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Research paper

Visual-MIMO for Software-Defined Vehicular Networks

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Abstract

The paradigm of software-defined network (SDN) is being applied to vehicle scenarios in order to eliminate this heterogeneity of vehicular network infrastructure and to manage packet flow in an application- and user-centrically flexible and efficient manner. However, owing to the random mobility of vehicles and the unpredictable road communication environment, efficient vehicle-based SDN development needs further research. In this study, we propose the concept of a sub-control plane for supporting and backing up, at the data plane level, various functions of the control plane, which plays a key role in SDN. The sub-control plane can be intuitively understood through the image processing techniques used in color-independent visual-MIMO (multiple input multiple output) networking, and the function of the control plane can be backed up through various vehicle-based recognition and tracking algorithms under the situation of disconnection between the data plane and the control plane. The proposed sub-control plane is expected to facilitate efficient management of the software-defined vehicular network (SDVN) and improve vehicular communication performance and service quality.

Keywords:software defined network (SDN); visual-MIMO; generalized color modulation (GCM); vehicular networking; mobile optical networking

1. Introduction

Owing to the indiscreet application and development of vehicular networks, current vehicular network infrastructure has considerable heterogeneity among the networks, making network management and integration difficult [1]. Moreover, in high-mobility application such as automobile, network-to-network interconnection becomes further difficult. Distributed protocols, however, can improve the performance of the entire network system by allowing selection of the appropriate protocol according to the situation in a spatiotemporally varying environment. Based on this concept, the recently introduced vehicular-based software-defined network (SDN) scenario allows construction of a data plane based on the overlay network to minimize the heterogeneity of the existing vehicular networks [2]. The data plane of the configured software-defined vehicular network (SDVN) is classified as mobile data plane and stationary data plane on the basis of mobility.

In this paper, we improve the architecture of existing SDVN systems by introducing a sub-control plane that assist in the function of the control plane by interconnecting with the data plane. In practice, as a unit, the sub-control plane consists of a color-independent visual-MIMO networking system [3] applied to each switch of the SDVN. Figure 1 shows the color-independent visual-MIMO transceiving procedure using image processing [3].

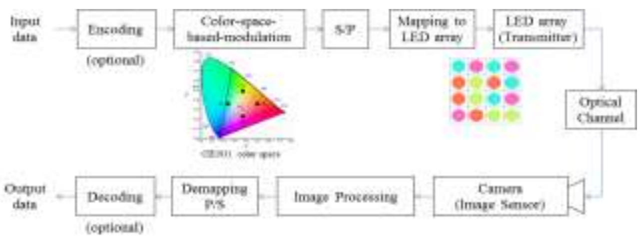

Figure 1:. Color-independent visual-MIMO based on color space.

2. Sdvnsystem Incorporating Color-Independent Visual-Mimo Networking

Although the conventional SDVN system architectures are well designed and well suited for vehicular scenarios, the distributed protocol across multiple switches and the high mobility of the vehicle still threaten the stability of the SDVN system. In this study, we improve the hardware and software redundancy of the SDVN system by incorporating in it a color-independent visual-MIMO networking. The color-independent visual-MIMO networking uses the light-emitting array (LEA) as a transmitter and the camera as a receiver for inter-switch communication. Some of the vehicles currently in the market are equipped with a front camera and rear LED lamps, which may gradually become essential for all types of vehicles. Therefore, vehicles considered as switches of SDVN can utilize color-independent visual-MIMO networking method in addition to existing vehicular networking method at the same time.

Figure 2 shows the difference between a multi-hop routing scheme [2] using an existing heterogeneous wireless interface and a scheme when the color-independent visual-MIMO networking is newly added. If the visual-MIMO networking scheme is used between the switches which can secure the LOS, the multi-hop routing scheme under various routes becomes possible, and as a result, the SDVN traffic burden can be alleviated by not directly passing through the control plane.

Since the color-independent visual-MIMO networking approach handles images received from the camera [4], it can be managed more intuitively than other networking methods, simplifying the flow of SDVN which is integrating the complex heterogeneous networks. In recent years, interest in autonomous vehicles has increased, and a number of image-based object recognition and tracking algorithms have been developed [4]. In this study, we define the color-independent visual-MIMO networking switch as the control point to express it as a lower concept of the SDVN control plane. Thus, multiple switches in the data plane can contain control points that act as separate controllers regardless of the control plane, and a set of control points can assist the SDVN control plane. In this paper, we introduce the concept of a new plane, called "sub-control plane" as a set of control points. Figure 3 shows the proposed SDVN system architecture with a newly added sub-control plane.

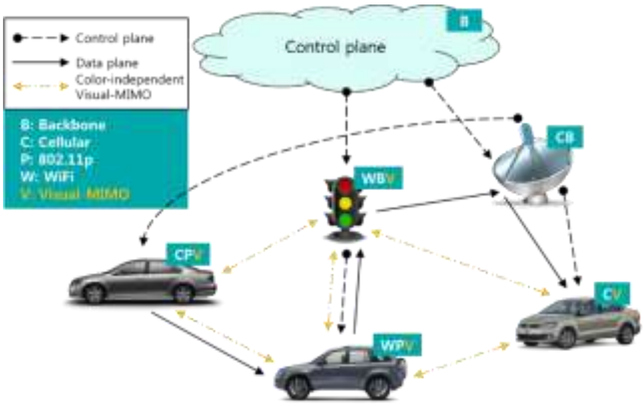

Figure 2:. Multi-hop routing using heterogeneous wireless interfaces with color-independent visual-MIMO networking.

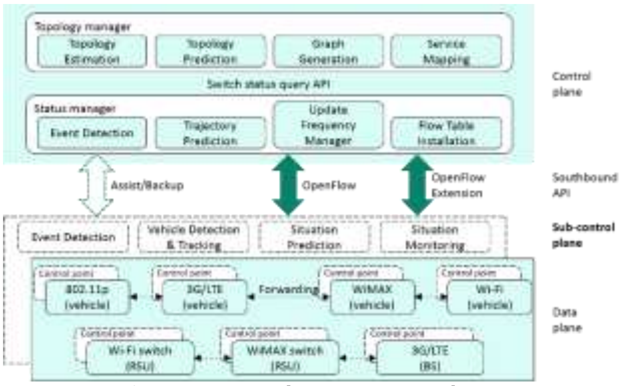

Figure 3:. Proposed SDVN system architecture.

3. Conclusion

In this study, we proposed the concept of a sub-control plane to support and serve as a backup, at the data plane level, for the functions of the control plane, which plays a key role in SDVN. The sub-control plane consists of color-independent visual-MIMO networking switches. In general, the image processing technique used in visual-MIMO enables intuitive understanding of network flow and application of various existing vehicle-based recognition and tracking algorithms. This allows the role of the control plane to be faithfully backed up under an unexpected situation of disconnection between the data plane and the control plane. The proposed sub-control plane is expected to facilitate efficient management of SDVN and improve the performance and service quality of vehicular communication.

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