Connected Truck Automation

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Abstract Commercial trucking is an industry ripe for connected and automated vehicles. The operations of the trucks combined with the highly analytical nature of the customers makes for the possibility of very rapid adoption. By combining partial automation with vehicle-to-vehicle and vehicle-to-cloud communication, these fleets can see massive fuels savings and safety improvements in the near term.

Keywords Platooning · Commercial trucking · Freight

1 Commercial Trucking: An Ideal Application of Connected and Automated Vehicles

Commercial trucking in the US and internationally is a huge industry that moves the vast majority of freight [1]. The vehicles are very flexible in their architecture because of the demands of the fleet customers, and these fleet vehicles are highly concentrated on major arteries (See Fig. 1). These factors together make trucking ideal for automation and connected vehicles.

1.1 Trucking

The trucking industry in the US alone is over $650 Billion [2]. Each truck in a long haul fleet may spend between 80 and $100 k per year on diesel fuel, with a large

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G. Meyer and S. Beiker (eds.), *Road Vehicle Automation 3*,
Lecture Notes in Mobility, DOI 10.1007/978-3-319-40503-2_15

Fig. 1 Freight trucking concentration on major arteries [4]

fleet spending hundreds of millions of dollars a year or more on fuel [2].[1] Fuel is typically close to 40 % of the operating expense of a fleet, and the number one expense (American Transportation Research Institute 2015). These fleets, as many large established industries do, operate on very thin margins, typically 2–3 % net margins [3]. This means that savings on fuel can make a massive difference to their bottom line.

1.2 Flexible Vehicles

Heavy trucks are built upon a much more open and modular architecture compared to cars. Whereas a typical car will have a 3–5 year design cycle for each significant change, a truck platform will typically be around 10 years. Modifications requested by a fleet will be brought in in between these cycles. Fleets demand semi-custom trucks, with a typical order including not only the engine, the transmission, the brake supplier, but even features such as the wheelbase of the truck. To accommodate both the rapid design cycle, and this "mass-customization", the trucking industry has adopted features such as a standard for messaging: J1939. These allow the customization requested by fleets, and include messages needed for truck

[1]Calculated based on data from [2]. Average fuel cost per mile for truck-tractor was $0.64 in 2013; long haul tractors can drive 125–150 k miles per year and large fleets typically have over 10,000 tractors.

systems to interact, including engine operating parameters, chassis parameters such as wheel speed and steering angle, as well as supporting commands for engine torque and braking.

All together these messaging standards and the mass customization mean that new features can be introduced much more easily, and rapidly, on trucks compared to passenger vehicles.

1.3 Operations Well Suited to Platooning

Fleets are profit-driven operations, and as such the most successful are also highly organized. This has created several characteristics that are well suited to platooning and automation.

First, fleets do an excellent job of concentrating their operations on the roads that are most efficient for them. These are generally interstates and major US Highways. Figure 1 shows a map from the Federal Highway Administration, where the thickness of the line indicates the number of freight trucks per day.

This shows that trucks are very highly concentrated on this small number of routes and relatively small number of miles of highway. This is excellent for automation and platooning because it means that the roads that have to be considered when designing such a system can be constrained to this small number. It also means that trucks with cooperative/connected equipment will be near each other on the highway much more often than one might think when considering the millions of miles of road total in the US.

Many fleets also tend to have multiple trucks running together at the same time one each route. Many fleets have a high concentration of trucks on dedicated or line haul routes. For some fleets this is due to a planned hub-to-hub operation, while for others it is due to hub-and-spoke operation such as from a distribution center to stores. Other fleets have operations where the truck dispatch timing and routes are variable on a daily basis, due for example to customer requests. Some of these fleets still have many trucks running together due to a high regional concentration.

2 The Power of Connected Trucks

For the trucking industry there is great potential for connecting trucks to each other and to the cloud. Connecting them together overcomes some of the limitations of trucks, and connecting them to the cloud allows these systems to be constrained to certain operating conditions, which provides safety improvements and allows much more rapid deployment of the systems (Fig. 2).

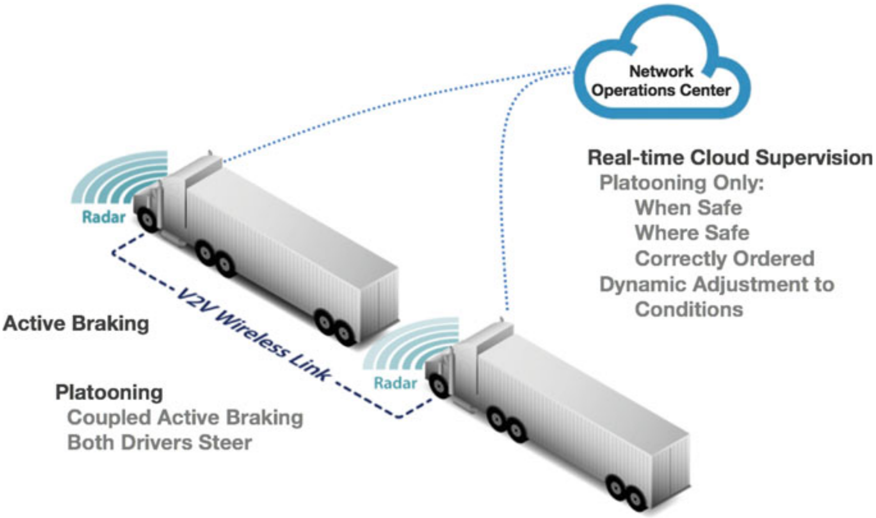

Fig. 2 Connecting trucks

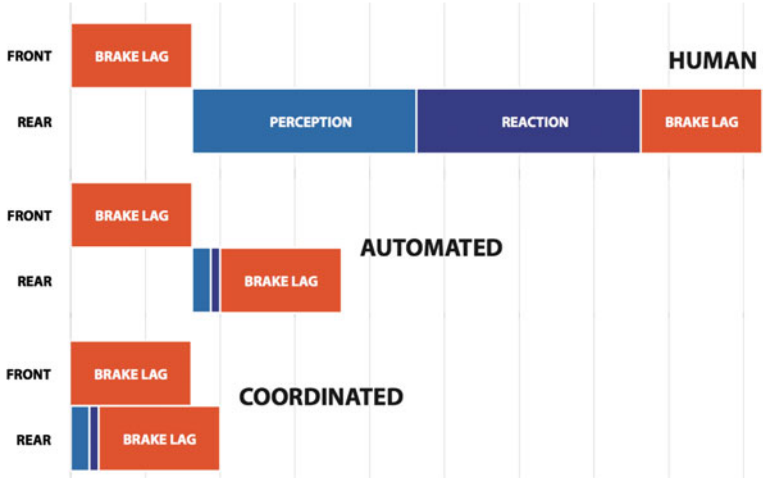

Fig. 3 Connected braking compared to manual and automated braking

2.1 Connected Braking

Connecting trucks to each other, through vehicle to vehicle communications, allows a direct method to overcome some of the limitations of heavy trucks. The biggest way is through connected braking.

Figure 3 shows three scenarios for a braking event between two trucks: Manual braking, automated braking, and connected braking. In each case the various time delays are represented by a bar graph, where each time delay corresponds to a distance at a given speed.

In the manual, or "Human" braking, a front truck applies the brakes, and after a brake lag the front truck starts to slow down. The driver of the rear truck can then perceive this slowing, and can then react to it. Finally the rear truck starts to slow after its brake lag.

This long, serial, process is the primary reason why truck drivers are instructed to follow at very long following distances: They are fundamentally limited in how well they can react the truck in front of them, due to both the characteristics of the truck brakes and their own human limitations.

By adding automation, such as a radar or lidar sensor, the human perception and reaction time/distance can be dramatically shortened, because the sensor is able to detect the slowing of the front truck before a human could perceive it, and because a computer can react much more quickly than a human can.

However this is still a serial process, where the perception and reaction can only occur once the brake lag of the front truck has elapsed. Only by coordinated/connected braking can this be eliminated. In this case the signal of braking is sent directly from the front truck to the rear truck upon *initiation* of braking. So even before the front truck has started to slow, the brakes can be applied in the rear truck.

This means that connected braking can provide a more immediate reaction than even the best automated system, because it overcomes one of the fundamental limitations of truck brake systems.

2.2 Cloud Connection

The second critical type of connection for truck automation/platooning is to connect the trucks to central cloud service. This is shown in Fig. 4.

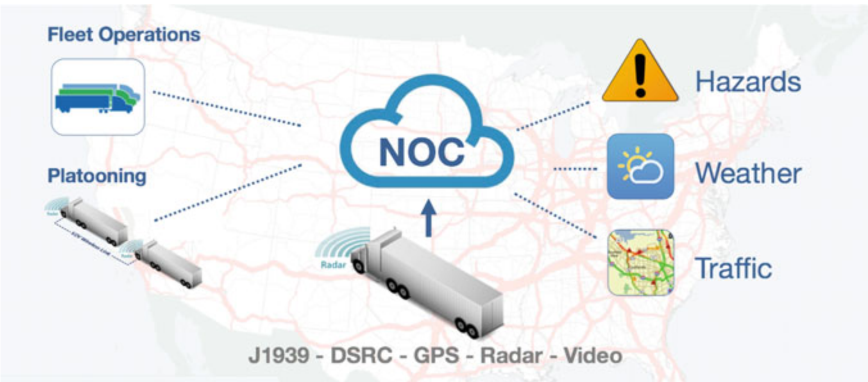

Fig. 4 Cloud connectivity to enhance platooning

The basic concept is to provide intelligence to the vehicle that would either be very difficult to determine from local information, or simply would be impossible to determine from local information.

For platooning and automation this means that we can restrict operations to only where it is safe or effective, when it is safe or effective, and how it is safe or effective. So we can restrict it to major interstates and US highways for example. We can adjust operating parameters such as following distance in platooning, or other parameters, in real-time. We can adjust these parameters based on information that trucks cannot possibly have from local sensors, such as upcoming traffic or weather information.

These types of operating restrictions mean that the development of these systems can be dramatically simplified. Rather than considering every possible type of road as one on which the system might be operated, it can be designed for only *known* roads. This makes for a much simpler validation process, and thus the systems can be deployed sooner than they would otherwise.

3 Conclusions

The trucking industry is ideally suited to platooning and automation due to the characteristics of their operation. Connecting trucks can also overcome limitations of the trucks themselves, and lead to a simpler and faster validation process.

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