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Handover method in visible light communication between the moving vehicle and multiple LED streetlights

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ABSTRACT

When the moving vehicle is communicating with LED streetlights by visible light, the multiple LED streetlights signals will be selected or signal may be interrupted between adjacent streetlights. The method of receiving signal power (RSP) handover between the moving vehicle and multiple LED streetlights transmitters will be studied. Considering two cases, no power coverage and power overlap between adjacent streetlights. Hard RSP handover used in no power coverage model and soft RSP handover used in power overlap model. Simulation results show both RSP handover methods can protect the communication between the vehicle and LED streetlights and improve the stability of communication.

1. Introduction

VLC (Visible Light Communication) is an emerging wireless communication technology which used the white LED light. Compare to traditional radio communications, VLC has many advantages, including harmless to human, no electromagnetic interference, energy conservation, and communication while lighting, etc. [1]. So there are great developing prospects on VLC technology in the future.

Outdoor VLC is mainly used in Intelligent Transportation Systems (ITS), since there are many LED devices such as LED traffic lights, car LED lights in ITS, and do not need to invest in the construction again [2–4], thus it can solve the cost-effective problem when VLC is applied to ITS. On the highway or ordinary road, a reliable way of communication is needed to show the road condition ahead, traffic and other safety information, because of no electromagnetic interference, VLC with high reliability just meets this requirement.

Recently, these studies have used VLC in the communication between the vehicle and the traffic light or between the vehicle and the vehicle, in addition the communication system including the vehicle, traffic lights and other equipments was established to solve the vehicle's position and communication problem, then the maximum communication distance can reached 15–20 m [4,5]. However these studies are mainly about point-to-point communication and there are no selection problems among multiple transmitters. But the discussion in this paper is mainly about the communication between the vehicle and multiple LED streetlights, where LED streetlights' deployments have been identified and the signal power distribution of each LED streetlight is also fixed, thus there are two situations, namely no signal power coverage and signal power overlap. Therefore we must discuss seamless connectivity in signal power coverage situation and handover problems in signal power overlap situation.

In this paper, according to the real situation of LED streetlights, two communication models are built to study the models' distribution of signal power. And received signal power (RSP) handover method is proposed in two communication models, the vehicles can communicate with the streetlights normally by RSP handover when the vehicles are moving on a highway. Finally, the simulation results show that the method can balance the received power successfully and reduce BER.

2. RSP handover between moving vehicles and LED streetlights

2.1. Visible light wireless channel model

Based on the two patterns of channel model, which are direct link and reflex link, channel model can be divided as direct channel and diffuse channel. The source of outdoor visible light communication mainly depends on high power LED streetlights with both capabilities for providing light and ensuring reliable communication for signal transmission [6]. When LED streetlights are considered as transmitters, white light as its signal, namely the signal coverage area is the irradiation area.

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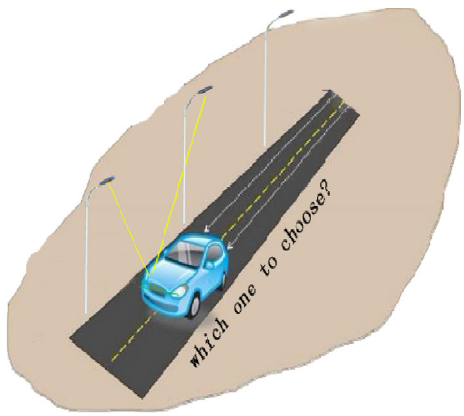
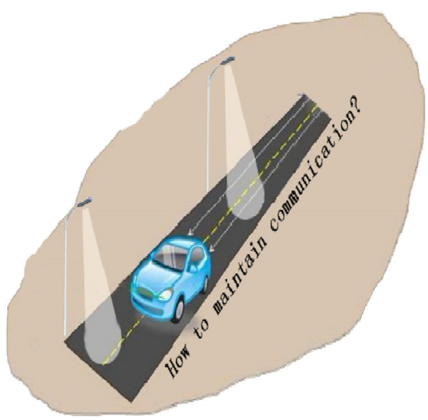


(a) Multiple signals between adjacent streetlights



(b) No signal between adjacent streetlights

Fig. 1. LED streetlights wireless communication model. (a) Multiple signals between adjacent. (b) No signal between adjacent streetlights streetlights.

The communication models of the moving vehicle and streetlights are showed in Fig. 1, LED streetlights which as the transmitters will communicate with the vehicle which as the receiver by visible light. Since the outdoor view is large and there are only few obstacles, diffuse phenomenon can only impose little impact on receiving end. Thus the main performance is determined by light, the diffuse phenomenon will be ignored accordingly. There is power overlap area between two streetlights as show in Fig. 1a, thus for the vehicle a more powerful signal's choice can improve the reliability of communication. While for Fig. 1b, the communication will be interrupted since there is no power coverage area, the receiver's estimated buffer size should be big enough to maintain seamless connectivity. Thus in what follows, signal power distribution of streetlights, the choice of signal with RSP handover method and the size of estimated buffer will be described in great detail.

2.2. Power distribution of coverage area of LED lights

The radio source with whose radiance along all the direction of source is permanent is called Lambertian radiation, as shown in Fig. 2, the lights in Fig. 2 corresponds with the model of Lambertian

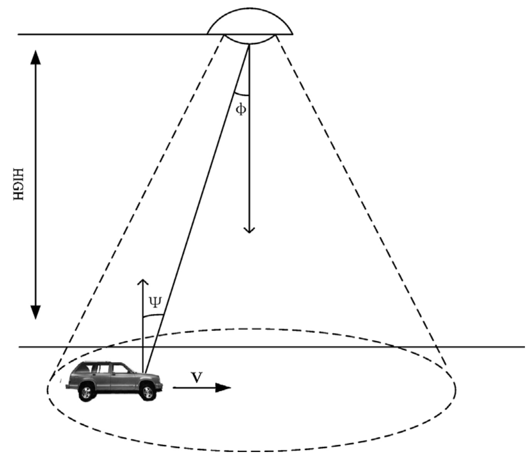


Fig. 2. Direct view signal channel of LED streetlight.

radiation, and the reflex light can be ignored in outdoor area. The direct gain of direct distance optical is defined as $H(0)$ [6]:

$$H(0) = \begin{cases} \dfrac{(m+1)A}{2\pi d^2}\cos^m(\varphi)T_s(\Psi)g(\Psi)\cos(\Psi), & 0 \le \Psi \le \Psi_c \\ 0 & \Psi \ge \Psi_c \end{cases} \quad (1)$$

where m is the model of radiation source, A is the area of receiving point, d is the distance between transmission point and receiving point. Ψ is the angle of incidence, φ is the laugh angle, $T_s(\Psi)$ is the gain of optical filter, $g(\Psi)$ is the gain of optical concentrator, Ψ_c is the receiving field of view. The model of radiation source m can be described as:

$$m = \frac{\ln 2}{\ln(\cos\phi_{1/2})} \quad (2)$$

where $\phi_{1/2}$ is the transmit power half-width, in this paper we define $\phi_{1/2}$ as 60°, thus $m = 1$.

The gain of optical concentrator can be described as:

$$g(\Psi) = \begin{cases} \dfrac{n^2}{\sin^2(\Psi_c)}, & 0 \le \Psi \le \Psi_c \\ 0 & \Psi > \Psi_c \end{cases} \quad (3)$$

where n is the index of refraction.

In VLC system, the transmitting power is P_t, and the receiving power in coverage area is:

$$P_r = H(0)P_t \quad (4)$$

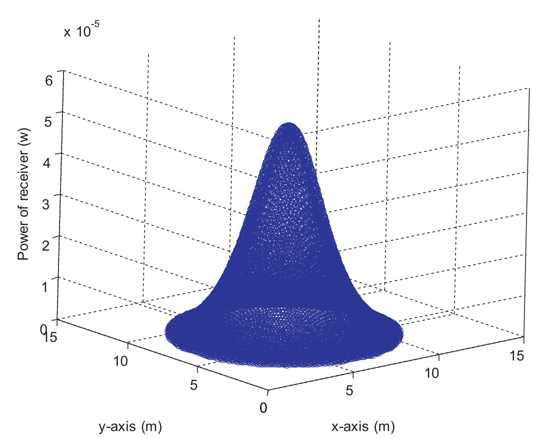


Fig. 3. Signal power distribution of single LED streetlight.