Overview of platooning systems

OVERVIEW OF PLATOONING SYSTEMS

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Abstract

This paper presents an overview of current projects that deal with vehicle platooning. The platooning concept can be defined as a collection of vehicles that travel together, actively coordinated in formation. Some expected advantages of platooning include increased fuel and traffic efficiency, safety and driver comfort. There are many variations of the details of the concept such as: the goals of platooning, how it is implemented, mix of vehicles, the requirements on infrastructure, what is automated (longitudinal and lateral control) and to what level. The following projects are presented: SARTRE – a European platooning project; PATH – a California traffic automation program that includes platooning; GCDC – a cooperative driving initiative, SCANIA platooning and; Energy ITS – a Japanese truck platooning project.

Keywords:

Platooning, Road-train, Cooperative traffic system, ITS, Highway automation, Vehicle to vehicle communication, ETSI ITS-G5, SARTRE, PATH, GCDC, Energy ITS

Introduction

This paper gives a brief overview of five current vehicle platooning projects. There also exist other relevant projects, such as the German truck platooning project KONVOI [6], but these have been omitted here due to space constraints. New ITS applications (Intelligent Transportation System) are enabled, for example, due to advances in communication technology between vehicles (V2V) and with the infrastructure (V2I). Communication enabled vehicles and infrastructure can form a cooperative system where the users exchange information and cooperate to improve characteristics such as safety, fuel economy, traffic efficiency and comfort. An example of ITS application is platooning which can be defined as a collection of vehicles that travel together, actively coordinated in formation. The details of a platooning concept vary among projects because there are different goals and motivations for doing platooning and also different technical solutions. Three examples of these variations are: 1) SARTRE, PATH and Energy ITS offer automation of both longitudinal and lateral control while GCDC and SCANIA automate only longitudinal control; 2) SARTRE and GCDC assume mixed platoons of both heavy and passenger vehicles. PATH, SCANIA and Energy ITS assumes homogenous platoons of a single vehicle type; 3) SARTRE and SCANIA assumes no change to infrastructure while PATH assumes dedicated lanes with embedded reference markers in the road surface, GCDC assumes high precision positioning and Energy ITS assumes lane markings. The paper describes four platooning projects and then gives a comparison according to different parameters.

SARTRE

SARTRE [1, 2] is a European Commission Co-Funded FP7 project that seeks to supports a change in transport utilization. The project vision is to develop and integrate solutions that allow vehicles to drive in platoons on public motorways without modification to the infrastructure, such as dedicated lanes. SARTRE defines a platoon (or road train) as a collection of vehicles led by a manually driven heavy lead vehicle. The vehicles behind (trucks and passenger cars) follow the lead vehicle automatically; both laterally and longitudinally. Vehicles may join or leave the platoon dynamically e.g. leave on arrival at the desired destination. SARTRE aims to explore technology for platooning on roads without changes to the infrastructure and that it is safe enough to allow mixing with other users of public roads. Expected advantages of platooning include a reduction in fuel consumption, increased safety, traffic efficiency, increased driver convenience and comfort.

V2V communication is a vital part of the system and is based on ITS-G5. V2V communication allows sharing of local vehicle signals such as speed and sensor data among vehicles in the platoon. The shared signals are used in the control algorithms of the platoon. The platoon forms a cooperative system where sensing, control algorithm and actuation are distributed throughout the platoon and data is communicated between vehicles. Automatic control over an individual following vehicle is partly external from the lead vehicle and partly internal from the systems and sensors in the following vehicle itself. The following vehicles automatically strive to maintain the specified gap to the vehicle in front and the path and trajectory as specified by the lead vehicle. The local systems in the following vehicle can also take over in emergency situations and during loss of communication. Another aim is to maintain the gap at a size which discourages interference from other vehicles, i.e. driving inside the platoon. The goal of longitudinal control, e.g. the speed of the following vehicles, is to make coordinated movements that are accurate and adequately safe. Two examples are keeping a set gap between vehicles and being able to perform an evasive manoeuvre such as emergency brake or lane change. Lateral control, such as steering, has a similar goal, solution and also faces similar challenges.

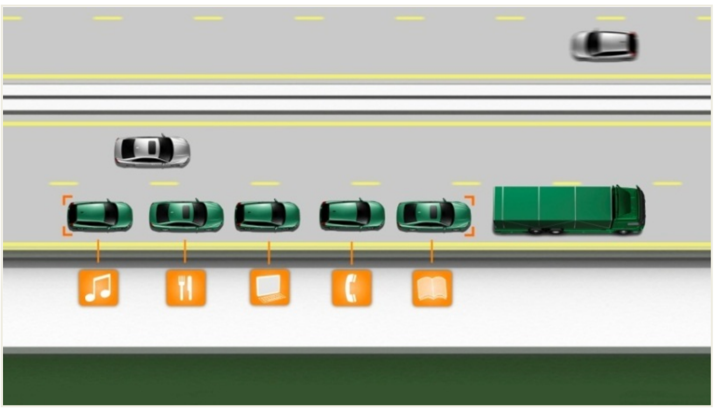

Figure 1 – A SARTRE platoon

The platooning application requires that V2V communication is used in addition to local sensors in each vehicle. Using V2V implies that data can be sent directly from the source rather being indirectly measured locally with sensors. Detecting platoon movements via only local sensors is prone to lag and to accumulate errors. This is because local sensor measurements are only based on the adjacent vehicle, i.e. there is no “look ahead” e.g. of intended movements. For example the lead vehicle can directly send requested acceleration as measured at the pedal rather than having a following vehicle measure the acceleration with its local sensors. With local vehicle sensors a change in acceleration has to “propagate” through the platoon from the lead vehicle to each of the following vehicles and be detected. This affects, for example, the minimum gap size that can be safely achieved. Without V2V it has to be larger gap to allow for the slower response. Using only local sensors can lead to lateral and longitudinal instability, increasing oscillations, and unsafe behaviour of the platoon. Figure 1 shows a SARTRE platoon. A platoon containing five vehicles was demonstrated on public roads near Barcelona, Spain in May of 2012. A description and measurements of the SARTRE V2V system are found in [6].

PATH

The PATH research on automated platoons was initially motivated by the need to produce a significant increase in the capacity of a highway lane, so that increases in travel demand could be accommodated with a minimum of new infrastructure construction. The PATH kinematic studies of highway capacity showed that it could be possible to increase passenger car lane capacity by a factor of two to three over today’s capacity if the vehicles were driven in platoons of up to ten cars [7]. The gaps between platoons would be long enough to ensure that even in the worst crash hazard condition, with maximum decelerations, a following platoon would be able to stop without hitting the last vehicle of the forward platoon, even while there could be low-speed crashes between vehicles within the forward platoon. An extensive modelling and simulation study of crash safety and capacity showed the advantages of the platoon mode over individual automated vehicles [8]. The PATH studies have been based on the assumption that all vehicles would be automated, including the first vehicle of the platoon, in order to maximize efficiency and remove the potential for driver errors to cause crashes.

PATH first tested the longitudinal control of a four-car platoon at 4 m separation at highway speeds in 1994, and then developed the eight-car automated platoon for the National Automated Highway System Consortium (NAHSC) Demo ’97 in 1997. Close to one thousand visitors took demonstration rides in these vehicles, which did a variety of manoeuvres including lane changing and joining and leaving the platoon as well as normal car following, all under completely automatic control. All of the intelligence, providing for sensor signal processing, V2V communication and coordination, and lateral and longitudinal control, was done on a single Pentium computer running at a 166 MHz rate, so this did not require high computational power. The gaps between the vehicles within the platoon were maintained with a 20 cm RMS error, which is small enough that vehicle occupants felt as if they had a mechanical coupling to the preceding car, while also maintaining a smooth ride quality for comfort [9].

More recently, the PATH platooning research has focused on heavy trucks, mainly because of the potential for energy saving associated with aerodynamic drag reductions. Operating tractor-trailer trucks in close-formation automated platoons of three trucks could enable a capacity of about 1500 trucks per lane per hour, which is twice the capacity achievable with trucks driven individually. The PATH experiments on truck platoons have shown the technical feasibility of driving two trucks at a gap of 3 m and three trucks at a gap of 4 m between trucks. These experiments have also shown direct fuel consumption savings in the range of 5% for the lead truck and 10% to 15% for the following trucks under conservative assumptions [10]. These offer the potential for future savings at least half again as large when the trucks are driven at typical U.S. highway speeds and at or near sea level atmospheric pressure.

GCDC

Low cost and reliable communication systems have recently renewed the interest in cooperative vehicle-highway systems. In the *2011 Grand Cooperative Driving Challenge* (GCDC) [3], a number of vehicles cooperated in platoons in both urban and highway driving scenarios. The aim of the 2011 GCDC was to accelerate the development, integration, demonstration and deployment of cooperative driving systems, based on the combination of V2V and V2I communication infrastructures and the state-of-the-art of sensor fusion and control. The challenge was to demonstrate how traffic shockwaves can be attenuated and to increase the road throughput, i.e., by reducing the spacing between vehicles. This was achieved by conveying surrounding vehicles' state and road information to each vehicle in the platoon and locally fusing the collected information into awareness of the surrounding context in order to automatically control the vehicle longitudinal motion and the distance to the preceding vehicle.

Figure 2 - Platooning scenarios on N270 between Helmond and Eindhoven in the Netherlands

The GCDC teams are not only using multi-vender vehicles but also a mix of both heavy and passenger vehicles participate. Each team uses different sensors technologies, but which conform to a number of technological prerequisites from the organizers. Interoperable communication based on IEEE 802.11p and an adaptation of the ISO CALM Fast protocol, positioning based on high accuracy real time kinematic (RTK) GPS and rigorous safety regulations e.g. minimum distances and speed, acceleration and deceleration limits paved way for a successfully demonstration of platooning in both urban and highway scenarios. All vehicles in the platoon were longitudinally automated. Any vehicle was also able drive in the lead position of the platoon, i.e. switch roles between lead and following vehicle.

Energy ITS

Energy ITS [4], a national ITS project by Japanese Ministry of Economy, Trade and Industry, started in 2008, aims at energy saving and global warming prevention with ITS technologies, and has two themes: an automated truck platoon and an evaluation method of effectiveness of ITS on energy saving. Another motivation for the project is mitigating the lack of skilled drivers. A platoon of three automated trucks currently drives at 80 km/h with the gap of 10 m on a test truck and along an expressway before public use. The lateral control is based on the lane marker detection by the computer vision, and the longitudinal control is based on the gap measurement by 76 GHz radar and lidar in addition to the V2V communications based on DSRC 5.8 GHz. Platooning of 10 m gap at 80 km/h can reduce energy by about 15 % (measurement) by the aerodyamic drag reduction, and CO_2 by 2.1 % along an expressway (simulation) when the 40 % penetration in heavy trucks by the roadway capacity increase.

SCANIA-platooning

Fuel is the single largest cost for a fleet owner; followed by salaries. Therefore systems that reduce fuel consumption are of high financial interest for the fleet owner [11]. Reducing the fuel consumption also reduces the environmental effect of the transport. Scania’s main interest in platooning is hence focused on heavy duty goods vehicle platooning on highways with focus on minimising fuel consumption. This interest is expressed in two national Swedish projects:

- Distributed Control of a Heavy Duty Vehicle Platoon
- iQFleet

Distributed Control of a Heavy Duty Vehicle Platoon is a collaboration between Scania and KTH (The Royal Institute of Technology) and is partly funded by the Swedish government. The main focus of the project is how a single vehicle operating in a platoon should be efficiently controlled without jeopardizing safety. Longitudinal movement is automatically controlled while lateral movement is manual. The control architecture has been developed based on distributed control, meaning that each vehicle is responsible for its own control based on information from onboard sensors like radar, cameras, etc, and information exchange between the vehicles in the platoon via V2V communication.

iQFleet is a collaboration between KTH, VTI (Swedish National Road and Transport Research Institute), Trafikverket (The Swedish Transport Administration) and is partly funded by the Swedish government. The project covers several research topics where platooning is one. Platooning research is focused on how platoons should be controlled with respect to other road users, road topology, infrastructure etc. The goal is to develop strategies and architecture that support driving and routing a number of platoons in an optimal way with respect to the road conditions. iQFleet also includes real road tests of platooning. The trials take place between two Swedish cities and with goods transport between manufacturing plants. There are several goals of the trials:

- investigate the fuel saving potential in real traffic conditions

- driver acceptance
- interactions between the platoon and surrounding traffic

For validity of the trials, professional truck drivers in real conditions are used. In the first phase, the platoon uses existing Adaptive Cruise Control based on radar information. The gap between the trucks will be 2-3s, which corresponds to 40-60m. In a second phase V2V communication will be introduced which will enable shorter distance. The gaps between the trucks will gradually be reduced, assuming that the driver finds the shorter distance acceptable.

Comparison

Table 1 gives an overview of the four reviewed platooning systems. Six parameters are compared: The vehicle type(s) in the platoon, the direction of automatic control, the requirements or potential changes to infrastructure, the integration with other traffic, the primary onboard sensors that are used and the main goals of doing platooning.

Table 1 – A comparison of four platooning projects

	Vehicle type	**Control**	**Infrastructure requirements**	**Traffic integration**	**Sensors**	**Goals**
SARTRE	Mixed	Lat + Long	None	Highway, Mixed	Production	Comfort, safety, congestion, energy
PATH	Cars or Heavy	Lat + Long	Reference markers in road surface	Dedicated lane	Mixed	Increased throughput per lane, energy saving
GCDC	Mixed	Long	Augmented GPS	Mixed	SoA and production	Accelerate deployment of cooperative driving systems
Energy-ITS	Heavy	Lat + Long	Lane markings	Dedicated lane	SoA	Mitigate lack of skilled drivers
SCANIA	Heavy	Long	None	Highway, Mixed	No V2V comm. in first stage.	Commercial fleet, energy

Some distinguishing features of the PATH approach include:

- all vehicles fully automated, including the platoon leader
- separate platoons for either light-duty vehicles, buses or trucks in order to avoid safety problems with mismatched masses of vehicles if they collide
- lateral control relative to absolute lane reference markings, but longitudinal control relative to preceding vehicle and platoon leader
- operation in a lane protected from intrusions by incompatible vehicles in order to maximize safety and minimize unexpected hazards.

State of the Art (SoA) sensors imply that they are currently infeasible or too expensive for commercial production. Automatic lateral control contributes mainly to safety and driver comfort, e.g. by relieving the driver from the driving task, but less to traffic flow and fuel efficiency. Automatic longitudinal control contributes mainly to traffic flow and fuel efficiency e.g. by reducing longitudinal shock-waves in dense traffic.

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