

Joined up thinking

The CVIS project presents a high-level architecture for cooperative vehicle-infrastructure system deployment in Europe. ANDREAS SCHMID, ZELJKO JEFTIC and PAUL KOMPFFNER take up what is promising to be an enthralling story

More and more voices are proclaiming the imminent birth of a brave new world of “cooperative systems”, to be built upon the foundation of an expected ubiquitous connectivity amongst vehicles, roadside infrastructure and management/service centres.

Of course, this wonder can only come to pass if indeed almost all vehicles can communicate, if a substantial fraction of traffic management hardware is equipped, if agencies and operators establish links to the vehicles and the roadside equipment – and if a suitable communication network infrastructure is in place.

Bringing all these elements together into a successful deployment poses challenges of a scale and complexity never before encountered in the world of ITS. In this article we describe the ambitions – and the achievements to date – of the CVIS project, that has set out to define “the” high-level architecture for cooperative vehicle-infrastructure systems in Europe. This consortium of over 60 partners is attempting, with the help of over €20 million in EU funding, to apply (and in some cases to define) international standards for wireless communication and networking in a number of example case studies illustrating the potential significant benefits for traffic safety and efficiency, for the environment and for driver comfort.

The CVIS project was launched in February 2006 to develop a platform which would allow vehicles to communicate and cooperate directly with other nearby vehicles and with roadside infrastructure. After six months, the specific and consolidated user needs, use cases and system requirements were published. A year later the second set of key results emerged – a CVIS high-level architecture for cooperative systems, and a set of specific component architectures, that, unlike much of today’s high-tech equipment, should not become outdated when each new communication technology arrives.

Unlike the patchwork quilt of different – and incompatible – technologies and services that makes up the landscape of tolling in Europe today, cooperative systems can never become an all-covering blanket if there is not profound agreement on the definition of the basic technical elements and, most importantly, how these can fit together. The process of discussing the different options and coming to a broad-based consensus is exactly what is happening now in CVIS, and whose interim results we present in this article. This consultation should help to ensure that the final architecture is a robust solution capable of delivering the most important requirements for key stakeholders and, most importantly, has the best chance of leading to a full deployment of cooperative systems in all of Europe’s vehicles and roadside equipment in all European countries.

Requirements for a successful architecture

If updatability is a necessary feature of a European cooperative systems architecture, other requirements

are equally important to ensure widespread deployment. These include:

- separation of applications and services from the choice of communication system(s) used to link vehicles and infrastructure;
- ability for a vehicle user or owner to subscribe to, or use (for free-of-charge services), any accessible function or service, anywhere in Europe;
- reciprocal interoperability: any vehicle is able to connect to available services, and any service can connect to any vehicle;
- any operator or service provider must be able to offer a (compliant or authorised) service anywhere and to any user;
- vehicle manufacturers must be able to guard the integrity of their on-board systems from security threats.

When such conditions are met, customers will find that cooperative system products are included when they buy a new vehicle, as vehicle manufacturers will install communication capability as a series feature. If a driver chooses to cross the continent, he or she will enjoy continuous “roaming” access to whichever services are provided locally.

From the driver’s point of view, services and applications, such as personalised route guidance, traffic alerts

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or local junction “green wave”, will work in the same way in Spain, Scotland and Slovenia. The cities of Stockholm, Strasbourg and Siena will each be able to collect “floating car” data from every vehicle on their roads – including foreign – and free to provide car park booking and payment or to collect any congestion charging fees due likewise from every vehicle.

Such a revolution in communication, interaction and cooperation amongst

vehicles and infrastructure demands a completely new architecture. It needs to be based on communication standards as robust and well accepted as those defining GSM/UMTS. But as it must be implemented in all vehicles it also needs to allow progress – i.e. include a new interface (e.g. WiMAX or DVB-H when this is widely deployed) without replacing all the in-vehicle hardware. Similarly, application software must also be flexible and updatable, allowing a free market in services and easy interoperability in both the vehicle and the roadside.

The bigger picture

In the CVIS cooperative vision, all vehicles, road-side equipment and management or operating centres (e.g. for traffic or fleet management), as well as other mobile road users equipped with a communication terminal (pedestrians for example) can communicate and share information with each other. Each participant in this cooperative systems world is seen as a “node” in a common “network”, formed either by ad-hoc links to nearby mobile users or by connection to an IP backbone.

Figure 1 overleaf shows the main entities encompassed in the high level architecture, and how they relate

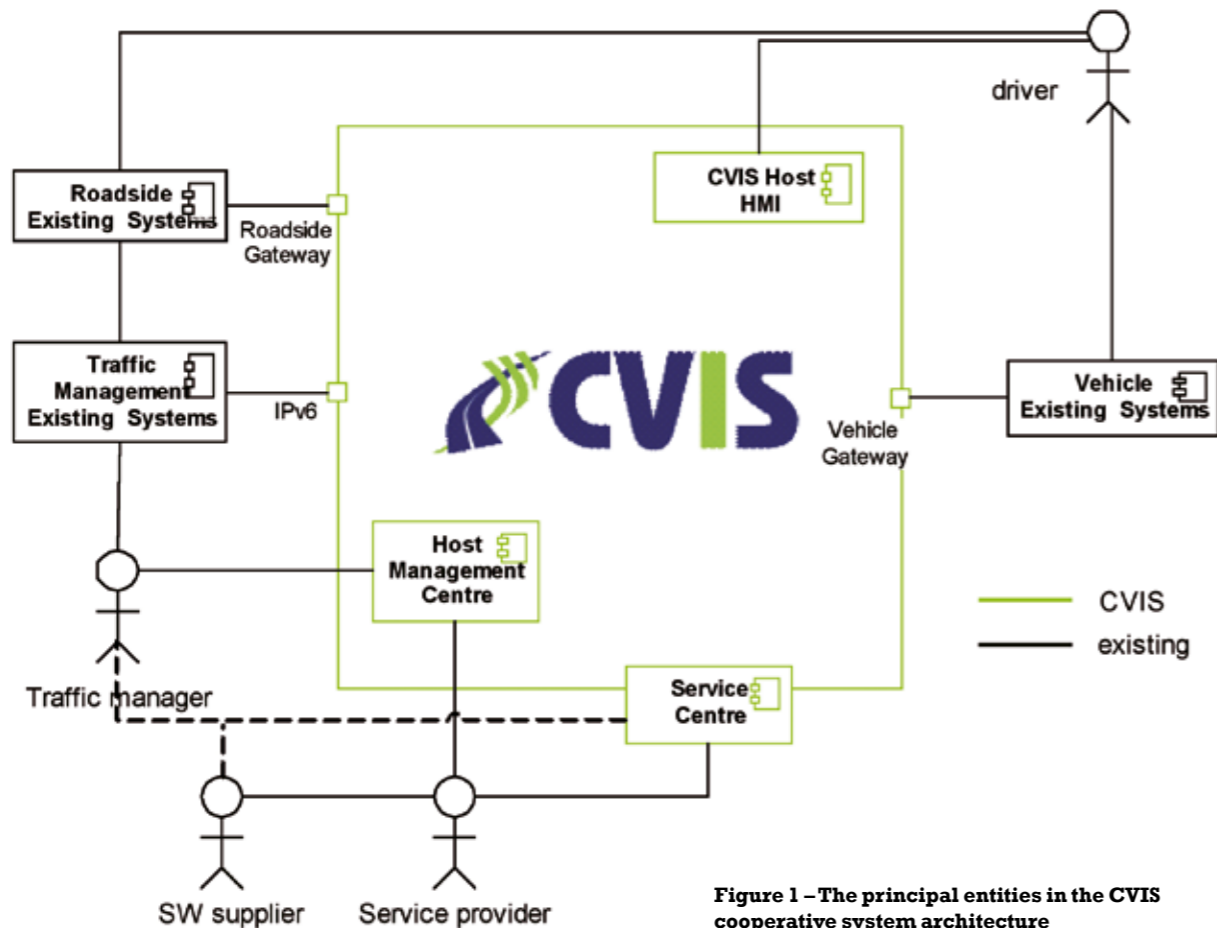


Figure 1 - The principal entities in the CVIS cooperative system architecture

to each other. Existing links are shown in blue, the new connections enabled by a CVIS network appear in green. This architecture is not limited to a strictly hierarchical view but allows each of these entities or nodes to communicate freely with each other (and in either direction) according to their needs. Nodes can communicate via the IP network or as peer-to-peer if needed, for example, for time-critical safety applications as elaborated by the “sister” SAFESPOT project.

Inside the box

Each cooperative system “node” belongs to one of four major sub-systems: central, vehicle, handheld and road-side. Figure 2 presents the CVIS project implementation architecture, showing how each node combines an interface (“gateway”) to any native or legacy systems, a host computer where services and applications are executed, and a communications and network router providing connectivity to an IPv6 network. In a real system deployment, these three components would be merged into one hardware unit.

Each node implemented within the CVIS project will have the same basic architecture, comprising three layers: communications, JAVA/OSGi-based middleware and applications. In practice, not all applications may need the features (and overheads) of the JAVA/OSGi

framework, being implemented in native code or subject to special real-time requirements. In the CVIS architecture, an interface to native applications can easily be developed if needed.

The middleware layer includes a number of core components needed for inter-node cooperation, grouped into Basic and Domain functionalities (“facilities” in CVIS-speak). Basic facilities include lifecycle management of services and applications, directory facilities for service publication and discovery, basic communication facilities, security facilities, remote management, and software download to enable dynamic downloading of software on CVIS hosts. The Domain facilities encompass e.g. positioning, location referencing, payment or traffic information.

Communication for cooperative systems

Cooperative transport systems are by definition based on mobile communications. In theory one single communication medium could provide a continuous – or near-continuous – IP connectivity. However, while mobile Internet on cellular (e.g. UMTS) is capable of being that unique channel, in practice it would be too costly, would not suit certain applications needing very immediate and short-range communication with roadside equipment, and might not offer sufficient network

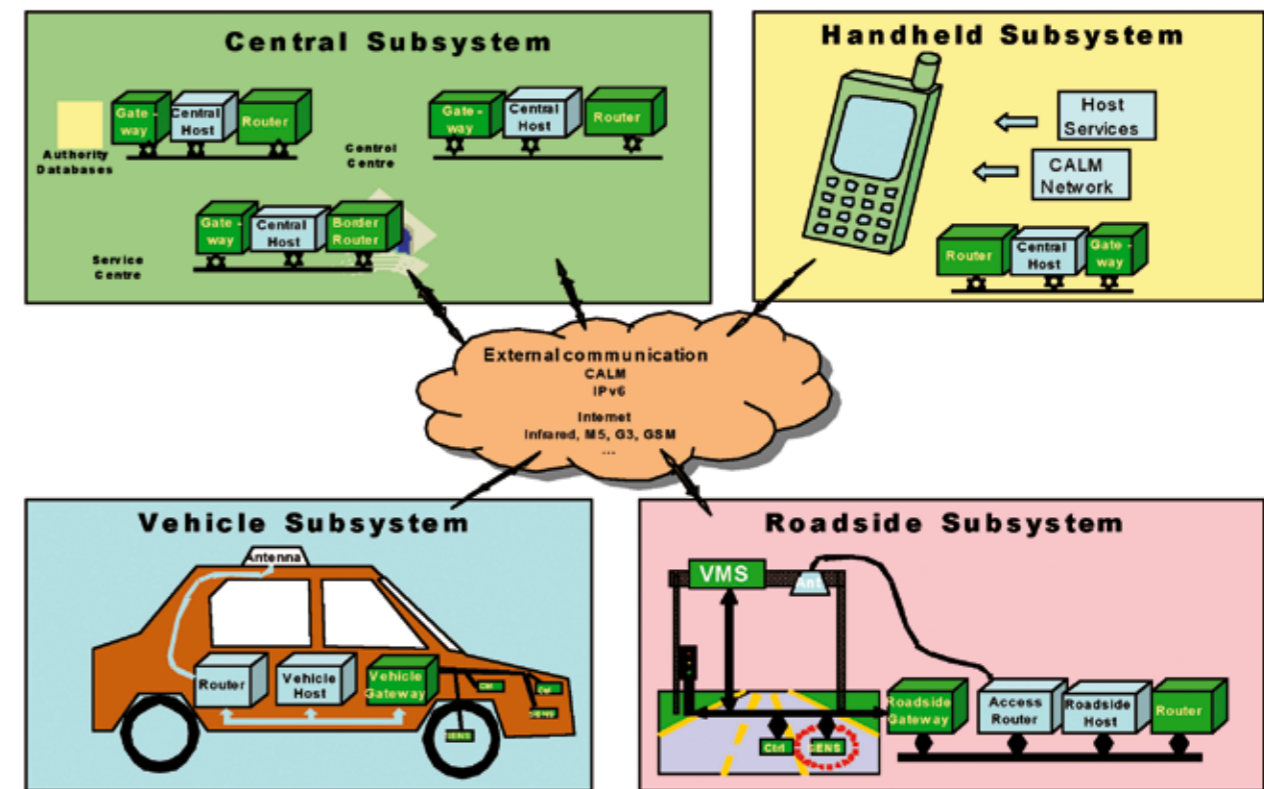


Figure 2 - Principal CVIS sub-systems

capacity if all vehicles were in near-continuous communication with infrastructure systems.

CVIS is therefore developing technologies linking communication partners over a global IPv6 network. Compared with today’s predominantly IPv4 networks, IPv6 offers a vastly increased address space as well as support for network mobility, both of which will be needed once every vehicle has one or more IP addresses and wants to maintain a connection whilst travelling at high speed. IP itself was chosen since the mobile system parts may use different media (e.g. 3G cellular, WiFi, DSRC, infrared) and IP is the most suitable common layer for managing the different physical media.

The management of the physical wireless “channels” beneath the IPv6 network layer is handled in CVIS by the application of CALM (Continuous Air interface for Long and Medium Range). This group of standards (currently under development in ISO/TC/204 Working Group 16) defines elements at different levels that work together to separate any high-level applications from the details of the particular communication interfaces and network layer in use. Figure W shows the full CALM stack as implemented in the CVIS architecture. This provides flexible management of whichever air interfaces may be available and in use, as well as of the way that the IPv6 network layer operates. A CALM management entity (CME) links the network layer in the CVIS router to the application layer in each CVIS host.

A co-operative ITS environment needs the availability of both two-way and one-way communications. Besides the dedicated peer-to-peer IP connections, features such as broadcast or geocast allow a large, unspecified number of communication partners in a region to be

addressed depending either on the range of the broadcast medium or on the specified geographic area. In case a peer-to-peer partner is not known, a Distributed Directory Service allows applications to be discovered according to specific search criteria (e.g. type of application and logical ‘network’ neighbourhood).

The CVIS communication-relevant components and protocols are provided by the COMM sub-project, that has defined technology for seamless and continuous communication from the vehicle towards the infrastructure and other vehicles. The CVIS communication system is based on standards for hybrid mobile networking from ISO, IEEE, IETF and ETSI.

The CVIS air interface is based on a number of communication channels including GPRS, UMTS, CALM M5 (mobile Wi-Fi), DSRC and IR (Infrared). The CALM technology uses policy-based rules to select the optimal communications channel at any time and place.

The CVIS open reference communication system can be optimised or directly ported into commercial products for vehicles and roadside systems alike. This reference communication platform is also available to other European ITS projects (e.g. SAFESPOT, COOPERS, SISTER), and CVIS maintains close coordination with these other projects.

Adaptive software environment

Both mobile and fixed system parts need to adapt their capabilities over either time and/or space when moving through the road network. This means that new software must be delivered to both vehicle and roadside platforms each time either there is a new software release or (if needed) when a vehicle comes into a new

“CVIS is developing technologies linking communication partners over a global IPv6 network”

service domain.

Mechanisms for flexible software deployment and management as provided by JAVA/OSGi CVIS framework, extended to fit the needs of co-operative systems, underpin the solution adopted by CVIS. Arbitrary system changes caused by software downloads would be a nightmare for all stakeholders, so each system entity (or "CVIS host") needing a software update must obtain this from its assigned "host management centre". Any stakeholder can operate a host management centre (HMC), in whatever way meets its needs and constraints. A host management centre knows the status of its assigned hosts and can permit or deny any software and configuration changes. CVIS also provides for dynamic mechanisms for hosts to obtain updates or new software on the fly, remotely if needed (and permitted).

The following illustration shows three hosts - nomadic, roadside and in-vehicle - linked by an IPv6 connection (blue lines symbolise the services' information flow). If needed, new software (applications) can be deployed through host management centres (red lines). Each host must be related to exactly one HMC. (Each HMC is under the control of its governing organisation, e.g. a vehicle manufacturer). The software applications may be requested from an authorised software supplier or - as shown - come from a service provider wishing to deploy a new service.

Figure 4 (right) shows clearly the distinction between information flows due to the normal operation of application services and software flows resulting from application software provisioning to a host from its host management centre.

Cooperative monitoring

The COMO sub-project is developing technology for collecting and delivering traffic-related data to any CVIS application that needs it, primarily through data gathered from moving "probe" vehicles, integrated with

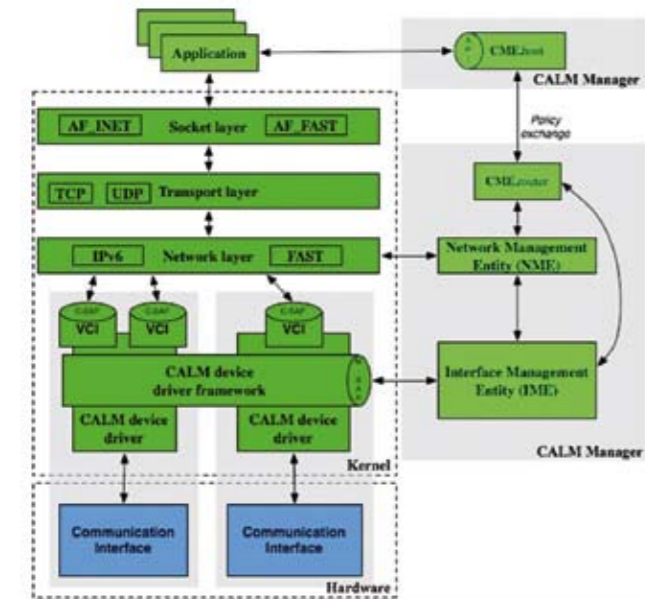


Figure 3: CVIS CALM management stack

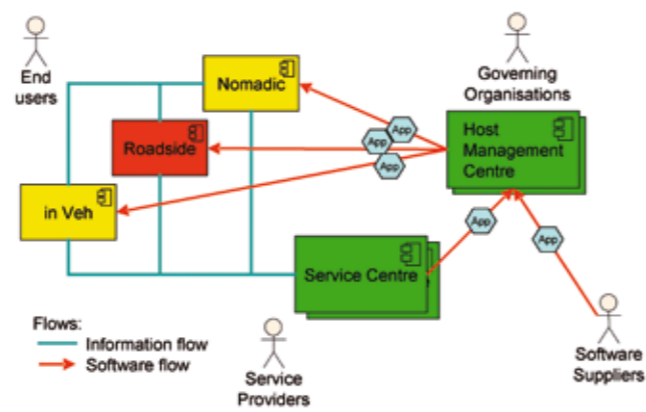


Figure 4 - Host management and service operation

data from roadside sensors and detectors. Since a great number of potential applications and services may need the same basic monitoring data, CVIS treats cooperative monitoring as a core service on call to applications. The use of COMO common specification and core software modules should ensure that data are interoperable across Europe, encouraging the development of an open market for traffic services.

COMO specifies the following data groups:

- 1) Vehicle sensor and/or processed data (such as XFCD/EFCD);
- 2) Roadside unit (RSU) sensor and/or processed data (such as loop or weather sensor data);
- 3) RSU local traffic status overview for the area around a given RSU;
- 4) Traffic centre traffic status overview for the area covered by a given centre.

To provide information with a high trustworthiness, COMO defines data fusion processes that guarantee that, wherever available, data from different sources - such as vehicles passing an RSU - will be used to provide the best possible quality of information.

In addition, COMO provides information on different levels, such as individual RSU and city traffic centre. As an example, a given RSU will provide a local traffic status overview containing more detailed information than the traffic centre's overview of the relevant area. A specific RSU might monitor traffic queues or turning rates for each lane at an individual signal-controlled intersection, while the traffic centre's overview might not contain data at a per-lane level.

The COMO data set will be extensible in order to cover future sensors and information, allowing for a wide area of applications to be defined in the future. COMO data sets can be accessed via a standard query interface. Additionally, CVIS applications can rely on subscription mechanisms which will provide COMO data according to specific rules, i.e. if new data sets of a specific kind become available.

Positioning and mapping

Other key sources of information to all CVIS applications are positioning and mapping facilities. Having an accurate position is crucial if it is to be used in traffic-related situations. The CVIS architecture describes two approaches to increased accuracy through use of

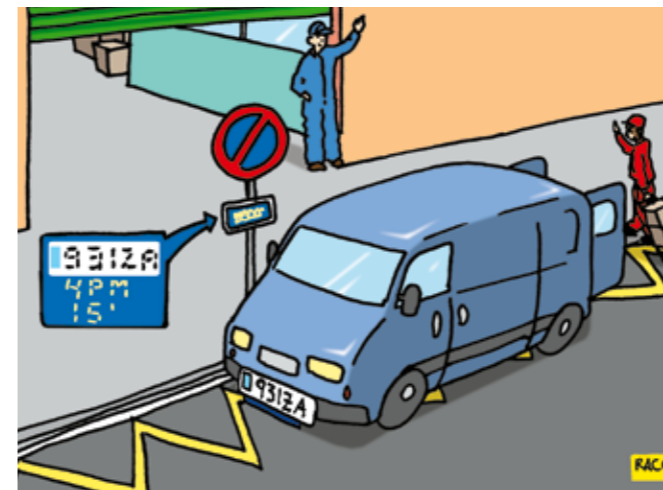


Figure 5: Typical CVIS applications

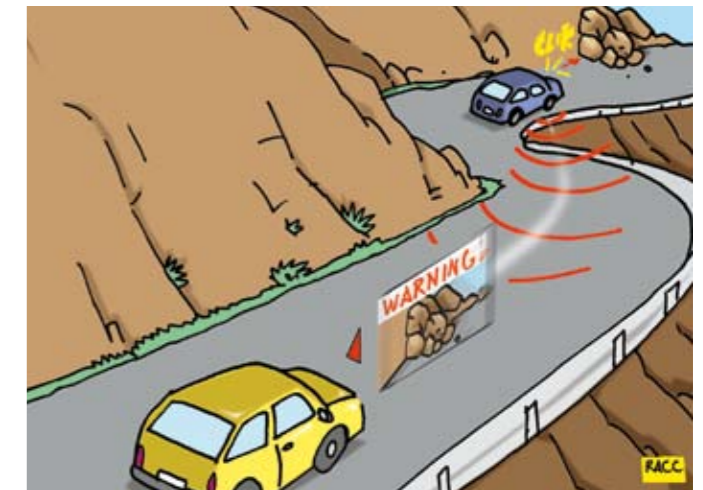
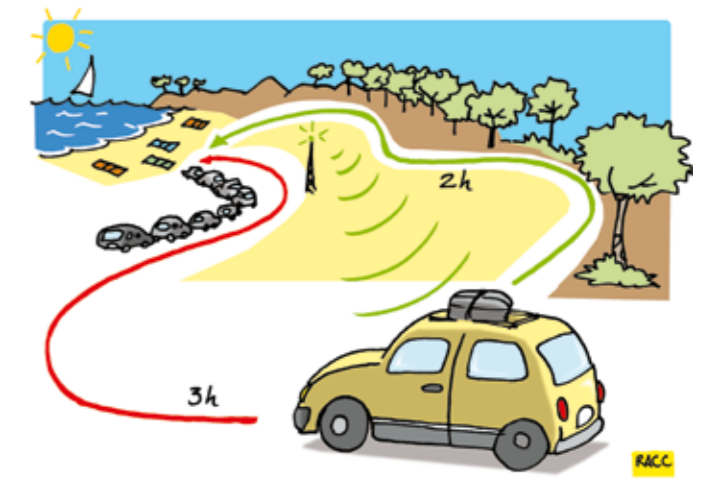
Wireless Local Area Network and Wireless Sensor Networks.

Concerning mapping, CVIS and SAFESPOT partners are working on an innovative approach for structuring near-environment information at certain locations. This new approach is called Local Dynamic Map, which is a layered database containing geo-referenced information about the static data, e.g. high accuracy map of an intersection, and dynamic data, e.g. information about other vehicles at the same intersection.

CVIS reference applications

CVIS partners are developing not only a technology platform but also reference applications whose aim is to demonstrate proof of concept that cooperation between different CVIS nodes leads to more safe and efficient transport. In addition to the unifying high-level architecture for the CVIS integrated project and a separate architecture view from each of the four core technology sub-projects, the three sub-projects targeting Urban, Interurban and Freight and Fleet applications have each developed an architecture concept for their own specific domain.

The application architecture is quite simple, but the application process is complex. The application is delivered using "standardised" software modules located in the vehicle and roadside hosts, and linked using the communication services described above. The same



principles apply to all the applications developed within CVIS, with the result that the project will make available a library of core application software that can be adopted (and adapted if needed) in order to establish future deployments relatively easily.

The challenges ahead

The CVIS consortium believes that it has built an architecture that should meet the needs of the majority of tenants who will come to inhabit the cooperative systems edifice. This includes the vehicle makers and their suppliers, governments and public authorities, traffic managers, road operators, fleet operators, service providers - and most importantly the final user (the motorist, the traveller and the transport business).

We welcome these stakeholders' interest, and feedback with their views of the value of the CVIS results. By closing this circle of cooperation all parties can work together to ensure that the resulting cooperative systems architecture is deployed successfully. TH

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