Abstract

Over the recent few years, optical wireless communication (OWC) has attracted significant attention in both academia and the research community. Contrary to radio frequency (RF) systems, the spatial confinement of the optical beams makes the OWC system a potential system offering higher data rates and secured communication. OWC systems find applications in several areas, such as terrestrial outdoor (free-space optical (FSO) communication), indoor and outdoor visible light communication (VLC), etc. For the terrestrial outdoor FSO systems, spatial diversity techniques are employed over FSO links to enhance the diversity and overall performance. To this end, the spatial diversity techniques corresponding to the state-of-the-art are repetition coding (RC), transmit laser selection (TLS), and orthogonal space-time block codes. Note that, TLS is the optimal transmission scheme in the FSO systems. In this dissertation, we name the conventional TLS scheme as a single TLS (STLS) scheme. However, the performance of the conventional STLS scheme is highly dependent on the feedback errors. On the other side, the outdoor VLC finds applications in vehicle-to-vehicle (V2V) communications, infrastructure-to-vehicle (I2V) communications, etc. Emphasizing the state-of-the-art corresponding to the outdoor V2V-VLC systems, there is a lack of comprehensive modeling and performance investigation under the adverse challenges of the outdoor VLC environment. Moreover, to address the challenges of the next-generation-based outdoor intelligent transportation systems (ITSs), an indoor testbed design for an outdoor I2V-VLC system is still missing.

In order to enhance the diversity and overall performance of the terrestrial outdoor FSO systems, the study begins by proposing two novel TLS schemes. We call the proposed schemes as two TLS (TTLS) and modified error-tolerant weighting scheme

(METWS). Note that, the conventional STLS scheme gives optimal performance under a perfect feedback scenario. However, its performance degrades significantly under an imperfect feedback scenario. To this end, the two proposed schemes overcome the practical limitations of the conventional STLS scheme. Moreover, we analyze the performance of the two proposed schemes for both perfect and imperfect channel state information (CSI)-based communication scenarios. Further, different performance metrics, such as bit error rate (BER), diversity gain, etc., are thoroughly analyzed. Furthermore, to gain more insights, the performance of the two proposed schemes is also compared with the conventional STLS and RC schemes.

We then investigate the diversity-multiplexing tradeoff (DMT) for the OWC systems. To this end, we mainly focus on the indoor VLC and outdoor FSO systems. For the DMT investigation of the indoor VLC system, we consider the random radial movement of the end-user in the proposed system model. The optimal DMT for both the single-input single-output (SISO) and multiple-input multiple-output (MIMO) VLC systems are analyzed. Novel analytical expressions for the probability distribution function (PDF), outage probability, and outage diversity order for the SISO-VLC and MIMO-VLC systems are derived. Moreover, we extend our study to the outdoor FSO system. For the first time in literature, a limited feedback-based DMT is investigated for the FSO system under different transmission scenarios. To this end, we consider a MIMO-FSO setup and investigate the DMT for single-rate and adaptive-rate transmission scenarios.

Further, we venture into the area of vehicular VLC and comprehensively explore the area of vehicular VLC. To this end, contrary to the state-of-the-art, we emphasize comprehensive modeling of the V2V-VLC system under the practical challenges of an outdoor VLC environment. For the first time, we model the vehicle's mobility as random with a specific PDF. Therefore, we emphasize a more realistic approach to model the vehicle's mobility. Moreover, a novel channel model that incorporates the joint impact of the outdoor V2V-VLC random path loss and atmospheric turbulence (AT) is emphasized. Further, different performance metrics are analytically examined, such as path loss, outage probability, average BER (ABER), diversity order, discreteinput continuous-output memoryless channel (DCMC) capacity, etc., under different weather conditions.

We also extend our work on vehicular VLC by proposing a shadowing/blocking-based V2V-VLC model. In a line-of-sight (LOS) VLC system, the communication link is exposed to temporary shadowing due to physical obstructions by vehicles in the same lane or nearby parked vehicles. Since VLC is highly dependent on the LOS, proposing and analyzing a V2V-VLC model under a shadowing-based transmission scenario is of extreme importance. The performance of the proposed V2V-VLC model is analyzed with the DMT metric. Moreover, to minimize the path loss at the receiver (Rx), a novel hemispherical optical concentrator-based Rx structure (offering an omnidirectional gain) is also proposed. Some striking insights are envisioned for the proposed work.

Finally, as a part of the next-generation-based ITSs, we also develop an indoor testbed for an outdoor I2V-VLC system. For the first time in literature, we experimentally demonstrate the communication between the traffic light acting as the transmitter (Tx) and the camera (i.e., the Rx) under different realistic I2V-VLC scenarios in a controlled indoor environment. Moreover, all the experimental findings are demonstrated for different exposure times of the camera for the first time, which is a very critical parameter when using a camera-based Rx. Further, different performance metrics are experimentally examined, such as BER, peak signal-to-noise ratio (PSNR), and capacity. Furthermore, LOS blockage-based communication scenarios are also experimentally analyzed.