



# COMMUNICATION NETWORKS FOR AUTONOMOUS VEHICLES TO OPERATE EFFECTIVELY: AN IN-DEPTH STUDY

**Sanath D Javagal**

Master of Science, Computer Engineering, Western Michigan University,  
Senior Network Systems Engineer, Autonomous Technology Industry,  
San Francisco, California, USA

## ABSTRACT

*This article explores the communication protocol networks essential for Autonomous Vehicles (AVs), including cellular networks, satellite networks, and Dedicated Short-Range Communication (DSRC). These networks are crucial in facilitating effective communication between AVs and surrounding infrastructures. The article examines each network type's features, benefits, limitations, and performance requirements, focusing on latency, throughput, and reliability. With their comprehensive coverage, low latency, and high throughput, cellular networks are ideal for non-safetycritical vehicle communications but face challenges in high-speed and high-density scenarios. Satellite networks offer global coverage, particularly benefiting areas where terrestrial networks are unavailable or unreliable, though they typically suffer from high latency and lower throughput. DSRC, designed explicitly for automotive use, enables low latency and high-reliability communication over short to medium ranges. The article concludes by suggesting that a hybrid approach, leveraging the strengths of each network type, might be the future of AV communication systems. Technological advances such as 5G, Low Earth Orbit (LEO) satellites, and DSRC will continually refine these communication capabilities.*

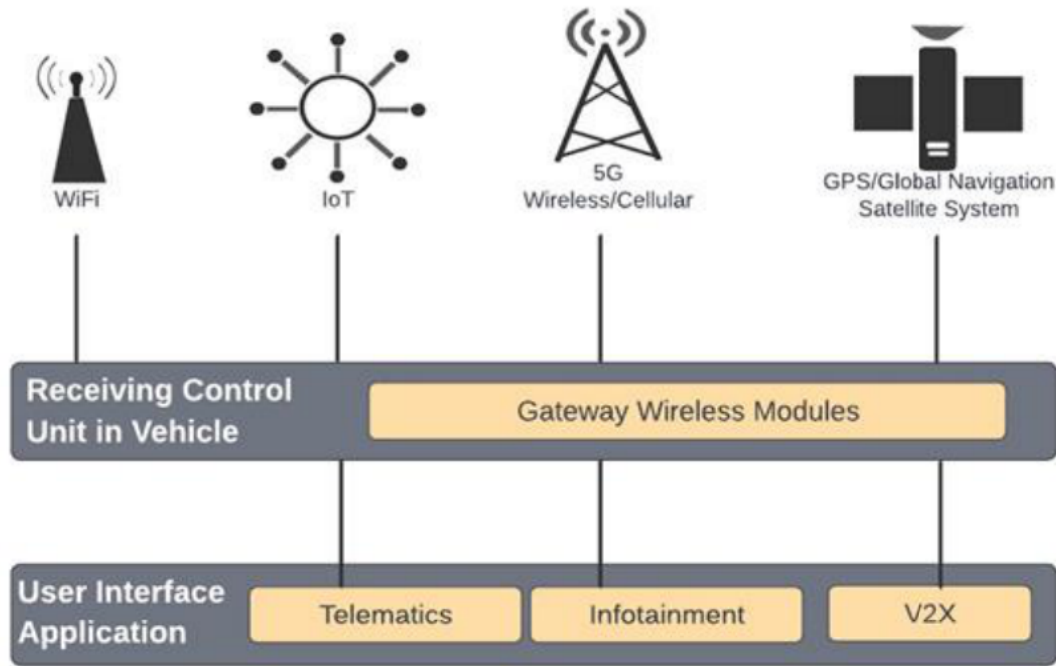
**Keywords:** Autonomous Vehicles (AVs), Communication Protocol Networks, Cellular Networks, 4G and 5G Networks, Latency, Throughput, Reliability, Network Congestion, Safety-Critical Communications, Satellite Networks.

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## 1. INTRODUCTION

The modern era of autonomous vehicles (AVs) or Self-Driving vehicles promises to revolutionize how we approach mobility. However, realizing these self-driving vehicles' true potential depends significantly on their ability to communicate effectively with the surrounding infrastructure and other vehicles. To facilitate AVs, various communication protocol networks are in play. They include cellular networks, satellite networks, and Dedicated Short-Range Communication (DSRC). This article aims to explore these networks in detail, examining their features, benefits, limitations, and requirements.



## 2. CELLULAR NETWORKS FOR AUTONOMOUS VEHICLES

Cellular networks primarily refer to mobile telephony networks such as 4G and 5G for communication. These networks have a widespread infrastructure and can provide services over large geographical areas.

These networks' latency, throughput, and reliability make them ideal for non-safetycritical vehicle communications. However, they need help with high-velocity mobility and high-density use cases.

### 2.1. Latency and Throughput Requirements

A fast network is crucial for AVs due to the time-sensitive nature of their information. The 5G network, with latency as low as one millisecond (ms), fulfills this requirement effectively. On the other hand, the throughput, defined as the rate of successful data transfer, should be high to handle the vast amount of data generated by AVs. A 5G network can provide a throughput of up to 20 Gbps, sufficient for AV communication.

- “Latency (L) = Propagation Delay + Transmission Delay + Processing Delay + Queueing Delay”
- “Throughput (T) = Total Data Transferred (in bits) / Total Time Taken (in seconds).”

## 2.2. Reliability Requirement

The reliability of a network can be defined as its ability to provide continuous and uninterrupted service. For AV communication, reliability is essential, as any interruption can lead to catastrophic results. Typically, it is expressed as a percentage, where 100% reliability indicates no service interruptions.

- Reliability (R) = (Total operating time - Total downtime) / Total operating time \* 100%

## 2.3. Limitations and Solutions

Despite the significant advantages, cellular networks do have limitations. Handover management between network cells becomes a significant challenge as vehicles move at high speeds. Moreover, in high-density scenarios such as urban traffic, the network might get congested, affecting its performance. Solutions like edge computing and network slicing in 5G can mitigate these limitations.

# 3. SATELLITE NETWORKS FOR AUTONOMOUS VEHICLES

Satellite networks provide global coverage that is not dependent on terrestrial infrastructure. They can be beneficial for providing connectivity in areas where traditional networks, such as rural or remote areas, may be unavailable or unreliable.

## 3.1. Latency and Throughput Requirements

Unlike cellular networks, satellite networks have higher latencies due to the large distances signals must travel. This latency typically ranges from 600ms to 1200ms. The throughput of satellite networks is also comparatively lower than cellular networks, usually between 50Mbps to 100 Mbps.

However, new technologies like LEO (Low Earth Orbit) satellites promise to reduce the latency to less than 50ms and increase the throughput up to 1 Gbps.

## 3.2. Reliability Requirement

Satellite networks' reliability can be higher than terrestrial networks, especially in remote areas. However, it can be affected by factors like weather conditions and line-of-sight issues. The reliability of satellite networks is enhanced through redundancy, achieved by having multiple satellites in the same orbital slot.

## 3.3. Limitations and Solutions

Satellite networks are unsuitable for AVs due to significant latency and lower throughput. Furthermore, the cost of data transmission over satellite networks is relatively high. However, as LEO satellite technology evolves, these limitations might be overcome.

## **4. DEDICATED SHORT-RANGE COMMUNICATIONS (DSRC) FOR AUTONOMOUS VEHICLES**

DSRC is a wireless communication technology specifically designed for automotive use. It operates in the 5.9 GHz band and is designed for short to medium-range communications.

### **4.1. Latency and Throughput Requirements**

DSRC is designed to support low latency, around 2ms, making it suitable for safety-critical communications. Depending on the modulation and coding scheme, its throughput ranges from 3 to 27 Mbps.

### **4.2. Reliability Requirement**

As DSRC is designed explicitly for vehicle communications, it has high reliability. It is resilient to interference and can operate effectively in high-density scenarios.

### **4.3. Limitations and Solutions**

DSRC's primary limitation is its range, which is approximately 1000 meters. This limits its utility for non-line-of-sight situations and over more considerable distances. Additionally, DSRC might face potential interference from other devices operating in the same frequency band.

## **5. CONCLUSION**

The choice of communication protocol for autonomous vehicles depends on various factors such as latency, throughput, reliability, and geographical coverage. Cellular networks are ideal for a range of applications due to their high throughput and low latency. Satellite networks can provide connectivity in remote areas, while DSRC is excellent for short-range, safety-critical communications.

The future of AV communication may involve a combination of these networks, leveraging the strengths of each to ensure reliable, robust, and efficient communication. The development of new technologies, such as 5G, LEO satellites, and improvements in DSRC, will continue to enhance the communication capabilities of autonomous vehicles.

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[editor@iaeme.com](mailto:editor@iaeme.com)