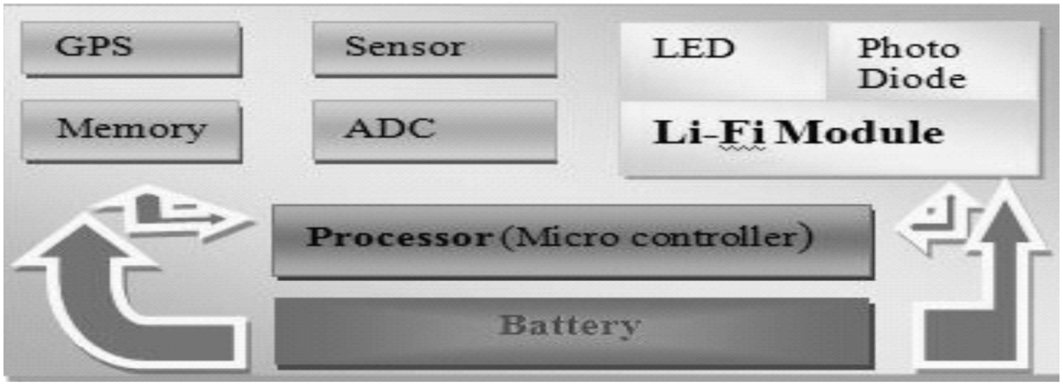

Figure 1: VLC-BR's node architecture

The most of the power of a network are use in trafficking, so it has been a novel approach to reconfiguring the node trafficking module which will consume less power and will be efficient enough compared to the conventional models.

In this paper, we have formulated and designed keeping this in our mind is that to less the power consumption of the node so that the total network lifetime can be increased.

III. LITERATURE SURVEY

Fabian Castano et al. [1] have come up with an approach to maximize network lifetime in a wireless multi-role sensor based network up to five hundred number of the sensor where connectivity is a constraint. In his paper they have tested instances which were generated randomly and maximum lifetime obtained by optimal cover identification and by operational time allocation, then which is solved through column generation approach decomposition. Maximization of network lifetime has been attained by Kemal Bicakci and team [2] in context to event – unobservable WSNs. In his paper, they have analyzed WSNs lifetime limit preserving event unobservability with a variety of proxy assignment methodologies using linear programming framework. Dipak Wajgi et al. [3] have surveyed how load balancing approach could able to maximize the network lifetime of a wireless sensor network. They have also discussed the different algorithm available to balance the node and also discussed how clustering in context to node balance increase the scalability of the network. Donghyun Kim et al. [4] have given a concept that a subset within a WSN gives a barrier-coverage of the region of interest if the inside sensor nodes in WSN can divide into two groups, as a result of which any movement from one group to another is guaranteed to be fetched by a sensor node. They have also given three solutions to a problem caused when there is penetration to protected area by barrier covers when one is replaced by its supplementary part that resulted in improving the WSN. Hosein Mohamadi et al. [5], the team have approached with a new technique to increase the lifetime of wireless sensor network through new learning automata where a sensing a range of nodes are not fixed. In their paper, they have given a possibility of having multiple power levels which counter the conventional assumption that a sensor is having fixed sensing range. To analyze multiple power level of a sensor they have proposed an algorithm called as learning automata embedded with a pruning rule. Han Zhang et al. [6] have proposed an approach to equalizing the load on a node in a wireless sensor network in context to gather the data by determining two factor, where one is the energy of members and the residual energy and another is the distance between the heads. They have optimized the threshold value imbalance to will intend to enhance the lifetime of the network. Ming Ma et al.[7] have design the lower layer of the network which form due to reorganization of node into clusters and the higher layer where the sensor sensing data is collected and send to the outside observers, likewise they have formed a hybrid sensor network where they have tried to balance the node by clustering which they have simulated in NS-2 and succeed to attain a 35% lifetime enhancement.

IV. STRUCTURE OF VLC-BR

The communication carried out among conventional node is based on radio wave communication where there is chances of many threat to the wireless sensor network in terms of data loss, data misinterpretation, failure in packet receive by the source node, data malfunction and attenuation and different type noise interference to the signal has been common. The problem can be minimized by use of another form of electromagnetic wave, i.e visible light. Which carry all the light wave communication advantageous during communication in WSNs.

If we are talking about the structure design point of view, in general, node system there is a transceiver module available, which meant to transfer the data and receiving data using radio signal over unguided media i.e. air. In our paper, we have proposed to replace the transceiver module to a light fidelity module, where we have basically two main units available. An LED has been used as a transmitter and a photodiode has been used as a receiver, which is shown in the fig. (1).

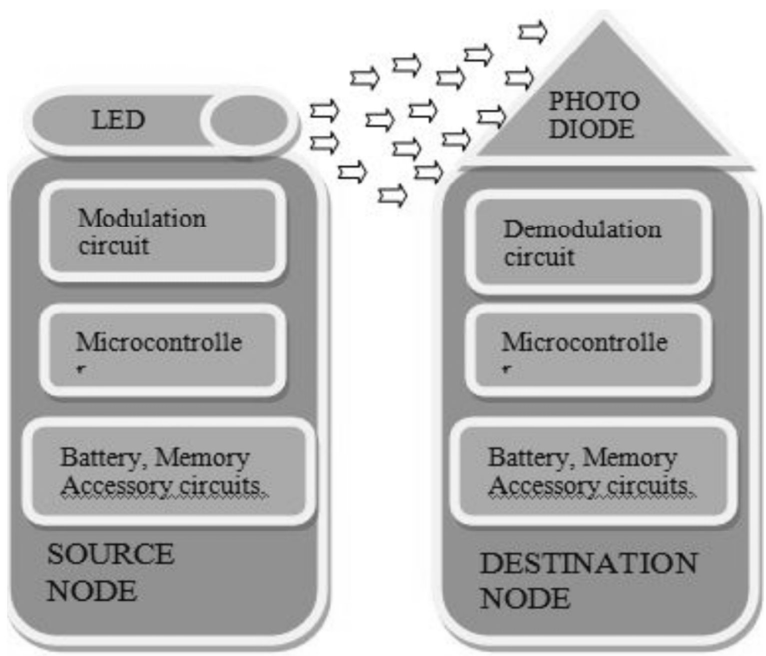

Figure 2: VLC-BR's sending traffic from source to destination node

The pattern of the light has been made such that it appears as a digital signal at the receiving end, and it is been generated by ultra speed light on and off which form a digital 1 and 0 at the photodiode. Whereas in conventional model the light first need to convert from digital to an analog signal form and then the modulated signal used to transmit over air to the source station, in the receiving section also the received light need to reconvert the analog signal to digital form, so as to convert the signal to microcontroller understandable form. Which states that in our proposed design every node saves the battery power by minimizing data processing.

V. TPC MINIMIZATION USING PROPOSED DESIGN

For any wireless network, the TotalPC, PC in individual node and AveragePC are main parameters that limit the efficiency and reliability for any cluster within a wireless network, that will be the deciding factor to estimate the span of a wireless network life .

The TotalPC of a WSN is a function of individual PC which is directly proportional to the power of 'α' to the distance 'd', mathematically TotalPC can be represented as

$$\text{TotalPC} = \sum_{1}^{N} \text{PC}_i \tag{1}$$

Where PC is the individual node power consumption And i = 1, 2 ..., N is the total number of nodes deployed in the WSN And the can be represented as[8][9][10][11]

$$PC = k \times r \times d^{\alpha} \tag{2}$$

Where k is constant whose value is taken as 1, the r = rate of sending traffic among nodes, the d= distance between the two consecutive shortest distance nodes, in other word distance from the source node to receiving node.

PC can be formulated from the Eq. no 2.and the unit is equal to [11]

$$= (\mu W/M\ \text{bit} \times m4) \times (\text{Mbps}) \times (m4) = \mu W/\text{sec}$$

The Average Power Consumption (APC) is the average of individual PC value and mathematically represented as,

$$\text{AveragePC} = \frac{\text{TotatlPC}}{N} \tag{3}$$

From eq. (4), APC can be represented in terms of node power consumption,

$$\text{AveragePC} = \frac{\sum_{1}^{N} \text{PC}_i}{N} \tag{4}$$

(A) Methodology

Let we will consider a directional, uniformly distributed network of 25 nodes as shown in the fig. (3). Where each node is sending and receiving traffic using LI_FI module, the proposed design module shown in fig(3). Where each node tends to send the traffic to the head or origin of the cluster. Here the cluster head is at node number 13 and treated to be the center of the cluster [11][9].

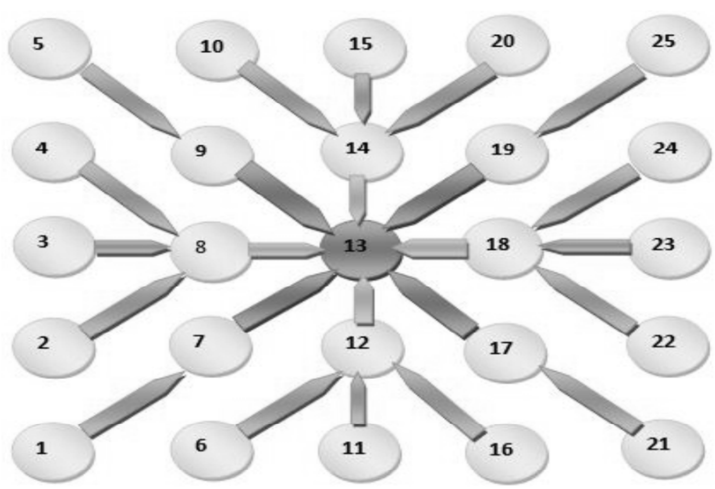

Figure 3: Sample network model routing using shortest path algorithm having uniformly distributed 25 nodes

to calculate the TotalPC we need to estimate the PC of each node by using the formula given in Eqn. (1) (2) (3).

Let us assume ‘β’ be the li-fi power saver factor, which has been introduced due to the replacement of transceiver with light fidelity module. The value of ‘β’ limits the network constant ‘*k*’, hence the equation (2) for power consumption for each node can be rewritten as,

$$PC = (\beta k) \times r \times d^{\alpha} \quad (5)$$

Where, β is the summation of total power saving which includes the followings. The saving of battery power due to sending the traffic, receiving the traffic, due to reducing use of ADC/DAC module and due to reducing use of filters and signal amplifier components.

Each component in an embedded system drops power backed by a fixed source battery that associated with any node. By use of light fidelity we could able to process our signal directly in the form of Digital signal, light is less prone to interference and attenuation, which implies that the amount of power usually drop in conventional model now becomes reduce by a factor ‘β’ And the value of which is vary from system to system, as according to the component power sharing with the traffic sending of the node, here in this paper we have estimated the value to be 0.15

So the new power per node will be PC′ and which can be written as,

$$PC' = PC - (\beta k) \times r \times d^{\alpha} \quad (6)$$

(B) Implementation

We have implemented the whole network design in MATLAB software and have simulated all the related calculation and estimation of different parameters of a WSN. By taking the value of rate of traffic as 1 mbps and the distance between the nodes as unity with fixed value of α, which is 4 to calculate the power consumption of network has been done for our simulation, we have also compared our VLC-BR PC’ with the existing model available for the same size and with same network parameter.

Table 1 is holding the magnitude value of PC and PC’ for the network model that we have taken and formed by taking the same platform as mentioned in R. K. Guha [9].

Table I
Power Consumption ‘PC’ of conventional and for VLC-BR power consumption ‘PC’ for Different Nodes

Node No.	*PC*	*PC’*	*Node No.*	*PC*	*PC’*
1	4	3.4	14	4	3.4
2	4	3.4	15	1	0.85
3	1	0.85	16	4	3.4
4	4	3.4	17	8	6.8
5	4	3.4	18	4	3.4
6	4	3.4	19	8	6.8
7	8	6.8	20	4	3.4
8	4	3.4	21	4	3.4
9	8	6.8	22	4	3.4
10	4	3.4	23	1	0.85
11	1	0.85	24	4	3.4
12	4	3.4	25	4	3.4
Total Power consumption				100	85

Fig. 4 has been prepared from the simulated data representing two lines, one red leading line, which is indicating the PC lines of conventional R. K. Guha based model and the blue trailing line which is its PC’ using our VLC-BR.

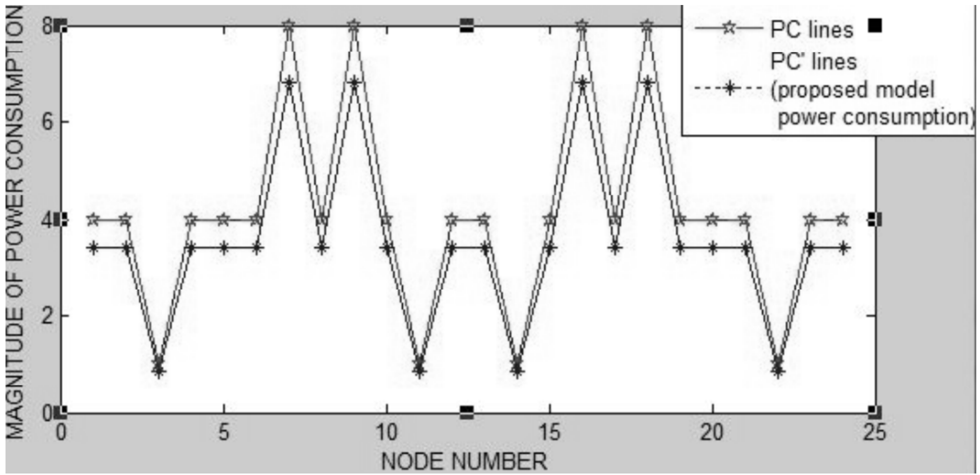

Figure 4: Compass plot to shoe the magnitude of the vectors of both PC (viewer's left side) and PC' (right side), PC' having low magnitude

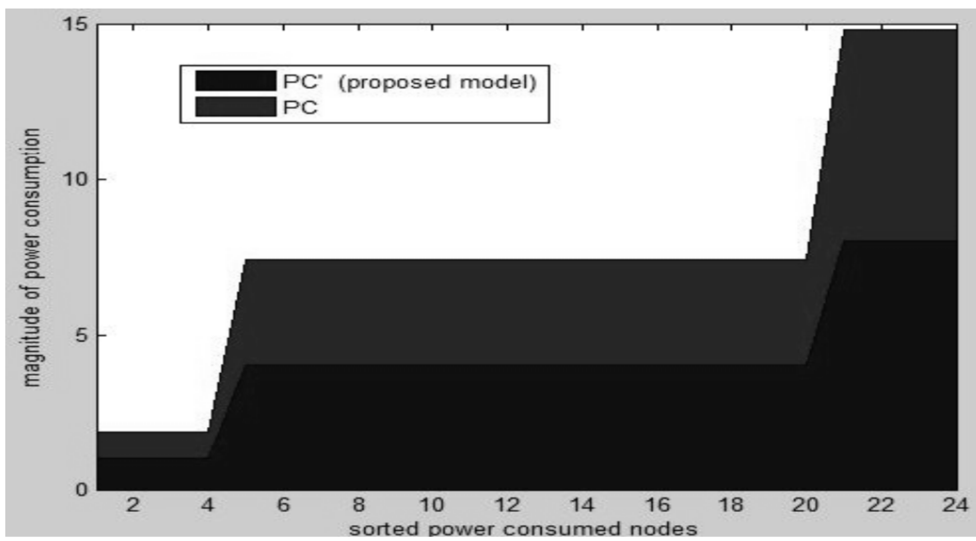

Figure 5: Area plot for sorted nodes in terms of power consumption for both conventional model and for VLC-BR

Table II
Total Power Consumption in (w/sec.) of r. k. Guha's model[10], k-m model [11], k-j model [12] and our VLC-BR.

Model	*Total Power Consumption µW/Sec*	*Total power consumption using our VLC-BR model*
R.K.Guha Model [9]	100 µW/Sec.	85 µW/Sec
K-M Model [8]	75 µW/Sec.	63.75 µW/Sec
K-J Model [10]	71 µW/Sec.	60.35 µW/Sec
CGNT Model [11]	62 µW/Sec.	52.7 µW/Sec

In fig. 6, there is a huge area difference we have found from the conventional model to our VLC-BR by taking the sorted nodes in terms of their power consumption in network trafficking.

In Table. II. We have tabulated the value of total power consumption for all existing models with the size and parameter we have taken for our consideration. The K-M model [8] having total PC 100 µW/Sec., the K-J Model [10] has the total PC 75 µW/Sec, CGNT Model [11] with PC 71 µW/Sec and our specimen model which is based on R. K. Guha [9] having total PC 100. We have done a comparison study among all with our VLC-BR value PC', which coming out with a good difference in magnitude and are been shown in fig. 7.

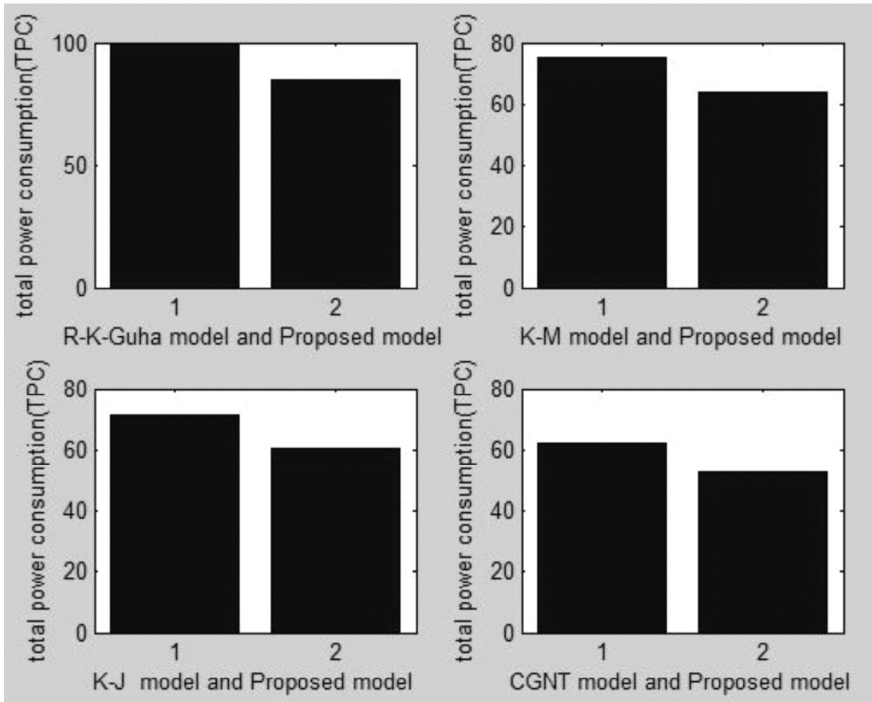

Figure 6: Area plot for nodes in terms of power consumption for both conventional model and for proposed model VLC-BR

VI. CONCLUSION

By simulating the proposed model VLC-BR, we have the results and tables which clearly speaking about the advantageous features of adapting to this new technology light fidelity into the WSNs for sending and receiving traffic that consumes the maximum power of the network, hence, with this we could able to increase the network lifetime by minimizing the battery power consumption. Replacing transceiver with the light fidelity module enhance the battery life which is cheap, reliable, large-scale availability, secure and having a large bandwidth than that of the conventional way of sending traffic over a network. This paper is opening a colossal area of research that will further increase the network lifetime in future.

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