Management of Autonomous Vehicle Communications over Heterogeneous Wireless Networks

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***Abstract* - The new generation of autonomous vehicles (AVs) is expected to support vehicle communication over heterogeneous wireless networks; however, vehicle-to-vehicle communication over such networks involves delays that can cause an increase in road traffic congestion. Therefore, it is important that these networks provide quality of service (QoS)-guarantees. QoS-availability varies from network to network. Also, QoS may vary over time on the same system, due to the need for each vehicle to share resources with a varying number of other vehicles. These fluctuations in QoS increase road traffic congestion due to interruptions in the communication between AVs. To overcome these fluctuations, a goal oriented agent that operates autonomously is proposed, Its autonomy increases the agent's flexibility in dealing with non-regular wireless networks and new situations involving traffic loads and decreases the information load on the network. This strengthens the robustness of the network as a whole, distributes information, and allows for negotiation when conflicts occur. Furthermore, the goal oriented agent plays a major role in the ability of the next generation of AVs to overcome the heterogeneity of wireless networks and differences between the attributes of current generation operating systems and NextG.**

Keywords - goal oriented agent, autonomous vehicle, QoS-negotiation, lane changing, data anomalies

I. INTRODUCTION

Growing road usage is strongly linked to increasing environmental problems at both local and global levels. Aside from high levels of energy consumption, the most important environmental impacts are related to climate change, air quality and noise. It is generally admitted that pollutant emissions are dependent on speed levels, and evidence shows that the highest rates of emission occur in congested, slow moving traffic. Emission rates are much higher under all conditions when numerous re-accelerations (stop-and-go conditions), are involved, more so than, when vehicles are moving more smoothly. Mobile wireless communication[10][11][25] has become a major means of AV communication.[1] With next generation mobile communication systems, it is envisioned that AVs will be able to access heterogeneous networks for various services via a set of heterogeneous IoT devices. To reduce road congestion and road accidents, there are three kinds of communication that AVs can use [8]. Also AVs communication over heterogeneous wireless networks is needed to support quality of service (QoS) requirements. However, AVs communication over heterogeneous wireless networks is faced with several challenges; must support hybrid communications, meeting QoS requirements and provide for the self-regulation of resource. In general, the goal of this research is to reduce road congestion by avoiding interruptions in AV communications.

Several studies [21][22], show that heterogeneous wireless networks feature different QoS characteristics (e.g., different bit rate, delay times, and bandwidths), and that session mobility has different attributes. However, the situation is made more complex by the fact that the QoS available varies from network to network, and it may also vary over time on the same system, due to the need for vehicles to share resources with changing numbers of other vehicles [15]. Today, there promises to be a proliferation of autonomous vehicles that we will expect to be able to use all the time and without limitation. To make these vehicles useable around the clock, however, we need greater resources, such as more bandwidth and better performance, which will enable them to communicate directly with one another. To manage these differences among wireless networks and assist AVs, this study suggests the use of middleware.

The core contribution of this research is the development of resource-efficient, accurate, and interpretable algorithms for federated- and transferable learning that can be applied by AVs to optimize communication performance.

To ensure reliable AV communication over heterogeneous wireless networks[3][5], certain QoS requirements must be met. Wireless networks have different QoS attributes. And these differences cause anomalies in road traffic data[6]. The problem addressed here is how to optimize AV communication by minimizing the signal-to- interference-plus-noise ratio (SINR). Optimally is achieved when the QoS requirements of all AVs are satisfied, while the data transmission is remains uninfluenced[7]. The quality of each active AV is determined by the SINR at the receiver. We assume that each link has a minimum SINR requirement $\gamma i > 0$, which represents the QoS requirement of the cognitive user, Ui. The novelty of this system model lies in the AVs assigned priority resources, which enable it to cross an intersection without traffic lights or stop signs[17] and in priority based cognitive data analysis that guarantees QoS and effective hybrid communication. This paper, introduces a system model based on goal- oriented agent technology that supports AV hybrid communication and guarantees QoS [14][16]. Our contribution consists of a carry out data analysis to detect data anomalies in data that cause interruptions in AV communication. The remainder of this paper is organized as follows: Section 2 presents the system model. Section 3 presents the implementation of goal-oriented agent. Section 4 concludes the report and outlines paths for future work.

II. AUTONOMOUS VEHICLE COMMUNICATION

AV communications are performed over heterogeneous wireless networks based on QoS-parameters, in order to accomplish useful tasks (see Figure 1). The agents in a system should be able to understand each other, and they should use the same message transport protocol. Messaging is a data oriented communication mechanism, generally used to transfer data between processes. It is either asynchronous or synchronous. Autonomous Vehicle Communication:

- Vehicle to vehicle (V2V) communication systems[2][9][26], enable safe transport, for example, they mediate safe distance keeping, collision avoidance, and early warnings about unsafe conditions[13].
- Vehicle-to-Infrastructure (V2I): vehicle to infrastructure (V2I) communication systems (and vice versa)[3][12], enable better use of existing infrastructure and provide valuable and consolidated information to intelligent vehicles for example, fresh information regarding travel times, ongoing roadwork, and weather and traffic conditions, and up-to-date information about parking availability and other means of transport.

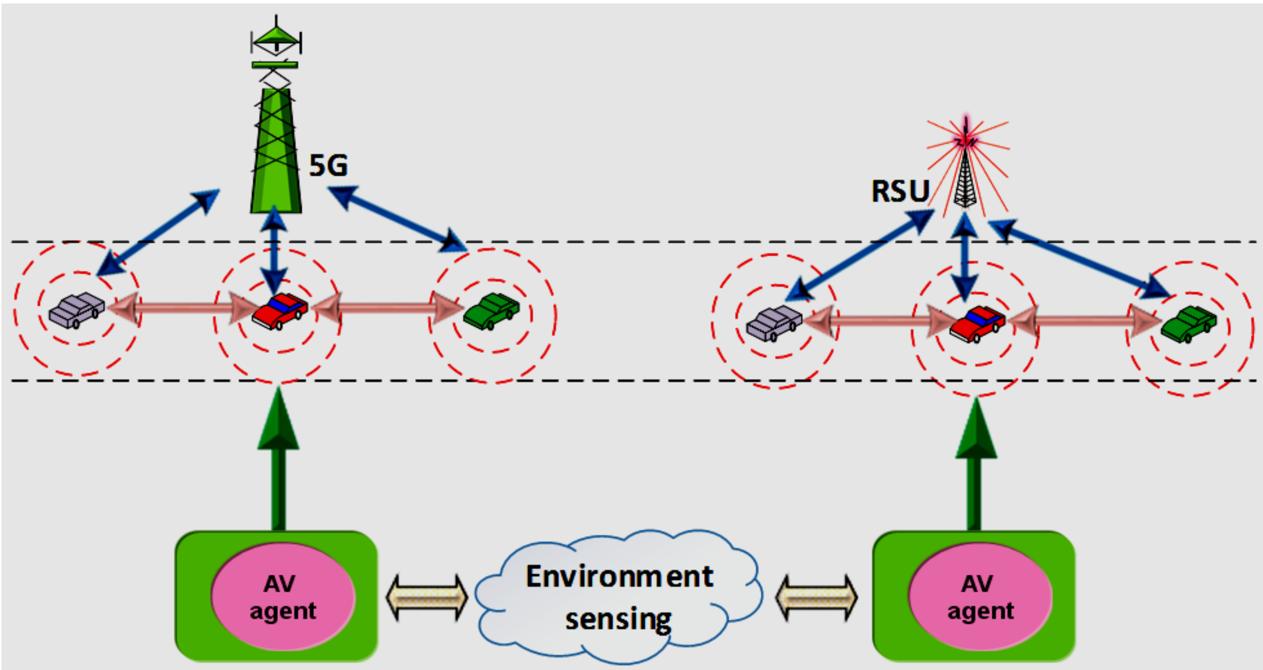

Figure 1. Heterogeneous networks

III. SYSTEM MODEL

The goal- oriented agent in this model aims to detect anomalies in traffic data that are influenced by noise. Anomalies data caused communication between AVs [18][19]. Cognitive data is data subjected to a cleaning phase and a visual processing phase, based on an artificial intelligence methodology that enable it to adapt autonomously to achieve its goals. The data are collected by numerous sensors which are installed on AV to sense road traffic. Mitola [23] introduced a concept in wireless telecommunication based on the concept of a cognitive radio (CR), in order to guarantee QoS. A CR is based mainly on soft defined radio (SDR). The CR can detect a signal at a very low signal-to-noise ratio (SNR or S/R) because AVs are allowed to communicate with primary signals under very low SNR conditions [20]. Figure 2 shows the phases of operation for the goal-oriented agent that taken by agent goal oriented.

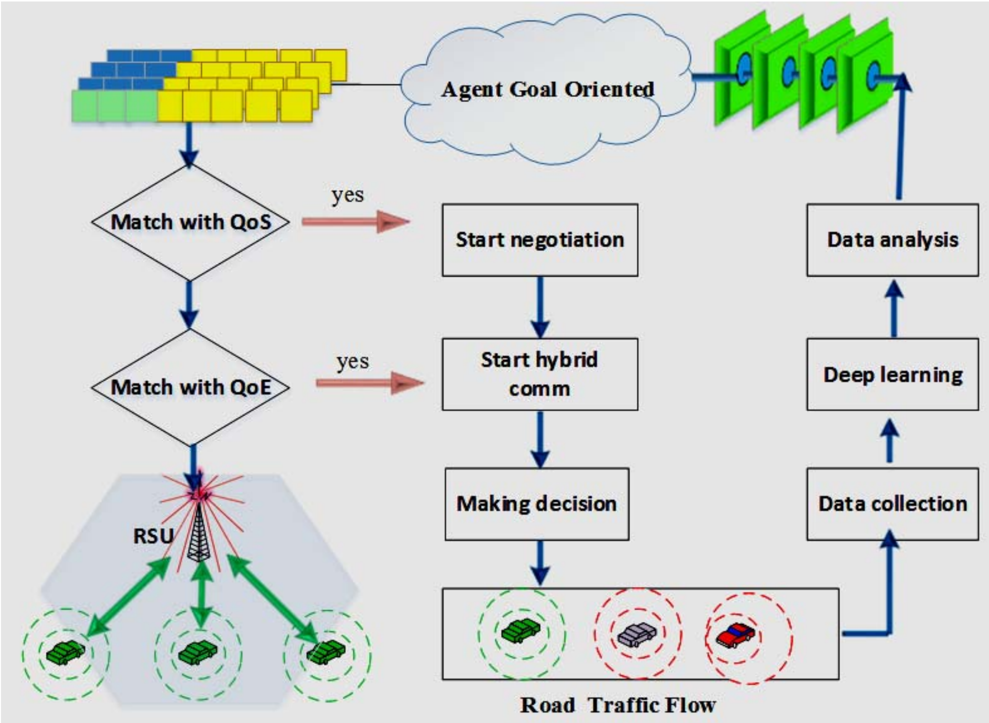

Figure 2. System model

A. The goal-oriented agent's decision process

In this phase, the agent establishes a communication request. If the request is granted, the agent on QoS requirements (e.g. signal power, signal-to-noise ratios and delay)[17]. The agent estimates the SNR and then determines whether or not to communicate. Furthermore the agent collects information about adjacent cells, and based on this determines the next AV communication.

- The propagation of radio signals on both uplinks and downlinks is affected by the physical channel in several ways.
- A signal propagating through a wireless channel usually arrives at its destination along a number of different paths, referred to as multi-paths. These paths arise from the scattering, reflection, refraction or diffraction of the radiated energy due to objects in the environment.
- The received signal is much weaker than the transmitted signal due to phenomena such as mean propagation loss, and slow and fast fading.
- Multipath propagation results in the spreading of the signal in different. Mean propagation loss comes from square-law spreading, absorption by water and foliage and the effects of ground reflection. It is range dependent and changes very slowly even for fast mobiles. Slow fading results from blockage by buildings and natural features and is also known as long-term fading, or shadowing. Fast fading results from multi-path scattering in the vicinity of a mobile. It is also known as short-term fading or Rayleigh fading, for reasons explained below.

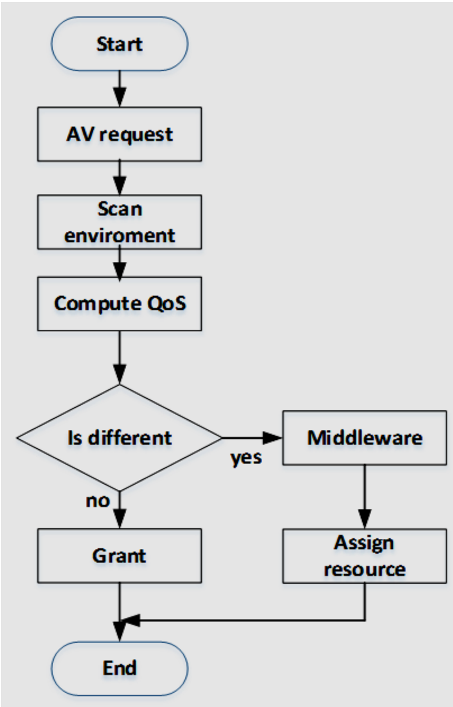

Figure 3. Establishment of AV communication

A new request by an AV is blocked when the QoS requested cannot be provided, that is, if the SIR is under a given threshold SIRtgt. The goal oriented agent considers, which are as follows:

i. Probability (Approve, SNR > SNRtgt)
ii. Probability(Reject, SNR < SNRtgt)
iii. Probability(Approve, SNR < SNRtgt)
iv. Probability(Reject, SNR > SNRtgt)

From the viewpoint of the goal oriented agent, there are two kinds of decisions: good and bad decision. A good decision is made, when the goal oriented agent can establish communication without interfering with neighboring AVs. A bad decision results when the use of a viable resource causes interference with other used resource.

IV. CASE STUDY AND RESULTS

On urban roads, anomalies cause discomfort to drivers, and the efficiency of traffic movement is affected negatively. When traffic accidents and traffic congestion occur, traffic flow is abnormal. In AV networks, anomalies [27] are caused by traffic accidents, bad weather, road work, and lane changing. A road traffic anomaly denotes a road section that is anomalous in terms of its traffic flow. For each road section, the calculation of the degree to which it is anomalous is based on measurement of statistical error. The model acts as a releasing node that functions as an early warning system for abnormal events in road traffic.

In general, the lane- changing process contributes to an increase in traffic flow efficiency. However, in some cases when the lane changing process is interrupted, it increases congestion. To manage the lane- changing process, an AV that would like to communicate with other vehicles must be held to a minimal distance from them. This AV positioning is estimated based on GNSS data. Cooperation should take place within the coverage area. In V2X communication, the QoS parameters should be controlled, to avoid delays. The lane- changing process in platooning is based on message exchange as illustrated in Figure 4. Messages are transmitted through wireless networks that provide V2V, vehicle-to-Internet, and vehicle-to-road infrastructure connectivity. The term connected vehicles refers to vehicles with wireless connectivity that can communicate with their internal and external environments, i.e., that can support interactions between onboard sensors and the vehicle V2V, V2R, V2I, and V2X communication.

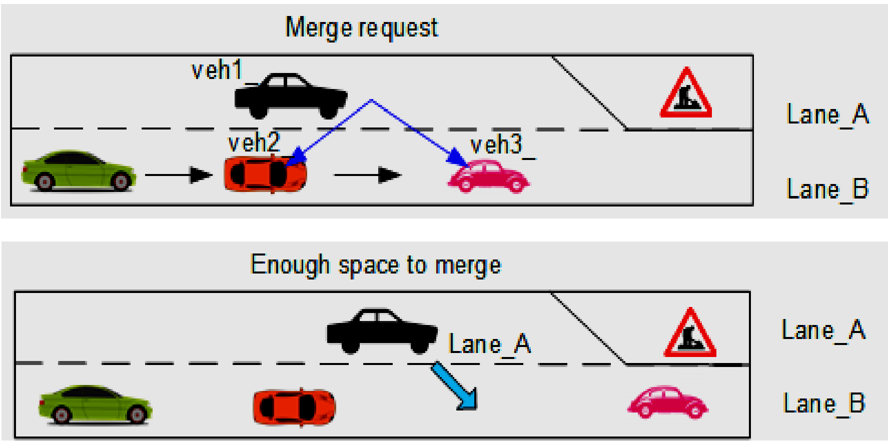

Figure 4. Lane changing process

The goal -oriented agent starts to compute the SNR, only when the AV arrives at the critical zone; it is not necessary to compute the SNR when an AV moves within the home zone. AV communication is generally established when the QoS is guaranteed. The required signal power density below the interference power density before dispreading, is designated as signal- to- interference- ratio (SIR), and it is also known as Ec/Io (In fact, Ec/Io and Ec/No are the same thing). Ec/No denotes the Energy per Chip (Ec) to noise spectral Density (No) ratio for one user. Based on the downlink power measurement reported by each node, a determination is made on whether the addition of a radio link is acceptable or not. A mobile station, during a call, de-modulates signals from three BTSs, The historical data were scored and ranked with the use of functions that were developed to detect lost data and data errors as illustrated in Figure 5. The road sections were scored according to the performance metrics of availability, accuracy, and integrity, which were characterized by the global performance of different devices. A decrease in the quality of the radio is expressed in terms of a decrease in of the total downlink throughput, as shown in Figure 6. Delays in the reception of messages by AVs result in road traffic congestion. A large number of delays in AV communication cause failures in lane changing, which in turn lead to road traffic anomalies.

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Consequently, the early detection of failed lane changing can reduce the number of anomalies (see Figure 7).

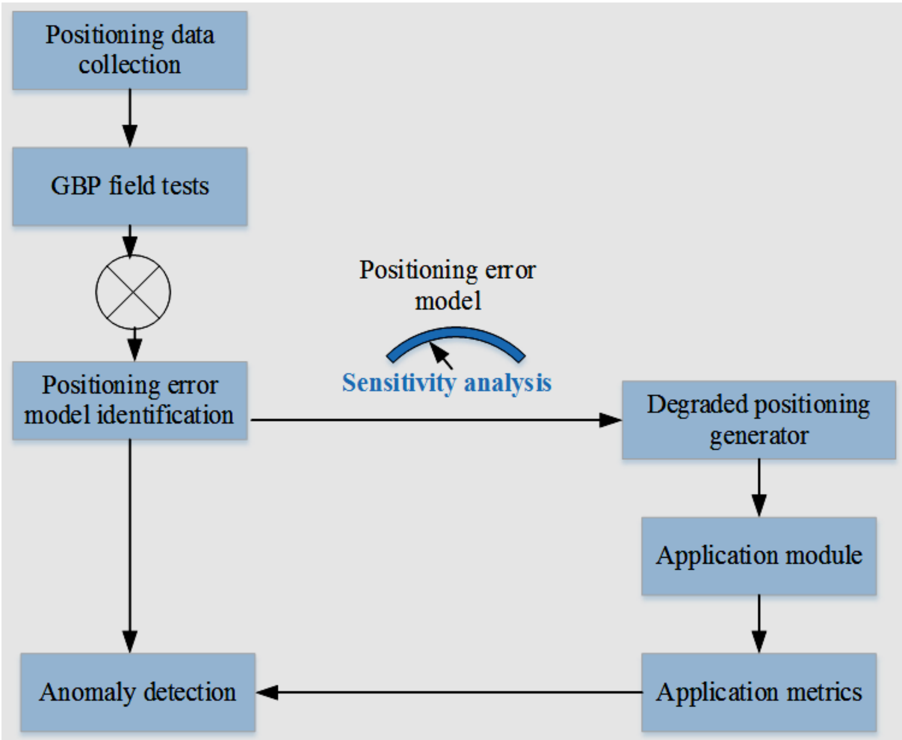

Figure 5. Positioning error identification

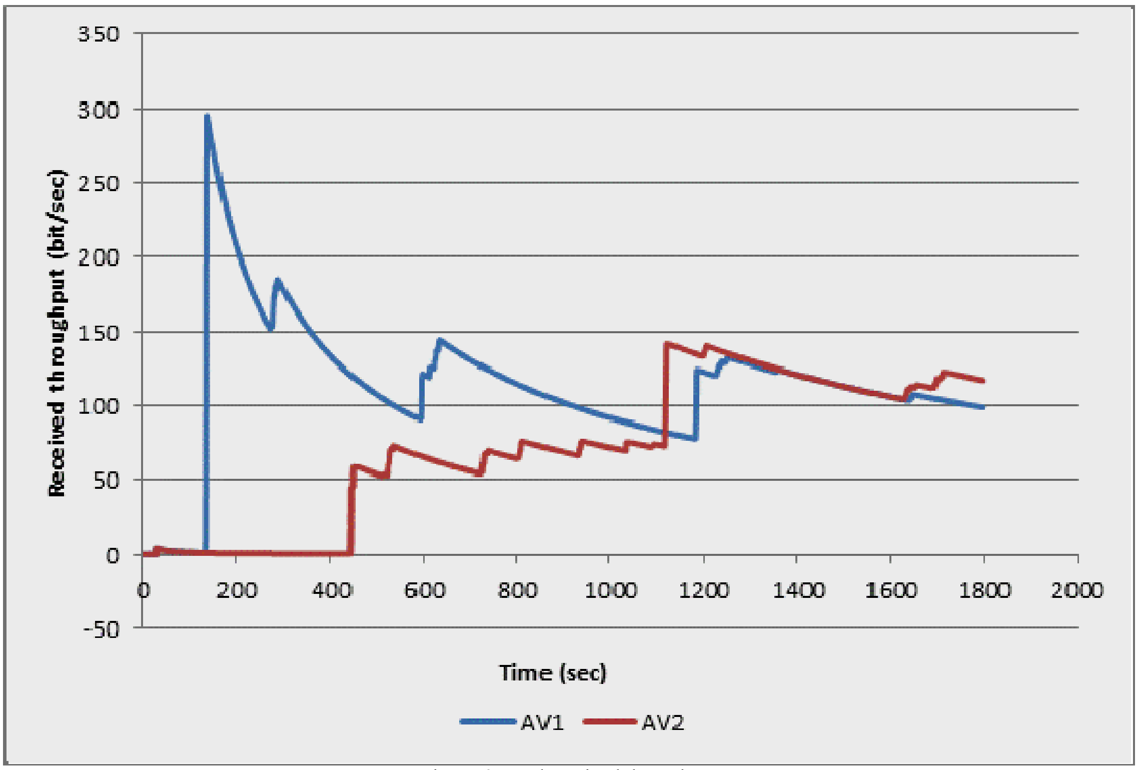

Figure 6. Total received throughput

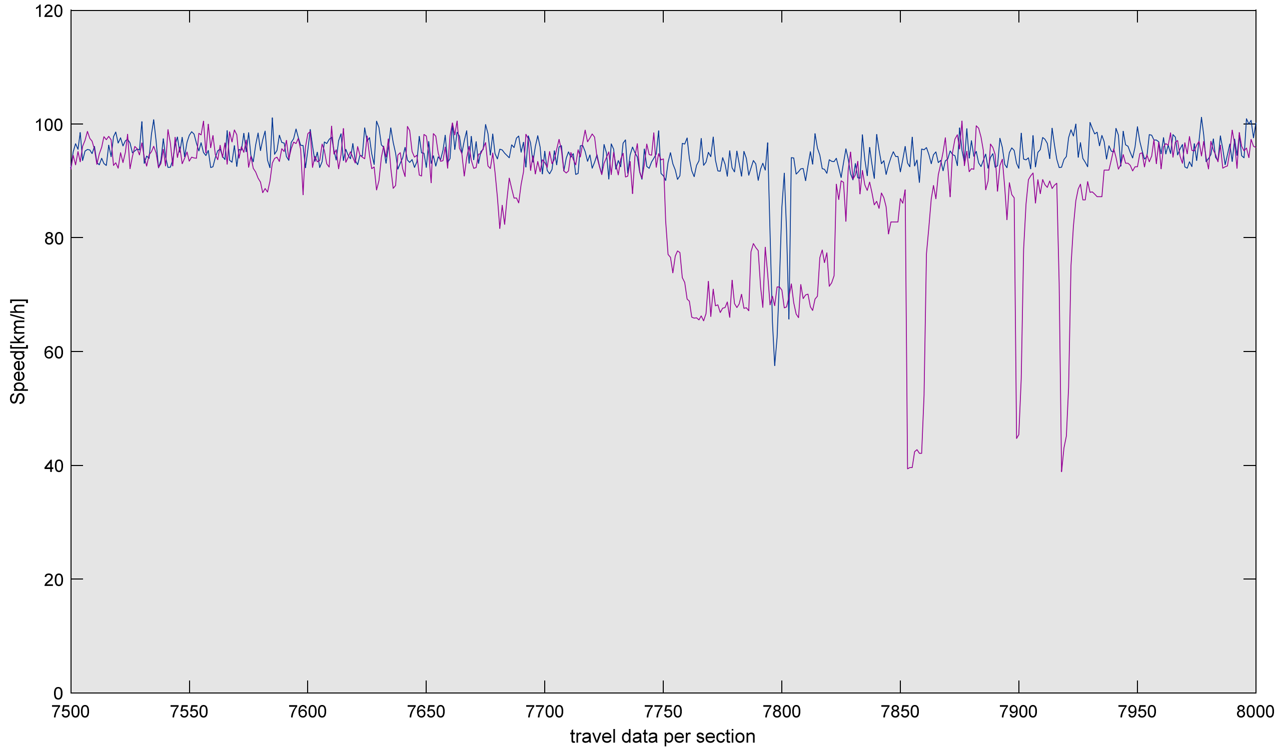

Figure 7. Detection of a failed lane change

V. CONCLUSION

AV functioning influenced by co-channel and adjacent interference, and by road reflection and multipath effects due to the environment. Furthermore, AVs can produce bad propagation conditions for long periods of time.

The effects of these forms of interference are only partially compensated for by global models in single frequency receivers. An AV uses vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-everything (V2X) communications to improve driving safety and traffic efficiency, and to provide information and entertainment to the driver. Its communication protocols are capable of driving without any human action. However, currently there are only theoretical ideas about how AVs with communication capabilities can improve traffic efficiency, and safety, and prevent problems such as traffic accidents, congestion, and CO2 emissions among others. One of the greatest challenges to cooperative communication systems in vehicles is fulfilling the QoS requirements for minimal delay. Increased delays in cooperative communication are the main cause of traffic congestion. This paper proposes and discusses the use of AV communication in dynamic and complex systems in accordance with environmental requirements. AVs need to establish communication among themselves to manage road traffic, and their communications must fulfil QoS requirements. To guarantee QoS for AV communication over heterogeneous wireless networks, a system based on goal oriented agent is proposed. The advantage of such a system is its effective performance using different data formats. The goal- oriented agent scans the environment and based on data collection, identifies critical zones. QoS requirements and helps to reduce road congestion.

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