IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-10, Oct 2018 E-ISSN: 2347-2693

Nurturing Wireless Communication: Coalition of Cognitive Radio with Li-Fi

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Available online at: www.ijcseonline.org

Accepted: 13/Oct/2018, Published: 31/Oct/2018

Abstract— Evolution of surplus gadgets accessing web facilities has eventually actuated the resource congestion. Several alluring data grabbing techniques are utilized with their respective pros and cons. The paper administers a concept which is based on the integration of the Li-Fi with the Cognitive Radio technology, diversifying the wireless communication with hiking spectrum utilization and vast capacity. The concept adheres to improve the multi-user communication by relying on the use of both the optical as well as the radio frequency spectrums in a communicating network which is more effective instead of using Li-Fi or Cognitive Radio independently.

Keywords— Cognitive Radio (CR), LED (Light Emitting Diode), Light Fidelity (Li-Fi), Visible Light Communication (VLC).

I. INTRODUCTION

Surging advancement in the technology is required to meet the escalating demand over the generations to access wireless spectra for data trans-reception. To alleviate the problem of spectrum scarcity crisis, several innovative techniques have been developed over the times.

Propounded by Dr. Joseph Mitola III at the Royal Institute of Technology in Stockholm in 1998, the concept of Cognitive Radio administers a technology that drives software based, smart and intelligently adaptable wireless transceiver in [1]. Cognitive Radios service to provide best spectrum utilization by methods of Spectrum Sensing by instant identification of the unoccupied licensed band (Spectrum Holes or White Spaces) of the Primary User, hooking to the channel by the Secondary User (unlicensed user) without any hindrance to Primary user's operation and vacating once the licensed user grips to that particular channel. This method of Dynamic Spectrum Access (DSA) as shown in Figure 1 deliberately enhances the massive user sustainability that has been studied from [2].

Other reformation in Wireless Communication is Li-Fi, a methodology coined by Professor Harald Haas in the 2011 TED Global talk. Light Fidelity uses flickering LED light bulbs with intensity faster than human eyes to follow yet with constant outputs for the optical data transmission in [3].

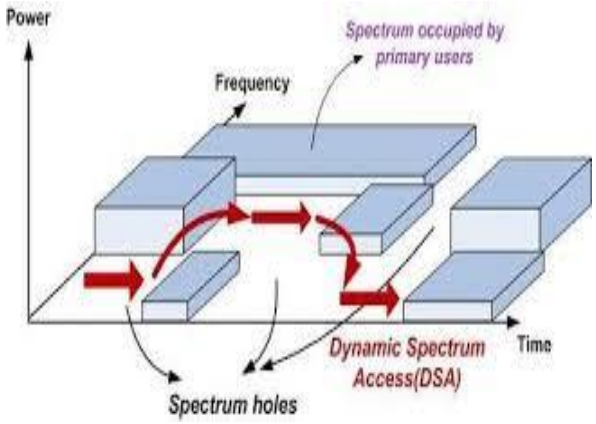

Figure 1: Spectrum holes concept in cognitive Radio

Accomplishing access to the optical spectrum for data reception by the method of illumination provides blistering transmission rates up to 10 Gbps and high data density. This appears as a new greener, healthier and cheaper module for high speed optical wireless system. Despite of all the advantages, issues regarding network coverage, reliability pertain in Li-Fi which account for development of new data communicating techniques. In this paper we have considered the problems with Li-Fi and examined how an innovative architecture of collaborating Li-Fi technology with the Cognitive Radio concept serves in overcoming the spectrum scarcity troubles faced by massive users.

The propounded architecture works at two levels. At one hand it is presumed to work with the optical communication

fundamentals i.e. Li-Fi and on other hand to operate based on the software defined Cognitive Radio resulting in an expedient Bandwidth harvesting.
The section II of the paper describes the operation of individual modules while section III details about the integrated working of Li-Fi and Cognitive Radio.

II. OPERATION OF MODULES

A. Light Fidelity: Li-Fi involves LED bulb at transmitting end, mobile devices and photo-detectors at receiving end to access the binary data via light as shown in Figure 2. Digital 1 is transmitted when LED is in ON state and vice-versa when it is OFF. By altering the brightness of light through LED bulbs flickering in manner that is imperceptible to human eye, data can be communicated at different rates. The photo detector receives the data from an infrared transmitter which enables high speed bidirectional data communication.
Advantages of Li-Fi can be listed as follows:
a) Security: As light does not penetrate through walls, Li-Fi enables secure data transmission.
b) Efficiency: LEDs consume less energy making it advantageous to use Li-Fi in contrast to cellular radio base stations which consume massive energy for cooling the base station rendering merely 5% efficiency.
c) Availability: Light in abundance is beneficial for easy usage and involves low implementation and cost effective communication via Li-Fi.
d) Energy Saving: Long service life of about 10-12 years with 8 Watt LED equivalent to 60 Watt ordinary bulb is more energy efficient.

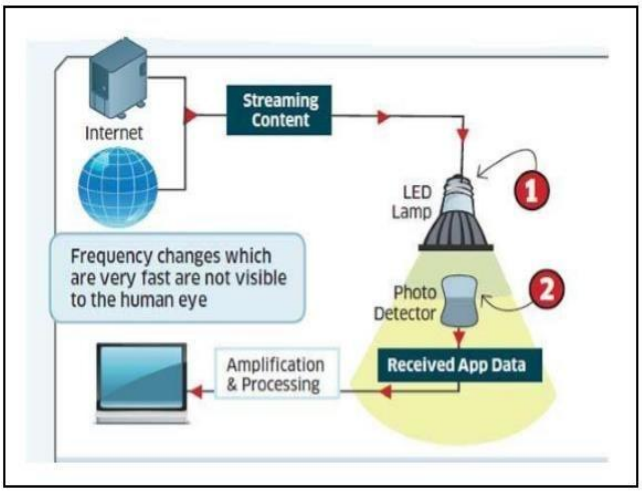

Figure 2: Block diagram of Li-Fi

e) Bandwidth Extensibility: Li-Fi networking has 1000 times the bandwidth than the radio waves.
f) Usage: It is suitable in underwater applications, provides cheap internet facility in aircrafts, street light usage for data access etc.

B. Cognitive Radio: Underutilization of the electromagnetic spectrum has exacerbated the problem of spectrum scarcity.

Dynamics of spectrum and QoS requirements pose significant challenges for the use of Cognitive Radios to serve the user needs. Cognitive Radio is a radio that has potential to change its transmitting parameters based on the observations from the environment it works with.

Features of Cognitive Radio:
Cognitive Capability: Sensing the underutilized spectrum and eventually selecting best spectrum for transmission.
Re-configurability: Ability of the radio to be programmed dynamically. It involves adjustment of transmitting power, operating frequency, modulation type, protocols.

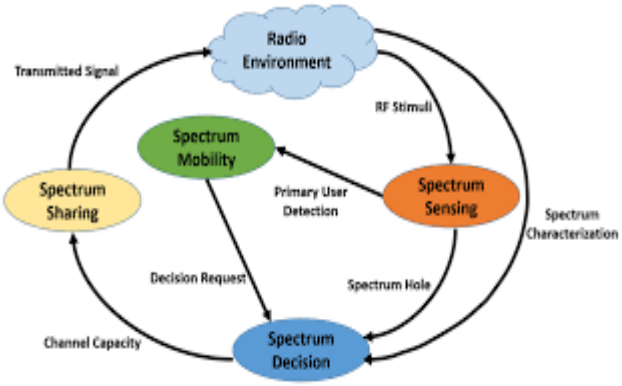

Figure 3: Cognitive Radio Cycle

The Cognitive Cycle as in Figure 3 comprises of the following:
a) Spectrum Sensing: Determining the presence of PU by various methods as energy detection method, matched filter method with a motive of detecting the spectrum holes in [4].
b) Spectrum Analysis: Evaluating the characteristics of detected spectrum holes.
c) Spectrum Decision: Based on the user requirements, bandwidth availability, appropriate data rate needs, the best spectrum band is chosen for transmission.

III. PROPOSED WORK

A. Description of the Model
Growing demand of wide spectrum bandwidth to serve multiple wireless applications consistently draws an attention towards a network with multi disciplinary usage capabilities [5]. In order to overcome the below mentioned issues, the concept of Cognitive Radio is used for multi user operation.

Following are the limitations of Li-Fi:
- Relies on Line of Sight and immobile transmitting ends.
- Range limitations due to physical barriers in the transmission path.

- Lamp failures.
- Insignificant transceivers.
- Constricted user service sustainability.

We can consider an indoor environment where both optical Li-Fi and radio frequency Primary Users operate. The predefined users are though using the optical and radio spectrum yet there remains unused optical spectrum which is not fully exploited plus the Radio spectrum also has white spaces.
Hence, to use the underutilized spectrum, non-legitimate Cognitive Users are deployed which operate according to the user requirements. The table on right gives a brief account of the features of Li-Fi and Cognitive Radio.

B. Cognitive Radio based photo detecting receiver
a) Integrated Mode:
Optical spectra remains underutilized when devices are less so it can be used by placing a cognitive based photo detecting receiving end in the Li-Fi network which enables increased users capacity. Whereas the Cognitive Radio will also search for the TV White Spaces in the existing RF spectra by firstly detecting the primary user (licensed user) using spectrum sensing and transmits data when possible as in Figure 4.

This hybrid methodology to use both the optical as well as radio spectrum can be used during heavy traffic loads resulting in significant capacity build ups. However, once the legitimate user arrives back the cognitive radio user has to step to another available channel via spectrum handoff mechanisms [6].

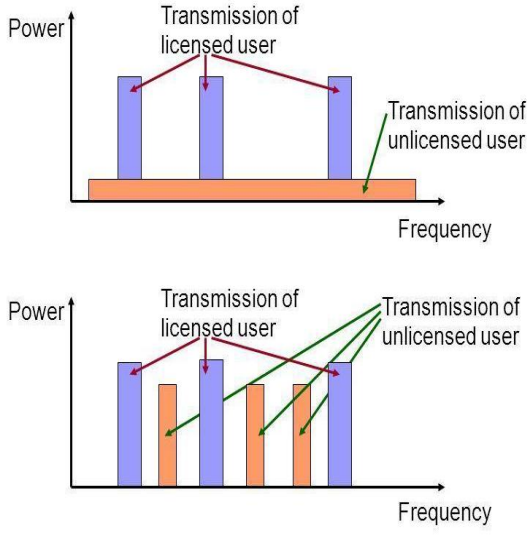

Figure 4: Secondary User accessing primary resources.

Table 1: Key Characteristics

Feature	Li-Fi	CR
Full Form	Light Fidelity	Cognitive Radio
Transmission Medium	Uses visible light communication	Uses radio wave as carrier
Components	Lamp driver, LED (lamp), photo-detector	Cognitive engine, operating system, sensor, radio
Topology	Peer to Peer, Star, Broadcast	Cluster type for Co-operative sensing
Power Level	Miniature size LEDs maintain minimal power consumption	Adaptive control
Operating frequency	10,000 times the Radio frequency	Dynamic access to Radio frequency spectrum
Privacy	Secure data transmission as light is blocked by walls	Location privacy issues in CR, Eavesdropping is certain
Advantages	High data transmission rates up to 10 Gigabits per second is achieved	Cognitive Radio potentially to be used in 5G networking

b) Day and Night Mode:
It would be best to use CR communication during day hours and photo-detection mode during night hours since lights are ON at homes or the workplaces during night up to certain time.

c) Lamp Failure:
Spectrum Mobility is a method by which CR user changes its frequency of operation by transitioning to best available spectrum. Difficulty to maintain sustained connectivity due to lamp failure can be rendered as a poor networking which can be compromised by enabling the secondary user to work on the cognitive RF mode.

CR based photo detecting receiver automatically would hook either to most certain RF channel once after the primary users interference or to strongest lamp once on availability for maintaining continuous communication.

d) Traffic Priority:

The traffic can be divided as either high priority or the low priority traffic based on the data rate, bandwidth, distance from the resource and mobility of the users as. Aggregation of cognitive radio with Li-Fi can be modelled to direct high priority users to use RF spectrum while enabling low priority users to transmit on to the optical spectrum as [7]. Certainly, this will account for better spectrum management and efficient resource utilization.

e) Multi User Sustenance:

It's the drawback of Li-Fi that its operation requires sustained Line of Sight and light can't penetrate through walls. This problem can eventually be sorted out by the usage of Cognitive subscribers of the licensed RF spectrum which work using wideband sensing frequency reconfigurable, radiation pattern reconfigurable, polarization reconfigurable antennas as described in [8].

f) Denial of Services:

Li-Fi is susceptible to malicious attacks due to interference from sunlight but using a Cognitive Radios sensing the spectrum cooperatively, the properties of the resource head can be known prior thus wasteful transmission over insignificant path can be possibly avoided.

IV. CONCLUSION AND FUTURE SCOPE

The paper reveals the advantages of using Li-Fi with the Cognitive Radio that accounts for multi user operation and manages the heavy data loads by traffic distributions on either of the spectrum. Opportunistic spectrum access capabilities of Cognitive Radio enables use the best available spectrum for communication. The advantages of Cognitive Radios, their operations keeping in view the drawbacks of Li-Fi have been studied.

Future works can be describing the limit of number of users to be serviced in an aggregated network with Li-Fi and Cognitive Radio and defining how could a Cognitive Radio be optimized to effectively operate in optical and RF band as per user requirements with minimal interference.

ACKNOWLEDGEMENT

A sincere vote of gratitude to Dr. Avtar Singh Buttar, Associate Professor, Department of Electronics and Communications of I.K. Gujral Punjab Technical University, Jalandhar for rendering due knowledge about the concepts of Cognitive Radio.

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Authors Profile

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