Introduction to Wireless and Mobile Networking mini-project

B10505005 蔣依倢

Toward 6G-V2X: Aggregated RF-VLC for ULTRA-Reliable and Low-Latency Autonomous Driving

Reconfigurable Intelligent Surface For 6G

Problem

As autonomous driving demand increase (deliver improved safety, traffic efficiency)
Connected autonomous vehicle (CAV) technologies are expected to support
1. ultra-reliable
2. low-latency exchange of sensing and control data

- Main stream recently

e.g. 5D-NR-V2X: C-V2X based on DSRC due to improved physical layer, centralized cellular infrastructure
disadvantage: the performance is achieved by the cost of requiring additional spectrum and hardware resources while utilizing LTE-based system architecture and mechanism

What's the Importance

6G is expected to provides

1. significant data rate increases (e.g., up to Tbps)
2. extremely fast wireless access (e.g., in the sub-milliseconds range)
3. a massive increase of connection density (e.g., 107 devices/km2 or higher),
4. more extensive, more energy-efficient,
5. more environmentally friendly three-dimensional (3D) communications through the emerging aerospace integrated networks

What is the proposed solution

The intrinsic amalgamation of Radio-Frequency (RF) and Visible Light Communication (VLC) tech which are complementary to each other, and the combination between RF-VLC communication based on Reconfigurable Intelligence Surface (RIS)

What is the contribution of the article

In this article, the author separately discusses the usage environment and difference between link aggregation and non-link aggregation of V-VLC and V-RF, and focus on how appropriate link aggregation of V-VLC and V-RF improves the network performance as compared to standalone RF or VLC based V2X communication systems under different meteorological factors at road intersections.

The author first discusses the advantages and disadvantages of typical VLC and RF technology, shows that the two method we applied in the system are complementary to each other.

For VLC, it can provide very large bandwidth and operations at THz, more energy efficiency and economically sustainable solution. In addition, its transceiver design is less complex than RF based systems, because of much less severe multi-path effect and thus, reduce the high density of RF users by switching to VLC connections where possible and, in reverse, to increase the range limitation of VLC technology. However, VLC suffer from limited transmission distance, sensitivity to back-ground light, and line-of-sight (LOS) blockage. one of the most critical issues for vehicular-VLC (V-VLC) arises from its outdoor operation. In particular, meteorological phenomenon such as fog, rain, snow, etc., can significantly influence the reliability and range of V-VLC.

In comparison, RF has wider coverage and higher transmission reliability without LOS, which is able to solve the weakness of VLC. While Pure RF links suffer from excessive RF interference and limited communication resources in situations of high vehicular density, leading to low throughput and large latency due to pack delivery failure.

The picture on the right side mainly describes under which situation the VLC-RF system can solve.

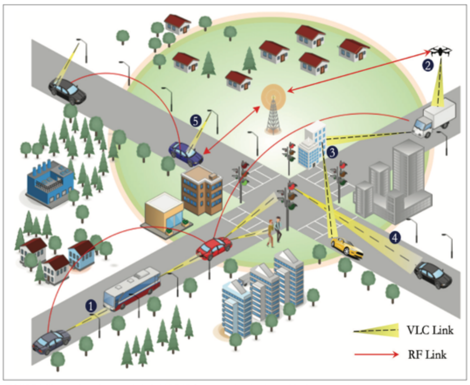

FIGURE 1. Illustration of a generic hybrid RF-VLC communication in a vehicular network.

i. V2V communication via front or back lights
ii. Unmanned aerial vehicle-to-Vehicle communication
iii. V2V communication via Reflecting Intelligent Surfaces (RIS)2
iv. V2X communication via traffic lights
v. V2X communication via street lights

In this scenario, the RF-based V2V communication of the two cars separated by large bus may be blocked due to shadowing effect; By using VLC to communicate with each other subsequently, the bus could relay the messages to the receiving car in the shadowed region.

In another scenario, the desired and interfering vehicles are equipped with both VLC and RF transceivers. The desired vehicle close to intersection is assumed to carry critical road info which needs to be communicated to the RSU, which positioned at the center of the road intersection. If using a LA hybrid RF-VLC V2X, the impact of interference and various meteorological phenomena such as rain and snow, can be reduced.

Noticing that the VLC channel gain is strongly dependent on the angel of irradiance of LED transmitter, the angle of incidence/ field-of-view (FOV) of optical receiver and the distance between transmitter and receiver.

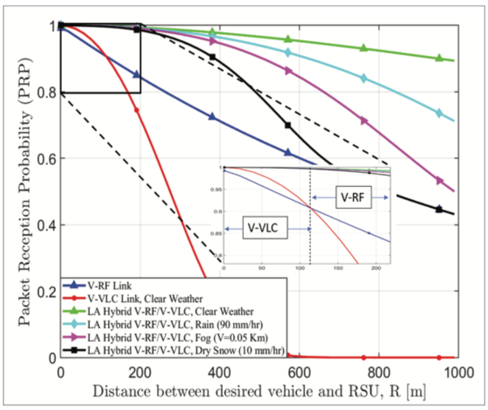

FIGURE 2. PRP at RSU for pure V-RF, pure V-VLC and LA hybrid RF-VLC V2X communication systems under rain, fog and dry snow conditions.

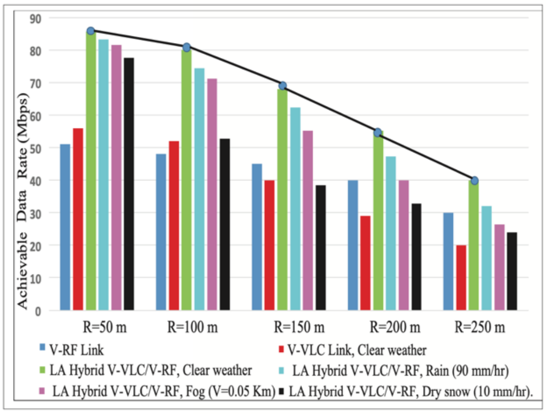

FIGURE 4. Achievable data rate for different network configurations for different values of distance between RSU and the desired vehicle.

The plot points out the advantage of using system architecture of Radio-Frequency (RF) and Visible Light Communication (VLC), shows that under most circumstances, it indeed performs better than pure RF and pure VLC communication.

The author also discusses about the system of reconfigurable intelligent surface-enabled mixed RF-VLC V2X system, since recently, RIS has attracted much research attention owing to its feature of transforming wireless channel into better one. By enabling an RIS controller to actively relay safety info from the source to the destination, which may be blocked by buildings, walls, surrounding vehicle.

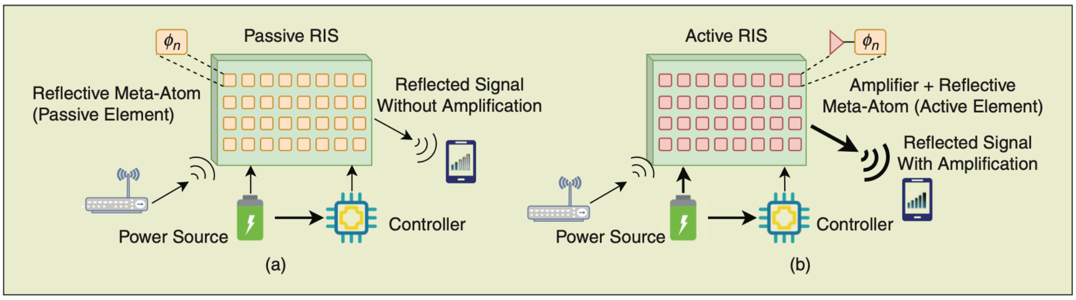

FIGURE 1 Comparison of (a) a passive with (b) an active RIS. The former's panel is implemented with simpler hardware but leads to lower signal strength at the receiving end(s). The effective tunable phase shift offered by each nth meta-atom is represented by ϕ_n. Links via a passive RIS suffer from multiplicative path loss, while those via an active RIS are subject to additive path loss. Both designs require a controller for the dynamic reflection configuration.

In another article, it provides the hardware architecture of active/ passive RIS, and the overview of various operating modes, enabling RISs to serve diverse purpose and flexible application.

RIS technology can empower network operator to optimize the dynamic wireless environment, which is exactly the scenario in the former scenario. An RIS is a planar array of unit cells, each with multiple digitalized states corresponding to distinct EM response and the end-to-end path loss is calculate by summing the individual path losses of the transmitter and RIS-receiver links, which is known as double pass loss.

In summary, the technology of RIS represents as an important role in future generation communication, and by implementing it into the architecture of RF-VLC V2X/V2V system, can promote the overall performance and provide a more stable communication. However, the energy of RIS and both RF, VLC should be taken into consideration and the performance aspect should be separately investigate, such as packet loss, data rate and error correction, to look into in what circumstances this aggregation system performs the best or performance increase the most, so that we can apply the architecture on different usage and meet the demand.

Reference

[1] Gurinder Singh, Anand Srivastava, Vivek Ashok Bohara, Md Noor-A-Rahim, Zilong Liu, and Dirk Pesch, “Toward 6G-V2X: Aggregated RF-VLC for ULTRA-Reliable and Low-Latency Autonomous Driving”, IEEE

[2] H. Abuella et al., “Hybrid RF/VLC Systems: A Comprehensive Survey on Network Topologies, Performance Analyses, Applications, and Future Directions,” IEEE Access, vol. 9, 2021, pp. 160,402–36.

[3] Ertugrul Basar , George C. Alexandropoulos , Yuanwei Liu , Qingqing Wu , Shi Jin, Chau Yuen , Octavia A. Dobre , and Robert Schober, “Reconfigurable Intelligent Surface For 6G”, IEEE Access