Shockwave
Traffic Jams A58

Partners in the project Shockwave Traffic Jams A58 launch open architecture and first practical application

First Dutch cooperative vehicle-roadside system in place

With European standards as a basis, the thirty partners in the project Shockwave Traffic Jams A58 have developed a new, open cooperative vehicle-roadside system and have also launched a first practical application. This brings opportunities to road managers, data suppliers, service providers and IT developers, with ample room for innovative services for road users.

A 'cooperative vehicle-roadside system' is best described as a communication and services platform that connects vehicles, roadside systems, service providers and road managers. These connections result in large quantities of data, providing real-time, highly accurate information on the traffic situation. That information can serve as the basis for developing intelligent services that reach the vehicle through the platform.

The opportunities this creates are abundant. The primary added value is the fact that the cooperative system facilitates communication between the vehicles and the roadside system and between the vehicles themselves, filling in a blank spot in traffic monitoring, and thus in the services to be provided. What happens in the immediate vicinity of a vehicle can be monitored by the road user himself, who is increasingly supported by vehicle sensors and cameras. What is happening a few miles down the road on the network level reaches the driver by means of long-distance communication: traffic jams, route advice, etc. But what is happening, say, just around the corner or a mile down the road, can only be learned if vehicles can exchange information at high speed with other vehicles and roadside systems within that range – and that is precisely the added value offered by cooperative technology. The cooperative vehicle-roadside system opens up possibilities for warning, information and driving-support services that are impressively smarter and more versatile than the services available now.

Next big thing?

Traffic experts consider the cooperative system to be the next big thing in the (international) traffic arena, promising to improve the flow of traffic, increase safety, reduce environmental impact and enhance comfort. However, some technical and organizational obstacles need to be overcome. The technical challenges include security and privacy. On the organizational side, numerous parties will be involved in the implementation and operation of a cooperative system, on both the side of the government (national, provincial and municipal authorities) and the market (including service providers, technology companies and car manufacturers). Cooperative technology also requires these two sides to find new ways to collaborate. In turn, that cooperation will only be successful if the government perceives sufficient benefit to society and if market players have suitable business models.

Those are significant obstacles that have caused both national and international stagnation: cooperative systems have been the 'next big thing' for a number of years now, but nothing really came of it. That is why, late in 2013, the Netherlands' Ministry of Infrastructure and the Environment, the Directorate-General for Public Works and Water Management, and the Province of Noord-Brabant took the task to hand by stimulating implementation of the cooperative system with specific targets. With the national *Beter Benutten* (Optimising Use) programme as its vehicle, the Shockwave Traffic Jams A58 (Spookfiles A58) project was launched in January 2014. The market was challenged to develop an open cooperative system in a pre-commercial procurement setting and also to deliver a first cooperative service. The A58 would be the testing grounds. Eleven consortia, with a total of thirty different participants – businesses and knowledge institutions – accepted this challenge.

In various project phases, with a number of competitions and selection procedures for the participating parties, a system architecture was delivered, a prototype was constructed, the A58 was prepared (with 34 radio beacons for short-distance communication via WiFi-P technology), and the cooperative system was implemented and went live. In December 2015, a small group of parties who were directly involved tested the first cooperative service: a 'shockwave traffic jam service' that sends personalised speed warnings for traffic jam shockwaves – hence the name of the service and the project – that helps to reduce such shockwaves. This service was expanded in the first two months of 2016 to include a few hundred 'regular' participants. This reflected an impressive milestone: an open cooperative system on a public road was put into operation for the first time ever in the Netherlands. Even more importantly, the project laid a solid foundation for the cooperative efforts in other Dutch Intelligent Transport Systems (ITS) projects, and even in international projects like 'ITS Corridor'. Because European standards have always been taken into account, the Netherlands is helping to shape the cooperative future.

Open approach

To get an idea of the opportunities offered by the new system on the A58, one should look at the approach that has been chosen: see Figure 1, showing the cooperative system's architecture.

Two key features of the system are that it is open and that it is compliant with *international standards*. As clearly shown in Figure 1, the cooperative system is divided into logical components (the blocks) that are connected physically or wireless by means of interfaces (the arrows). Both the components and the interfaces are specified and documented: what is the functionality of each component, and how does it 'talk to' other connected parts? In doing so, the European standard for ITS communication architectures, ETSI ITSC[1], was closely adhered to, albeit that this standard is not yet so broad that it covers all systems and subsystems of a

[1] The formal name of this standard is ETSI EN302 665, "Intelligent Transport Systems (ITS); Communications Architecture". See www.etsi.org.

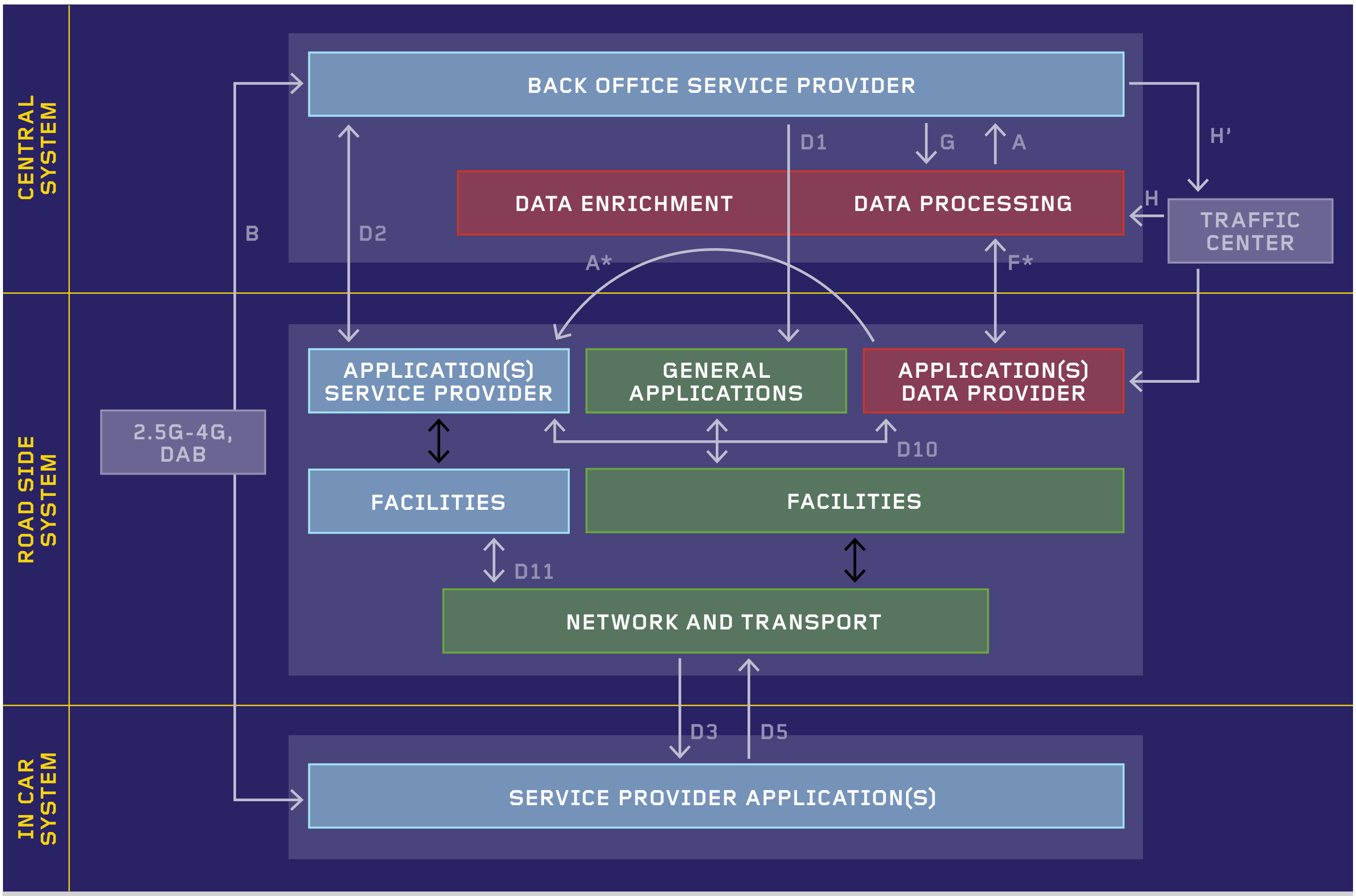

Figure 1: The architecture of the cooperative vehicle-roadside system delivered in the Shockwave Traffic Jams A58 project

cooperative vehicle-roadside system. So, where necessary, the ETSI ITSC standard was supplemented in line with existing directives.

An advantage of this approach is that knowledge development is stimulated while, in time, an appealing market is created. This applies first and foremost to the cooperative system itself. For example, market players will not need to deliver an entire system (which is something only a few major parties would be able to do) but instead they can focus on a single component, like a subsystem for data processing and data enrichment. This makes cooperative technology an appealing sector for a wide range of specialized companies, both large and small.

Moreover, compliance with international standards offers market players the advantage of scale: an operationalized system or subsystem can easily be used in other national or European projects. This in turn stimulates innovation, as it will continue to be useful and necessary to develop technology further with a view to new projects.

The benefits of compelling market opportunities also apply to the cooperative *applications*. Service providers will not need to process their own data, implement their own roadside systems and antennae, have their own on-board units installed in vehicles, etc. Rather, they can add on cooperative services, like apps, to the cooperative system, that utilize the generic services provided by the components, such as data processing, data enrichment and the connections with road users. This considerably simplifies the development of smart applications, exponentially increasing the chance that useful, smart cooperative applications will become available.

Two dimensions

All this means that the architecture can be viewed in two dimensions. The first is the dimension of the physical layers: back office, roadside and vehicle. Here, the focus is on the location or the level on which the various components – the subsystems – are positioned.

Thanks to its open and standardized nature, however, the system can also be divided into *functions*. This shows the type of market player that goes with a specific component. In the tendering of the Shockwave Traffic Jams A58 project, that functional dimension already proved its worth: the participating consortia could put in bids on the following three lots, depending on their expertise. These lots are:

- **Data lot** (red in the figure) The parties performing this role are responsible for the processing, enrichment and availability of data for the cooperative system.

- **Roadside lot** (green) Market players in this lot provide telecommunications capacity between vehicles themselves and between the vehicles and the roadside. The Roadside parties also make micro-data from the vehicle available to the Data lot, and enables the local running of services.

- **Service provider lot** (blue) The provider of a cooperative service for road users: information, advice, driving support. In doing so, the provider uses the data made available in the Data lot and the telecommunications capacity and local servers in the Roadside lot.

Naturally, the cooperative system also utilizes existing systems, services and telecommunications capacity. Long-distance communication, for example, is transmitted via the ‘regular’ 3G and 4G networks, and in addition to personal vehicle data, data concerning inductive loop detectors and traffic systems (such as the status of variable message signs), for example, can be accessed through connections with traffic management centres. These external elements are shaded purple in the figure.

Security and privacy

With the approach chosen for the Shockwave Traffic Jams A58 project, a number of the organizational obstacles mentioned have been overcome: the elected approach makes it interesting for both large and small market players to join in while laying the foundation for a compelling market for cooperative services. But what about the more technical obstacles, such as *security* and *privacy*?

When only advice services like the shockwave traffic jam service are involved, the risks in terms of security are rather limited. The worst that could happen is that the service becomes unavailable, or incorrect advice is sent, but because all of the driving is still done by the driver, this will not directly lead to danger on the road. Still, no one wants an advisory service to break down or be used improperly, which is why a team of experts has fleshed out a variety of security measures. In doing so, this team has also created a basis for future security measures for the time when applications are launched that entail greater security risks.

One interesting measure is that all communications, both from the roadside and from the vehicles, have digital certificate-system signatures. This safeguards the *integrity* and *authenticity* of the communication by ensuring that it has not been secretly changed or sent from an unreliable source. For this certificate system, an existing open-source PKI tool[2] was modified and made suitable for the cooperative environment. In the cooperative Shockwave Traffic Jams A58 system, only authorized roadside systems and vehicles can send communications with a 'validity certificate'. If a communication is changed, it is immediately invalidated.[3]

Innovative measures have also been taken in the area of privacy. Cooperative vehicles constantly transmit small data packages with their location information. The individual location data packages do not pose any privacy threat: they merely communicate that a cooperative vehicle with the ID *a* was at location *x* at the time *t*. However, lining up all of the data packages from ID *a* can violate privacy. Where the owner of vehicle *a* lives or works could be derived, for example. To prevent third parties from intercepting location transmissions in order to trace individual travel, the on-board units in the cooperative vehicle

[2] PKI stands for Public Key Infrastructure, a system enabling the reliable (electronic) exchange of information.

[3] In the Shockwave Traffic Jams A58 project, primarily the technology is being tested. This is why the registration authority has not (yet) been formalized in the project: that is a PKI component of a more organizational nature. See the security and privacy fact sheet.

are constructed in such a way that their ID can regularly change.

Privacy is also key on the server level. For example, the system can save the location transmissions it receives on a server, but the data cannot be automatically transmitted to a traffic management centre or another party. First of all, the data are aggregated. Another measure that has been prepared is to 'cut off' the origin and destination of every single journey before aggregating and handing over any data. Although the disadvantage of this is that no origin-destination matrices can be derived from the data, that is simply the price to be paid for privacy.

Gaining experience with the shockwave traffic jam service

With these security and privacy measures, the cooperative system along the A58 is ready to go: starting in 2016, selected pilot participants will test the first cooperative system aimed at reducing traffic waves (shockwave traffic jams) on the A58.[4] Incidentally, two shockwave traffic jam services will be tested from two different consortia: ZOOF and FlowPatrol. Each of the consortia developed its own on-board unit and smartphone app. Their equipment, algorithms and presentation differ, but the functionality is the same.

Briefly put, the cooperative shockwave traffic jam service works as follows. The Data lot generates a traffic image based on various data sources. The service provider – ZOOF or FlowPatrol in this case – distils the shockwave traffic waves from that image and transmits that information, via the roadside system, over WiFi-P: the location of a shockwave traffic jam, and its speed and length. The on-board unit receives all data packages via the ether and filters what is relevant.

[4] Pilot participants were already testing in 2015 within the context of the Shockwave Traffic Jams A58 project, but that was a 'connected' version of the service that only used long-distance communication and lacked the (high-speed) communication via WiFi-P.

The information on traffic congestion is transmitted to the smartphone app that generates the appropriate speed advice, taking the vehicle's speed and location in relation to the congestion into account. The aim is to enable the vehicle to travel in the congestion as smoothly as possible, avoiding harsh braking, so that the traffic shockwave is slowly reduced or even disappears. The user is also warned when arriving at the 'head' of the congestion: increasing speed in a timely fashion also contributes to dissolving a shockwave traffic jam.

The data, advice and responses (speed adjustments) from the users are logged anonymously. This makes it possible to evaluate how the services work, how accurate and timely the advice is, and how road users respond. The potential in terms of timeliness is significant in any event. When only long-distance communication is available, the traffic situation is updated every thirty seconds, which is much too slow considering the dynamics of a shockwave traffic jam. But with short-distance communication, the traffic situation update frequency within the cooperative system could be reduced to only one second!

Whether the shockwave traffic jam service will already improve the traffic situation during the trial depends on the number of cooperative users. At least sixty users must be travelling on the test section of the A58 at the same time in order to create a measurable effect. Whether that number will be achieved remains to be seen. In any event, the main objective of the trial is testing the cooperative system as provided and the provision of advice in itself - which will not be a problem considering the hundreds of participants, whether or not they are travelling the test section at the same time.

What's next?

All in all, there are enough reasons to view the cooperative system created in Shockwave Traffic Jams A58, including its application, as a milestone. Obviously, the object is not only to 'prove it works', but to lay the foundation for a definitive introduction of cooperative technology on the Dutch and European road network. The need for and determination of subsequent steps to that end will be decided by the Ministry of Infrastructure and the Environment, the Directorate-General for Public Works and Water Management and the Province of Noord-Brabant over the course of 2016. It is clear, in any event, that the products, knowledge and practical experience obtained through Shockwave Traffic Jams A58 provide a solid basis for future ITS projects within the context of the Beter Benutten (Optimising Use) programme. Shockwave Traffic Jams A58 products also provide extremely valuable input for the international project ITS Corridor.

But the opportunities presented by the cooperative system in the shockwave project are sufficiently appealing even apart from that: it has been tested in practice; it offers sufficient opportunities for smaller market players as well, making it easily manageable and controllable (because it is not a mega project); it is in line with international developments and standards, and – last but not least – it brings innovative and powerful services for road users within reach.

More information?
Road managers and market players who are interested in the knowledge and other products from the A58 shockwave project can consult <u>www.spookfiles.nl</u> or send an email to <u>info@spookfiles.nl</u>.

The added value of cooperative technology

In the end, whether a new technology has a chance of succeeding primarily depends on whether it offers real added value. How does the cooperative vehicle-roadside system compare to the usual *connected* applications in that regard? And won't self-driving vehicles soon make the cooperative technology redundant?

Cooperative technology is sometimes considered an intermediate phase. The reasoning goes as follows: we are currently in the connected period, and we will make some more progress in the years to come thanks to cooperative technology, but the real breakthrough will be the self-driving vehicle.

However, that reasoning is too simplistic; 'cooperative' and 'self-driving' are actually two *different*, more or less *simultaneous* paths of development that could merge in the future. To understand how these paths supplement each other, we should consider the question: where exactly is the intelligence located?

At a distance, in the vehicle, or … ?
With connected applications, the technology and intelligence are located in the back office. The on-board unit itself (navigation system, on-board computer, smartphone, etc.) also contains the necessary intelligence, of course, but for the more advanced services, the applications are strongly dependent on remote systems.

Self-driving vehicles also depend on a back office, if only to determine the best travel route in the network. The technology and intelligence in this path, however, are primarily located in the vehicle itself. Thanks to smart technology in the vehicle (cameras, lasers, etc.), for example, a self-driving vehicle is highly aware of its immediate vicinity and can anticipate and respond to it, using highly sophisticated systems. Self-driving vehicles may possibly exchange information directly with other smart vehicles in their vicinity as well.

However, the set-up of the cooperative system is different. A smart application can run on the back office's system, on the vehicle's system and also on the roadside system[5]: the 'intermediate layer' in the architecture. It is this very *distribution of intelligence* that offers unique opportunities.

A 'cooperative' service provider will locate many of its services in its own back office: the 'Back office service provider' in the Back office layer in Figure 1. Based on data that have already been processed and enriched and that are made avai-

[5] The roadside system is not necessarily physically located on the side of the road: it can also be at a distance. In that case, extremely rapid optic fibre cables are directly connected to the radio beacons, meaning that the system is 'virtually' located along the side of the road.

lable in that layer, the relevant application can transmit information and advice to the vehicles, for example about the route choice. The (long-distance) communication with the vehicles takes place through interface B (3G or 4G).

Part of the services can also be hosted on the roadside system, also known as Roadside ITS Station or RIS. This is because another application running on the data provider's RIS locally processes the large quantities of vehicle data received through the WiFi-P radio beacons (interface D5). Those data are immediately processed, enriched and made available to the applications of service providers (interface D10). By processing these in the RIS, time is scarcely lost and services that are highly time-critical can be provided, such as automatic traffic entry. Obviously, the data are also sent to the back office (interface F), where they contribute to further enhancing the picture of the traffic.

Lastly, there is the intelligence in the cooperative vehicles. These are connected not only with the radio beacons in the immediate vicinity by means of WiFi-P (and thus with the RIS), but also with other cooperative vehicles. In its turn, this direct communication and exchange of data between the vehicles themselves offers possibilities for services such as platooning.[6] A service provider could install the application providing such a service in the cooperative vehicle system: the Vehicle ITS Station (VIS).

The true added value, however, is the interaction between the layers. Thanks to the intermediate Roadside layer, the vehicles on the road are no longer 'intelligent islands' – which is what self-driving vehicles are to some extent. Rather, thanks to all of the communication possibilities, they are intelligent, cooperating *partners* that know not only what is happening in their immediate vicinity, but also what is happening 'around the corner'. The examples of automatic traffic entry and platooning were already discussed above, but imagine a combination of the two: a convoy of (freight) vehicles that automatically creates space when it knows that a number of vehicles will be coming in at the next entry ramp. There is a good reason why it is called a 'cooperative system'.

Cooperative also offers added value for self-driving vehicles

In summary, we may safely say that vehicle intelligence is progressing by leaps and bounds along the development path to a self-driving vehicle. By contrast, the path to the cooperative system focuses on the distribution of intelligence and on the cooperation and interaction that makes this possible.

Viewed from that perspective, the self-driving vehicle is not an alternative to the cooperative system: that vehicle is much more likely to benefit from cooperative technology. In turn, a cooperative system will be able to use the additional intelligence on the vehicle level. Depending on how you look at it, the outcome is 'self-driving vehicles plus' or 'cooperative plus'.

[6] Platooning means that a number of vehicles with driving support travel in a convoy. In this, the follower-vehicles automatically respond when the lead vehicle brakes or accelerates.