Signal Phase and Time (SPAT) and Map Data (MAP)

Version: 1.1	**Date:** 2015-09-01
Release Status: Released	**Document Type:** White Paper
Status: Completed	

Abstract:

This white paper presents the cooperative ITS application "Signal Phase and Time (SPAT) and Map Data (MAP)" as seen from the umbrella organisations of the Amsterdam Group; ACECAP, CEDR, POLIS and the CAR 2 CAR Communication Consortium.

Changes since last version:

Minor additions from CAR 2 CAR Communication Consortium

Outstanding Issues:

None

Document History

Date	Name	Action	Version number
2015-07-01	Amsterdam Group	First version	1.0
2015-09-01	Amsterdam Group	Minor additions from CAR 2 CAR Communication Consortium	1.1

Content

Executive Summary

During 2013 and 2014 two workshops have been held where SPAT/MAP was discussed with European cities from Germany and UK. The outcomes from these workshops are reflected in the white paper.

The function of Signal Phase and Time (SPAT) [1] will inform drivers about the current status and change of the traffic signal ahead as well as when the next signal stage change. It will also provide information about approaching traffic to optimize the signal system. Map Data (MAP) describes the physical geometry of one or more intersections.

The SPAT/MAP application is most relevant for cities and/or urban areas. These have vastly different local needs and priorities throughout Europe, which are also defined by political priorities. A common challenge is how to improve the aspect of mobility in city environments. In most cases this will imply restrictions on private cars, emphasis on public transport, goods distribution and personal mobility.

The SPAT/MAP application comprises benefits as well as challenges when it comes to deployment.

Among potential benefits is a more optimized and environmental friendly driving performance when the drivers are advised about the next change of the traffic lights ahead. Another possibility is to provide priority to selected groups like emergency vehicles and public transportation. It is also possible to optimize the signal system when it receives more information about approaching traffic.

This could have positive effects on traffic efficiency when minimizing the delay at traffic signals. Moreover, the delay of public transport, heavy vehicles and vehicles on main roads could be minimized. Hence, the SPAT/MAP application could have a positive effect on traffic flow and safety minimizing the number of stops resulting in less head-tail accidents.

The most significant challenge for cities is that there the benefits envisaged for SPAT/MAP have not yet been proven in practice. Most cities will feel reluctant to invest in such services until there is a sufficiently clear body of evidence from trials and demonstrators. This suggests the need for research projects.

One important challenge is that numerous Traffic Controller Suppliers and Control Software Suppliers have to be coordinated to achieve the same quality of SPAT/MAP. This issue would need to be supported by standardisation.

In addition, the handling of the information within the approaching vehicles may result in different speed and stop advice dependent on the supplier. This topic is not covered well in the current SPAT/MAP standardization work, but is more a topic for different car and support system manufacturers.

A crucial challenge is that traffic adaptive controllers are reacting very short term on actual traffic conditions especially where public transport is involved. It is a challenge to develop a user friendly forecast algorithm even for the next change.

In addition, there are traffic risks of deploying SPAT/MAP. It could be that driver behaviour changes to be (for instance) less safe, rather than safer, when in-vehicle SPAT/MAP information is available. There is an associated risk that regulation (not yet known) may limit the ways in which these services can be used, which reduce the positive benefits as well as the dangers. Again, robust demonstrators will be required to enable these risks to be understood and managed.

As a final remark, experiences with various SPAT/MAP implementations throughout Europe should be well documented and shared with the community.

1. Overall function of SPAT/MAP

The Signal Phase and Time (SPAT) function informs drivers of the current status of the traffic signal ahead as well as when the next signal stage change will occur in the current path. Map Data (MAP) describes the physical geometry of one or more intersections.

SPAT/MAP systems have the following characteristics:

- they concern communication between the traffic signal controller and approaching vehicles;
- they provide the driver with information about the residual signal time when approaching the intersection;
- they can be realised with centralised or local signal control, or a mix of them. SPAT/MAP information from a centralised system can be retrieved over cellular communication systems. The choice depends on road operator priorities related to existing and new signal control systems;

Within the CEN/ISO standardisation processes, SPAT/MAP is currently being addressed through the exchange of information between the traffic signal controller and approaching vehicles. SPAT/MAP is composed of four messages:

1. **Signal Phase and Timing (SPAT);** which describes the signal state of the intersection and how long this state will persist for each approach and lane that is active.
2. **Map Data (MAP);** which describes the physical geometry of one or more intersections
3. **Signal Request Message (SRM)**; which requests preempt or priority services for selected user groups.
4. **Signal Status Messages (SSM);** which describes the internal state of the signal controller. Provides a more complete summary of any pending priority or preemption events.

1.1. SPAT/MAP as part of a signal control system

Signal control systems are already quite sophisticated. There are several different architectures in current usage, each suited to specific city contexts and different signal control strategies all over Europe. These different architectures will have an effect on how SPAT/MAP could be usefully integrated.

First, there is a difference between fixed time and adaptive traffic control systems.

- Fixed time systems give a pre-set green time to each movement in the intersection and use a pre-set cycle time. This makes it is easy to predict the signal state for a vehicle approaching in a certain direction. The challenge is mostly related to the expected travel time towards the stop line.

- A traffic-actuated or adaptive system can alter the green time for each movement either within a fixed cycle time or with a changing cycle time. Even though the system might expect a certain pattern for the stages and green times, new information might introduce alterations. Typically, a bus arrival can change the green times and even the stage order. Vehicles with SPAT/MAP functionality approaching the intersection will receive new recommended speed advices. Different systems allow either small or larger shifts and therefore give more or less possibilities for changes in the advice for speed.

Hence, dependent on the traffic signal management philosophy, the SPAT information will be definitive with fixed time systems but only indicative with adaptive systems.

A distinction also needs to be made between standalone and centralised systems:

- In a local standalone system, the traffic controller at each intersection makes all the decisions for the next signal phase based upon local available information.

- In a centralised system, the traffic controller at each intersection communicates with a central system receiving certain parameters that goes into the algorithm deciding the next signal phase. An approaching prioritised vehicle would report its position and speed to the central system, which subsequently interacts with the local signal controller.

Finally, there is a question of communications choices. Standardisation has been focusing on using local control and communication via roadside ITS Stations as a day one application. An alternative for SPAT/MAP is based on centralised monitoring of signal changes and using mobile communication networks towards the users. This alternative architecture needs further consideration, as it may enable many of the same benefits to be delivered at a much lower cost. The local and centralised system solutions are illustrated in the figure below.

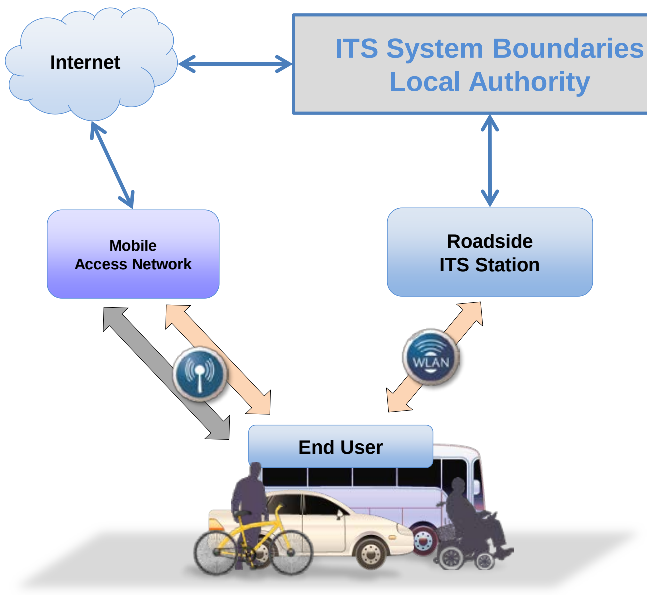

Figure 1 Local or central SPAT/MAP control

1.2. SPAT/MAP within the vehicle

SPAT/MAP services provide data to a vehicle system. There is then a next step, to establish by what application or display (if any) the information is to be provided to the driver.

This could have a potentially significant effect on driver behaviour, and therefore on the effective benefits of the system. A complex display might risk driver distraction, at a point on the road where attention is specifically required; alternatively, it might cause the driver to ignore the information as too confusing. Different drivers will doubtless react differently.

A simple display, perhaps focussed on a single function (like a warning light to slow) might be easier to pay attention to, but less easy to understand. Similarly, with audio warnings.

In a more highly automated vehicle, there is the additional possibility that SPAT/MAP messages could feed directly into the vehicle's Intelligent Speed Adaptation system. In this case the driver needs no display at all.

The various vehicle manufacturers will select different strategies for presenting SPAT/MAP information to the driver.

2. European Cities' Perspective on cooperative junctions

A workshop on SPAT/MAP was held in Frankfurt in October 2013 and Reading in September 2014 with the participation of Polis, OCA and UTMC members as well as standardisation experts from traffic systems suppliers and vehicle manufacturers. These meetings provided an opportunity for the cities and other transport authorities to gain an understanding of SPAT/MAP and for the other participants to learn about the priorities of cities and to gather preliminary views on the SPAT/MAP use cases.

The workshops provided local authorities an opportunity to provide input on SPAT/MAP use cases including service deployment scenario describing the vehicle, roadside infrastructure and traffic management functionality within a common context. To avoid starting with a blank sheet, it was decided to start with the use cases identified in the SPAT/MAP technical specifications within CEN/TC278/WG16 & ISO/TC204/WG18 DT8.1. These use cases are briefly summarised in appendix A.

Local authorities were urged to comment on these use cases and to propose alternative use. On the one hand they could share their views on significance, benefits, challenges etc. more generally with regard to use case groups, i.e. public transport priority, fleet priority, emergency vehicle priority etc. On the other hand, they could express comments and amendments to specific use cases.

A few representative cities (Düsseldorf, Hamburg, Kassel, Munich, Trondheim, London, Reading, Newcastle, and Bristol) with strong interest and knowledge in cooperative systems provided their comments. Input was also provided by the OCA and UTMC, which represent the ITS interests of many cities in Germany and the UK respectively.

2.1. SPAT/MAP as part of C-ITS

From the city perspective, SPAT/MAP is just one potential technical feature of a cooperative ITS (C-ITS) roadside system. A city buying such a system will want to ensure that it is gaining the maximum benefit from its investment from the bi-directional communication with individual vehicles.

European cities perceive that the main benefits of C-ITS come from improved data on vehicle movements:

- giving the traffic signal system data about individual vehicles approaching the intersection, so that it can optimize the traffic control at the intersection (and across the total road network);
- informing the signal system about specific classes of vehicle – such as buses – to enable priority to be given in signal phase alterations;
- reducing or removing the need for expensive vehicle detection systems such as inductive loops or CCTV;

2.2. Preferred SPAT/MAP applications

Among specific SPAT/MAP applications, there is a wide spectrum of views among cities.

The clearest support appears to be for **SPAT/MAP priority/preemption use cases**. These use cases receive most detailed comments and amendments from German cities. In the UK, this was seen as a potential way of delivering bus priority through more broadly based systems. However, the expectations of use were quite different: many (especially in UK) felt that this should be hidden from the driver, while others preferred an explicit presentation of information to the driver.

In general, **SPAT/MAP safety use cases** are considered less applicable to early deployment. Often there are recommendations to move these use cases to the driver's responsibility, or possibly the car manufacturers': the role of roadside infrastructure is not so clear. Concerning safety issues with public transport Kassel has added two specific use cases – these consider accidents with rail based public transport.

Regarding the **SPAT/MAP mobility/sustainability use cases**, there seems to be no strong voice.

2.3. SPAT/MAP as a city project

Several European cities are interested in SPAT/MAP as a start-up for C-ITS applications, but they are also cautious.

The main challenge is felt not to be the technical aspects of how to implement and maintain SPAT/MAP, but rather how to finance, organize and maintain it as a permanent service.

Besides installations based on EU-projects, it is not yet clear that the local version that standardisation has committed to will prevail as a day one implementation. It is in any case interesting for cities to obtain an easy instalment plan for a larger area by a centralized monitoring system.

So fare it seems like the different vendors of traffic signal surveillance and monitoring systems have uneven possibilities to implement a centralized SPAT/MAP concept within their current software. Cities will need to have a clear system proposal before committing investment.

The largest trial so far has been within the European project Compass4D [2] that has made two large installations in Verona and Berlin for SPAT/MAP based on centralised monitoring of signal changes and hybrid communication (mobile and local G5) towards the users. Here the communication is from the back office system towards the vehicles instead of from roadside units. This seems to be an easier start-up for cities that are planning C-ITS application for Day one.

In the Austrian part of the European C-ITS corridor SPAT/MAP will be introduced using local control based on G5 communication.

Experiences with these and other SPAT/MAP implementations throughout Europe should be well documented and shared with the community.

2.4. SPAT/MAP as enabler for V2X applications

The members of the Car-2-Car Communication Consortium, among which 15 vehicle manufacturers, have investigated over the past years the advantages gained by vehicles when having access to the information provided through the SPAT and MAP messages. Beside from the obvious advantages offered when advising the driver on a phase-specific cruising speed (GLOSA – Green Light Optimal Speed Advisory), many additional use-cases could also contribute towards an increased CO_2 efficiency and towards a more efficient traffic flow.

3. Day one SPAT/MAP use cases

It is interest around in some of the European cities to implement SPAT/MAP pilot systems. Hence, SPAT/MAP seems to be one of the potential day one applications for C-ITS out of the many use cases demonstrated in the research community over the last decade.

Interested cities have different needs so it is difficult to pinpoint exactly the day one use cases. This will vary from city to city. However, it seems for the time being to be more interest in the group of **priority/preemption** and **safety use cases**, and less interest in **mobility/sustainability** use cases.

4. SPAT/MAP Message standards

The list below shows the progress in ISO/CEN as of March 2015:

- SAE J2735 Including EU aligned SPAT and MAP dictionary and structure elements, published.
    - Currently all EU requirements are covered.

- ISO TS 19091 SPAT/MAP Specification
  Further work needed, expected to be finalised end 2015.
    - As EU requirements are covered by SAE J2735, this specification only include a description at this release.

- ETSI TS 103 301 Facilities layer protocols and communication requirements for I2V messages (minimized standardisation approach);
  A mature version is expected mid-2015.
    - Rapid progress is currently made to support deployment.

5. Potential benefits

Many potential benefits have been described for applications based on SPAT/MAP services. The following is a summary. However, it is noted that these are essentially unquantified and would certainly be expected to depend on the details of the road network, application design, and driving culture.

If that the driver only receives behaviour recommendations that are based on driving at or below the speed limit, there is a potential for drivers to drive more safely and more environmental friendly by reducing aggressive gas pedal and throttle use. The driving process for a platoon of vehicles with this functionality should be perceived as more relaxed and calmer.

Feedback loop to the traffic signal system with priority requests may also be evaluated by selected priority user groups as a benefit that attracts more users to the functionality of cooperative systems.

Some other potential benefits:

- cost reduction by using cooperative systems to realise public transport priority;
- cost reduction by savings on induction loops;

- better data base for traffic management strategy implementation;
- better data base for transport planning processes;

If the traffic signal system will receive more data about approaching traffic, it should be possible to find a better optimum for controlling the intersection, according to the city policy.

This may have positive effects on:

- traffic efficiency (minimizing the delay at traffic signals; moreover the delay of public transport; minimizing the waste of green time by a more accurate log off of public transport vehicles at the stop line, heavy vehicles and vehicles on main roads could be valued differently);
- safety (minimizing the number of stops resulting in less head-tail accidents);
- environmental effects (minimizing emissions, noise; e.g. there are opportunities to distinguish between heavy vehicles and other vehicles);

In the same way, the extra data per intersection could be used to reach a better optimum for the traffic management on the road network as a whole.

In the long run, when a high proportion of vehicles are equipped with cooperative systems, the relatively expensive inductive loop detectors for traffic lights should no longer be necessary. This could result in important savings for the road operators, which seem quite likely to outweigh the extra costs for wireless communication. This cost-saving issue can apply to a number of other services as well, as the cooperative on-board unit can host a number of different services.

The Start-Stop function of the vehicles makes use of the SPAT information assess if the engine should be stopped at all on a red phase. Similarly, the engine will be started just seconds before a green phase becomes active, this enabling the driver (or an enabled ACC - Automatic Cruise Control system) to minimize the time lost at the beginning of a green phase.

In the future, when an increasing number of vehicles will automatically drive through urban areas, the SPAT and MAP information will be closely integrated with Connected ACC information and so enable full platoons of vehicles (a string of vehicles driving at around 1 second distance to each other) to pass through the intersections at a green phase. This will minimize the “harmonica” effect currently observed at the beginning of each green phase (the distance between the first and the second car is around 2-3 seconds, the one between the second and the third around 2 seconds, and so on) and eventually allow a better throughput ratio for each green phase.

The MAP message could also be employed for providing information not just at intersections, but also on other contexts, like roadworks. This is especially important for the future automatically driving vehicles that will require very accurate digital map information of their surroundings. Since a building site will normally change the way vehicles pass through it, the information about the temporary topology could be provided through a MAP message. The vehicles will use this information and present it to the driver, or pass it to an automatic driving function that will use it to adjust its driving trajectories and paths.

6. Challenges

There are a number of challenges associated with the SPAT/MAP application. Some of them are listed below.

- There will fewer benefits under saturated conditions. However, the first, second and third cars at a red light know beforehand when it will be green and can minimise dead times, like Start-Stop, shifting into gear, and so on.
- **Financing construction and maintenance of road side units may be problematic**
- The supply market for controllers and system software is large and varied: **a lack of standardisation on the interfaces between road side units an signal controllers will hinder the procurement process**
- **There may be legal issues when providing information for third parties**
- **Cities' priorities today are not on implementing cooperative systems**
- Vehicle positioning has to be very accurate (especially with two or more signal phases in one approach)
- Forecast algorithms may be difficult to deliver in adaptive systems (even for the next change). However, there is still some time before an abrupt change, and this information is still important for the cars that will update the information received before.
- Existing public transport priority is widespread and effective – the benefits of a SPAT-based system will therefore be marginal
- The political focus on prioritising public transport (and emergency vehicles) will constrain the desire to invest in systems that will benefit ordinary traffic
- The regulatory / legal framework in the countries of the EU is not clear (for example, who is responsible in case of an accident caused by a wrong SPAT/MAP message received in a vehicle?)
- Changing driver behaviour at junctions may invalidate the operation of existing traffic management strategies and applications
- If SPAT/MAP is available, users will expect accurate information – but there is no clear model for quality for systems offering SPAT/MAP services

- Controllers may need to be less flexible in order to provide realistic SPAT forecasts, limiting the benefits of adaptive signal control

7. Conclusion

SPAT/MAP offers a potential channel for detailed information exchange between traffic systems and road users. A series of use cases indicates some potential benefits, and European cities are open to discussion of how these can be delivered. Several European cities are interested in SPAT/MAP but they are certainly cautious.

SPAT/MAP could have a positive effect on traffic flow and safety

- More optimized and environmental friendly driving performance
- Priority to emergency vehicles and public transportation.

However, the market in systems based on SPAT/MAP is extremely rudimentary and there are many major challenges that will need to be overcome before cities feel comfortable investing in them.

These challenges constitute a significant risk for any city exploring SPAT/MAP. As a minimum, countering these requires effective demonstrator projects, clear application designs, and a clear steer on regulation. These should explore SPAT/MAP in the context of both existing facilities (such as loop detection and GPS-based bus priority) and a wider scope for C-ITS (including the provision of vehicle data to the traffic system, and the potential use of wide area rather than local communications).

It is also essential that the options for the driver interface are fully tested, to reduce the risk of factors like driver distraction.

Pilot projects should demonstrate potential benefits of SPAT/MAP

- SPAT/MAP in the context of existing facilities (such as loop detection and GPS-based bus priority)
- SPAT/MAP in a wider scope for C-ITS (including the provision of vehicle data to the traffic system, and the potential use of wide area rather than local communications).

Experiences with various SPAT/MAP implementations throughout Europe should be well documented and shared with the community.

8. References

[1] ISO/TC 204/SC/WG 18, Intelligent transport systems — Cooperative Systems — SPAT (Signal Phase and Timing) message, MAP (Intersection topology) message, Draft versions 2013.

[2] Compass4D, [Online]. Available: http://www.compass4d.eu/. [Accessed 11 12 2014].

Appendices

A. SPAT/MAP use cases in ISO/TC204/WG18

ISO [1] are defining a set of SPAT/MAP use cases. The list in the table below reflects the status of identified use cases by November 2013. They are listed here as an indication of use cases that are being discussed by the standardisation community.

Table 1 ISO SPAT/MAP use cases

Preemption and Prioritisation related use cases
• Use Case PR1: Localized Public Transport Signal Priority • Use Case PR1-a: Localized Transit Signal Priority – Near Side Stop • Use Case PR2: Transit Signal Priority along an arterial (group of intersections) • Use Case PR3: Localized Freight Signal Priority • Use Case PR3-a: Localized Freight Signal Priority with a Platoon • Use Case PR3-b: Arterial Freight Signal Priority for a Platoon • Use Case PR4: Emergency Vehicle Single or Multiple Vehicles without PSOBE • Use Case PR5: Emergency Vehicle Single or Multiple Vehicles with PSOBE
Safety related use cases
• Use Case SA1: Dilemma Zone Protection • Use Case SA2: Red Light Violation Warning • Use Case SA3: Stop Sign Violation Warning • Use Case SA4: Turning Assistant - Oncoming Traffic • Use Case SA5: Turning Assistant - Vulnerable Road User Avoidance • Use Case SA6: Non-signalized Crossing Traffic Warning • Use Case SA7: Crossing Vulnerable Road User Advisory (Non-signalized)

Mobility/Sustainability related use cases
• Use Case MS1: Basic Local Traffic Signal Actuation • Use Case MS2: Platoon Detection for Coordinated Signals • Use Case MS3: Congested Intersection Adjustment • Use Case MS4: Traffic Signal Optimal Speed Advisory • Use Case MS5: Signalized Corridor Eco-Driving Speed Guidance • Use Case MS6: Idling Stop Support • Use Case MS7: Start Delay Prevention • Use Case MS8: Travel Lane Advice • Use Case MS9: Inductive Charging at Signals

B. Abbreviations

C2C-CC:	Car-2-Car Communication Consortium
CCTV	Closed-circuit television
CEN:	European Committee for Standardization
C-ITS	Cooperative ITS
G5	Short range communication link on 5,9 GHz standardised bt ETSI for C-ITS systems
ISO:	International Organization for Standardization
ITS	Intelligent Transport Systems
MAP:	Map Data
OCA:	Open Traffic Systems City Association
OEM:	Original Equipment Manufacturer, i.e. vehicle manufacturers in this document.
Polis	Polis is a network of European cities and regions cooperating for innovative transport solutions
SPAT :	Signal Phase and Time
SRM:	Signal Request Message
SSM:	Signal Status Message
UTMC:	Urban Traffic Management & Control
V2X	Vehicle-to-Vehicle or Vehicle-to-Infrastructure