RESOURCE ALLOCATION FOR HYBRID PLC/VLC/RF COMMUNICATIONS

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Internship provided by:

Technical Education Quality Improvement Programme (TEQIP) Cell,

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Internship Duration:

One month (13th June '19 – 13th July '19)

INTRODUCTION

A radio frequency (RF) signal is a wireless electromagnetic signal, which is used in many industries like television broadcasting, computer and mobile platform networks, remote control, and many more. It has many limitations like spectrum deficiency, electromagnetic interference and power inefficiency and these limitations are overcome by VLC as it has high bandwidth, immunity to electromagnetic interference and ability to be used both as illumination sources and communication. VLC is a data communication wireless method which uses light emitted by LEDs to deliver networked and high speed communication. LEDs are extremely energy efficient and consume up to 90% less power than incandescent bulbs. The main disadvantage of VLC is that in the absence of line of sight(LOS) it's performance decreases and this can be overcome by RF communication due to its higher penetration ability. Both VLC and RF system work together to improve the overall system capacity and to achieve the higher data rate services. The energy efficiency of a heterogeneous system has been calculated when both RF access point (AP) and a VLC AP transmitting to a number of mobile terminals (MTs) located in the coverage area of both Aps [1].

Then they added power line communication(PLC) as the backbone of VLC transmitter as PLC gives higher data rate and it can be easily coupled with VLC. PLC serves as a mode of carrying data and also able to carry data for communication purposes . it can be used for smart home and system control and automation. Then integrating PLC/VLC system with RF system gives many benefits. Then they have formulated and solved power allocation problems to maximise the achievable data rate and to minimize the total transmission power[3].

SYSTEM MODEL

I.VLC SYSTEM MODEL

VLC gives better service when light is on and they proposed power and bandwidth allocation optimization problem when light is ON. This VLC system is to calculate the electrical signal to noise power ratio(SNR) which controls the VLC system performance.[1]

The set of MTs(M) ={1, 2,3….., n}
The driving current of the LED = x(Amp)
Driving power= P_{dr}
For nth MTs the power is = $P_{V,\ n}$
The output of the LED will be an optical intensity signal which is denoted as x_{opt}
The power gain between the VLC AP and the nth MT is denoted as $G_{V,\ n\ .}$
Responsivity= p(Amp/Watt) which measures the input output gain of a system which converts the optical signal into electrical signal.
At the nth MT the electrical signal is denoted by x_n

$$X_n = p\ x_{opt}$$

The average electrical power,

$$P_{e,n} =(\ kpG_{V,n}\ )^2\ P_{V,\ n}\ ,$$ where k is the proportionality factor (Watt/Am)

SNR CALCULATION OF VLC SYSTEM

The signal to noise power ratio of the VLC upto the nth MTs is denoted by $Y_{V,n}$. The transmission power of VLC to the nth MT is $P_{V,n}$. The bandwidth of VLC to the nth MT is denoted by $B_{V,n}$ The transmission power of VLC to the nth MT is $P_{V,n}$. ρ (Amp/Watt)is the responsivity which measures the input output gain of the photo-dectector.

$$Y_{V,n}= P_{V,n}(k \rho G_{V,n})^2/B_{V,n} N_{0,V}$$

$N_{0,v} = K_B T$, $N_{0,V}$ represents the thermal noise density of the VLC system , where T denoted ambient temperature and K_B denotes Boltzmann's constant.$G_{V,n}$ is the channel power gain .The noise affecting the vlc system is independently explain by gaussian noise [5].

In the presence of LOS, the channel power gain is denoted by $G_{LOS,V,n}$ and for the NLOS ,channel power gain is denoted by $G_{NLOS,V,n}$ [1].

$$G_{V,n} = (k + 1) \cos^k(\varphi_n)A_n \cos(\theta_n) /2\pi(d_{V,n})^2 ,$$

where angle of irradiance to the nth MT is denoted as φ_n ,k is the order of Lambert's emission ,θ_n denotes the angle of incidence and A_n represents the physical area of the photodiode detector at the nth MT.

The data rates of VLC communication system is denoted by $R_{V,n}$. Responsivity of the VLC system is denoted by ρ_V .

$$R_{V,n} = B_{V,n}\ \rho_V \log_2(1 + Y_{V,n})$$

2.RF SYSTEM MODEL

The RF transmitter which is directly connected to source and used to transmit data through transmission power $P_{R,n}$. The data transmits travel through a wireless RF channel described by its power gain factor denoted by $G_{R,n}$. The bandwidth of RF system is denoted by $B_{R,n}$.

The noise affecting the RF receiver is known as thermal noise power spectral density (PSD) and denoted by $N_{0,R}$.

$N_{0,R} = k_B\ T$,where T denoted ambient temperature and K_B denotes Boltzmann's constant.[2]

The pathloss of RF communication is denoted by PL.

$$PL[dB] = A \log_{10} (d_{R,n}) + B + C \log_{10} (f_c /5) + X ,$$

where d represents the distance between transmitter and receiver .system frequency is denoted by f_c [GHz].Parameter A includes the path loss exponent,parameter B is the intercept , parameter C represents the path loss frequency dependance.X stands for an environmental specific term [6].

SNR CALCULATION FOR RF SYSTEM

The received signal to noise power ratio of the RF communication is denoted as $Y_{R,n}$.

$$Y_{R,n} = R_{R,n} G_{R,n} / B_{R,n} N_{0,V}$$

$G_{R,n}$ represents the channel power gain of the RF communication system.

$$G_{R,n} = 10^{-PL[dB]/10}$$

If line of sight is present then the power gain is represented by $G_{LOS, R, n}$ and for non line of sight power gain is represented as $G_{NLOS, R, n.}$ The SNR of RF transmission for LOS system is denoted by $Y_{lOS, R,n}$ and for NLOS system the SNR is denoted as $Y_{NLOS,R,n}$. ρ_R represents the responsivity of RF the system.The data rates of RF communication is denoted by $R_{R,n}$.[1]

$$R_{R,n} = B_{R, n}(\rho_R \log_2(1 + Y_{lOS, R,n}) + (1-\rho_R) \log_2(1+Y_{NLOS,R,n}))$$

3. PLC SYSTEM MODEL

The data is transmitted from the source node R_0 to the destination node R_N. The distance between these two node is denoted as d . the series of intermediate relay nodes are R_1 ,R_2 …...R_{N-1}.The intermediate nodes retransmit the received data from one hop to the next. Each intermediate node decodes the received symbol and then forward the decoded symbol to the next node, thus known as a DF relay.this system can transmit and receive data at the same time using FDD(frequency division duplexing) this means it operates in full duplex mode. In FDD, each node uses different frequencies to transmit and receive. in [9] it is assumed that the bandwidth of the signal is less than the coherence bandwidth of the channel.

The PLC channel suffers from signal attenuation, fading and additive noise (addition of noises at nodes R_1, …, R_N are mixtures of independent background and impulsive noises)[9]. Impulsive noise fluctuates more rapidly with time as compared to background noise. background noise is caused by common household appliances like computers, television, etc., where as impulsive noise occurs due to switching transients at irregular intervals in the power network. Bernoulli-Gaussian modeling(noise model) of the PLC noise is given in [7].

The average noise power is denoted by N_0 and calculated as,

$$N_0 = \sigma_G^2 (1 + p\,\eta),$$

where $\eta = \sigma_I^2 / \sigma_G^2$, σ_I^2 represents the impulsive noise and σ_G^2 represents the background noise. The SNR of the PLC system is represented as γ_i of the ith channel is represented as[7],

$$\gamma_i = h_i^2 E_b / N_0 \text{ ,where } E_b \text{ is the average energy.}$$

Multipath is a serious issue for PLC channel because the distribution of power line becomes complicated.The signal passes through a shortest path between the transmitter and receiver but additional path should also be considered.It will result in multipath scenario with frequency selective fading . The multipath signal propagation is explained in [10].

The fading, the signal attenuation and the noise affect the reliability in data transfer of a long-distance communication system. Attenuation increases with increase in length and frequency.

SNR CALCULATION FOR PLC SYSTEM

The SNR for PLC system is denoted as SNR_P .The transmission power for mth subcarrier for the PLC system is denoted as $P_{P,m}$ and the bandwidth is denoted as B_P .The thermal noise power spectral density is denoted as N_0 and channel gain is represented as $G_{P,m}$.

$SNR_{P,m} = P_{P,m} G_{P,m} / N_{0,P} (B_P / N_P)$.

4.RF/VLC HETEROGENEOUS SYSTEM

The transmission power of VLC and RF Aps up to the nth MT are $P_{V,n}$ and $P_{R,n}$ maximum bandwidth of the system is denoted by $B_{V,max}$ and $B_{R,max}$. Before transmission some amount of power used for circuit operation and that is called as fixed power and the fixed power of the Aps are denoted by Q_V and Q_R . The data rate obtained by nth MT are denoted by $R_{V,n}$ and $R_{R,n}$. The sum of the data rates of the VLC and RF Aps should not be less than the minimum required data rates that is denoted by $R_{min,n}$. The distance between the nth MT and the Aps is denoted by $d_{V,n}$ and $d_{R,n}$.

ENERGY EFFICIENCY CALCULATION

The total data rate in RF/VLC hybrid network is denoted by R_T,

$$R_T = \sum R_{V,n} + \sum R_{R,n}$$

The total consumed power of the VLC and RF communication is the sum of the power consumed by VLC AP and power consumed by RF AP and it's value is,

$$P_T = Q_V + Q_R + \sum P_{R,n}$$

The energy efficiency of hybrid RF/VLC network is denoted by *n*, $n = R_T / P_T$
The total data rates is , $R_{V,n} + R_{R,n}$
The maximum efficiency will be,

$$\text{Max } n \ (P_{V,n}, P_{R,n}, B_{V,n}, B_{R,n})$$
$$\text{st.} R_{V,n} + R_{R,n} \geq R_{min,n}, \text{for all } n \in M,$$
$$\sum P_{V,n} \leq P_{V,max},$$
$$\sum P_{R,n} \leq P_{R,max},$$
$$\sum B_{V,n} \leq B_{V,max},$$
$$\sum B_{R,n} \leq B_{R,max},$$
$$P_{V,n}, P_{R,n}, B_{V,n}, B_{R,n} \geq 0, \ \forall \ n \in M.$$

5. PLC/VLC/RF HYBRID MODEL

This system model has three transmitter that are PLC, VLC and RF transmitter. It has two communication link which are parallel to each other the first link is the RF channel and the second link is a cascaded link which consist of two channel that is PLC channel and VLC channel. In RF, VLC and PLC, the numbers of used subcarriers are denoted by N_R, N_V and N_P, respectively. Orthogonal frequency division multiple (OFDM) is used for the data transmission in all three transmitter that is PLC,VLC & RF . The total number of subcarrier for VLC is determined by G_B ,G_B represents the bandwidth utilisation factor where,$N_V = 2N_1/G_B$ .The value of G_B depends on the optical OFDM [2]

The transmission power for mth subcarrier for the RF, VLC and PLC system is denoted by $P_{R,m}$, $P_{V, m}$ and $P_{P,m}$. The channel power gain of the RF, VLC and PLC system for the mth subcarrier is denoted by $G_{R, m}$, $G_{V, m}$ and $G_{P, m}$. The bandwidth of the RF, VLC and PLC system is denoted by B_R, B_V and B_P. The relation between the PLC and VLC bandwidth is BP = $B_V G_B/2$.

SNR CALCULATION

For the RF communication link the SNR at the mth subcarrier is denoted as $SNR_{R,m}$ and calculated as

$$SNR_{R,n} = P_{R,m} G_{R,m} / N_{0,R} (B_R/N_R)$$

The PLC/VLC communication link is composed of two cascaded channels. In [2] , it is assumed that VLC transmitter uses decode and forward (DF) relaying without pairing such that the subcarriers are allocated with the same order for both PLC and VLC transmitter.The noise at both the VLC and PLC receivers are independent of each other and also independent of the transmitted signal. Thus, the received SNR for VLC system is denoted as $SNR_{V,m}$ and the SNR for PLC system is denoted as SNR_P . The received electrical SNR for PLC and VLC is calculated as follows,

$$SNR_{P,m}= P_{P,m}G_{P,m}/ N_{0,P} (B_P/ N_P) ,$$

$$SNR_{V,m} = P_{V,m}G_{V,m}/ N_{0,V}(B_V G_B/ 2N) .$$

For data decodability at the VLC transmitter, the achieved data rate at the mth VLC subcarrier should be less than or equal to the achieved rate of the corresponding PLC subcarrier. The rate is computed using Shannon's formula . Hence, the following condition for all the cascaded PLC/VLC system subcarriers

$$(B_P/N_P) \log_2 (1 + (1/\Gamma_p)SNR_{P,m}) \geq (B_V G_{\mathbf{B}} /2N_1) LOG_2 (1 + (1/\Gamma_V) SNR_{V,m}$$

where Γ_p and Γ_V are the air gap factors that involve the data rates of the PLC and VLC systems, respectively.

The total transmission power consumed is equal to the power consumed by both the communication link that is RF channel and a cascaded channel which consists of PLC and VLC channel.

$$P_T = \Sigma P_{R,m} + \Sigma (P_{P,m} + 2P_{V,m}).$$

Hence , the minimization of transmission power will be written as ,

$$\min P_T (P_{R,m} ,P_{P,m} ,P_{V,m})$$

$$\text{s.t. } \phi (P_{R,m} ,P_{P,m} ,P_{V,m}) \geq \phi_{min} ,$$

$$(B_P/N_P) \log_2 (1 + (1/\Gamma_p)SNR_{P,m}) \geq (B_V G_{\mathbf{B}} /2N_1) LOG_2 (1 + (1/\Gamma_V) SNR_{V,m}$$

$P_{R,m}, P_{P,m}, P_{V,m} \geq 0$

$\Sigma P_{R,m} \leq P_{R,max}$

$\Sigma P_{P,m} \leq P_{P,max}$

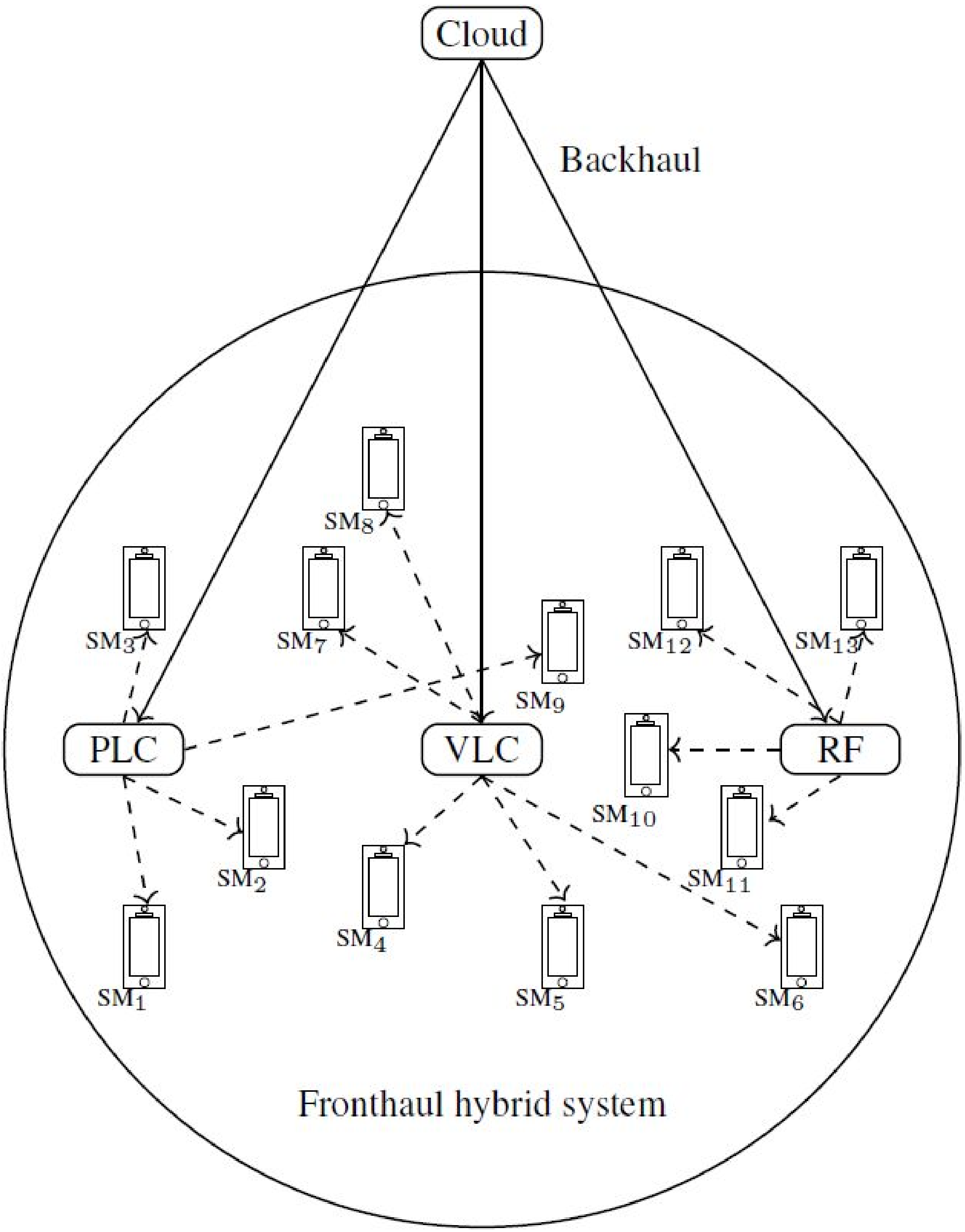
$\Sigma P_{V,m} \leq P_{V,max}$

RELATED WORK

In [11], it is proposed to move an extra energy harvesting nodes as relays over an existing non energy harvesting network. An effective strategy is proposed to reduce the transmit power of multiple S-D pairs with the help of EH relays. Here the algorithm are of low complexity and optimality can be achieved when the number of transmission blocks is sufficiently large. The proposed algorithm in this paper is an efficient bisection algorithm, which is used to solve the original joint power assignment and relay selection problem. Cooperative communications has been proven to be an effective technique to improve the communication performance as well as the energy efficiency for wireless networks. In [12] the proposed algorithm is an efficient sensing algorithm that utilizes the least required number of CRs(Cognitive radio) for a target error probability. In [13], a unified cross layer framework for resource allocation in cooperative networks is presented. In this paper,multi-state energy allocation algorithm is used.In [14], relay assignment and power minimization algorithm for multisource multi relay scenario is presented. In this paper, algorithm of relay allocation, with minimum transmission power for the wireless network of limited no of sources and relays is used. This algorithm is basically used to minimize the total transmission power required to transmit the information.

In [15], the derivative based algorithm is proposed.The proposed derivative-based algorithm can achieve near-optimal EE with better performance than the conventional BB algorithm.In [16],the author proposed an iterative algorithm to maximize the EE of D2D communication in the single-cell scenario. In [17], a distributed resource allocation algorithm was proposed. In [18], the authors investigated the EE maximization for a multiuser AF MIMO relay system with a holistic power model , where a joint selection of the active antennas and the user, as well as the optimization of transmission power is considered. In this paper, a low complexity joint user and antenna selection for EE maximization algorithm (J-SEEM) is proposed. Another paper that investigates the maximization of EE in MIMO relay systems is [19]. The authors proposed a suboptimal algorithm based on fractional programming and alternative optimization for the single-user scenario where the numbers of active antennas among nodes are fixed.

proposed model:



here, we use fiber as backhaul for RF, PLC and VLC transmitter. In future, we will propose an efficient resource allocation algorithm for the proposed system.

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