

Innovations in the domain of wireless communication technology have supported the massive growth of interconnected personal devices and intertwined sensory equipment owned by different agencies. However, the everlasting emergence of connected devices has increased the demand on the research community to develop a wireless communication enabler to support continuous and reliable data flow between the connected devices. Many are thinking that the fifth-generation wireless communication network or 5G will be the enabler to connect and support numerous connected devices under the broad umbrella of the internet-of-things or IoT (1). IoT refers to the networked integration of highly distributed day-to-day devices via embedded systems (2). 5G wireless communication once deployed has the potential to provide better communication reliability to the IoT interconnected devices compared to the existing fourth-generation wireless communication (4G). In transportation, connected autonomous vehicles (CAVs) are one of the major components of IoT, and numerous safety, mobility and environmental benefits can be derived from CAV applications. In this paper, we have studied how CAVs can leverage the 5G wireless communication. As identified in previous literature, the advantages of 5G over 4G are: increased spectrum allocation, availability of directional beamforming antennas used at both 5G enabled base stations and mobile entities, increased capacity to aggregate numerous simultaneous users within the coverage area, highly increased bit rates within increased proportions of the 5G coverage areas, and lower cost of infrastructure (3).

For 5G to increase communication network reliability, throughput, and connectivity in the IoT environment, researchers are showing more interest than before on spectrums higher than 6 GHz. The under 6 GHz spectrum is already divided into different Long Term Evolution (LTE) spectrums. The unused spectrums above 6 GHz are the potential areas that can provide higher throughput for the increasing number of CAVs in the future, especially in dense urban areas. The term 'mm-wave' in '5G mm-wave' simply refers to the wavelengths within the range of one to ten millimeters (4). Compared to recent 4G, the carrier frequency of 5G mm-wave allows for the broadcast of highly increased data rates while reducing the communication latency. Due to this inherent capacity offered by 5G mm-wave for both backhaul links (within multiple base stations) and access links (within the base station and end users), it can support the CAV environment where multiple data-intensive safety, mobility, and in-vehicle infotainment applications can run in numerous CAVs in highly congested areas. The CAVs can be equipped with in-vehicle devices with dynamic beamforming-enabled multi-element antennas to connect with the mm-wave base stations. The coverage area of the mm-wave network is limited compared to LTE. To overcome this limited mm-wave coverage area issue, the base stations should be closely spaced. Wireless network operators are continuously reducing the cell coverage areas to enhance relaying, implement cooperative multiple-input-multiple-output with multiple antennas at the receiver and sender, and reduce interference (3). As a result, the number of base stations will increase in the future mm-wave based deployments, which will be applicable to the future CAV environment where an unprecedented number of CAVs will demand multi-gigabit/second to support CAV applications and to stream real-time in-vehicle infotainment components. The applications of mm-wave communication have been studied earlier. For the mobile communication system, Dehos et al. (2014) have identified mm-wave as the primary technology for next-generation communication (5). Mastrosimone and Panno (2015) have studied the performance of hybrid mm-wave and LTE access links and compared the hybrid system against pure LTE-based access links, and they have found an increased throughput of 33% using the hybrid mm-wave and LTE access links compared to the only LTE scenario (6).

Recent pilot deployment sites in the US to evaluate connected transportation applications are mostly equipped with Dedicated Short-range Communication (DSRC)-based devices, and in a few cases, a large area is wirelessly connected with combined DSRC and 4G LTE to support the safety and mobility applications. However, cellular network service providers are pursuing the plan to deploy a 5G network commercially. A comparative investigation between 5G mm-wave and DSRC for different CAV applications is missing. The International Telecommunication Union Radiocommunication Sector has planned to finalize all specifications of 5G by 2020 (7), based on pilot real-world tests conducted in various countries. Before conducting the real-world tests, studies conducted in a simulation environment can provide extensive understandings of 5G-mmwave benefits for different CAV applications in multiple scenarios, such as congested/uncongested and low/high penetration of CAVs. Several studies have investigated the 5G mm-wave network for vehicular communication. However, the feasibility of the 5G network has not been thoroughly studied for the environment that considers CAV application requirements. The research objective of this paper is to investigate the potential benefits of a 5G mm-wave network for CAV applications. Using the evaluation framework developed in this paper, public agencies can evaluate the use of 5G mm-wave to support CAVs in congested areas