Hybrid Electronic Tolling Solution for France

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ABSTRACT

We present a new hybrid electronic tolling platform which is being introduced to France in 2013. The new French "écotaxe" system will be the first actual instance of implementing a real hybrid tolling system operating with both microwave and GPS-based technologies. In other words, Dedicated Short Range Communication (DSRC) and Global Navigation Satellite System (GNSS) technology will be used simultaneously, for different parts of the tolled road network. The new Hybrid On Board Unit (OBU) has been developed for new GNSS-based toll domains as well as for legacy toll domains based on proprietary DSRC interface protocols already in use in France.

Keywords: Global Navigation Satellite System, Hybrid Electronic Tolling, Hybrid On Board Unit, French Écotaxe System, Open Road Tolling.

1. INTRODUCTION

All over the world, many countries have a long history of tag and beacon DSRC solutions on their motorway networks, usually in combination with large toll plazas. Some countries have either launched new Open Road Tolling systems (often based on DSRC), or have begun to migrate their barrier-based systems to DSRC-based Open Road Tolling (ORT) solutions. France is now implementing an innovative new approach by keeping the existing tolling infrastructure on the concessionaire's routes and expanding the tolling policy on most of the national roads which have not been tolled at all up to now. The existing toll gates continue to operate with the DSRC "tag and beacon" approach, while the added national roads will be charged using GNSS with a very limited amount of new roadside infrastructure needed for the ORT solution. The French approach may very well start a new trend in countries that have already invested in a great amount of roadside infrastructure. In Europe there is a clear movement to introduce ORT schemes on a national level, particularly on heavy vehicles on all major roads.

Nationwide truck tolling schemes have already been introduced in Switzerland, Germany, Slovakia, Hungary, Austria, Poland, Belarus, and in the Czech Republic; half of these

countries have deployed DSRC technology, while the other half is already using GPS technology. This year Belgium and Russia have initiated their tender procedures for the creation of satellite-based systems for all trucks travelling on all major roads (i.e. not only motorways).

2. THE HYBRID APPROACH OF FRANCE

By the end of 2013, all trucks in France above 3.5 tons will be equipped with new Hybrid On Board Units, which will use GNSS technology for the automatic payment of tolls on the new tolled network of 15,000 km. These mandatory OBUs also contain a 5.8GHz DSRC microwave interface, allowing for the automatic payment at all of the existing toll plazas of motorways already subject to tolls (approximately 8,000 km in length). It is anticipated that over 800,000 new Hybrid OBUs will be distributed to the trucks driving in France, replacing the DSRC tags that are currently in use. Major toll providers in France will be offering the Siemens "plug and play" Hybrid OBU to their clients, illustrated in Figure 1, to enable them to travel on the new tolled roads – in addition to the existing ones. The new units can be installed by the driver in a matter of minutes, and will be provided to the vehicle owners free of charge.

Figure 1. The windshield-mounted "plug & play" Hybrid On Board Unit from Siemens

The intelligent Hybrid OBU developed by Siemens includes the following components:

- GPS module for tolling the national roads in France
- DSRC module for automated tolling of the concessionaire's routes as well as for enforcement and as an additional mode of tolling under free flow conditions.

- GSM module for the transfer of vital data between the OBU and the back-office;
- Motion detection for automatic OBU activation;
- Security Access Module (SAM) for secure and reliable data encryption;
- A host processor, for complex computational tasks such as section recognition (i.e. for an "intelligent client" OBU approach).

Figure 2 below illustrates the two different environments in which the Hybrid OBU operates. In the GNSS ORT approach, toll data is collected in the OBU based on the position information and sent via GSM to the proxy. On the other hand, at existing DSRC Toll Plazas, the OBU behaves like a DSRC tag and transmits basic vehicle data to the gantries which collect toll data and send them to the proxy. Both proxies send their respective toll calculations to the back end so that all tolls in both domains can be collected from the toll road users.

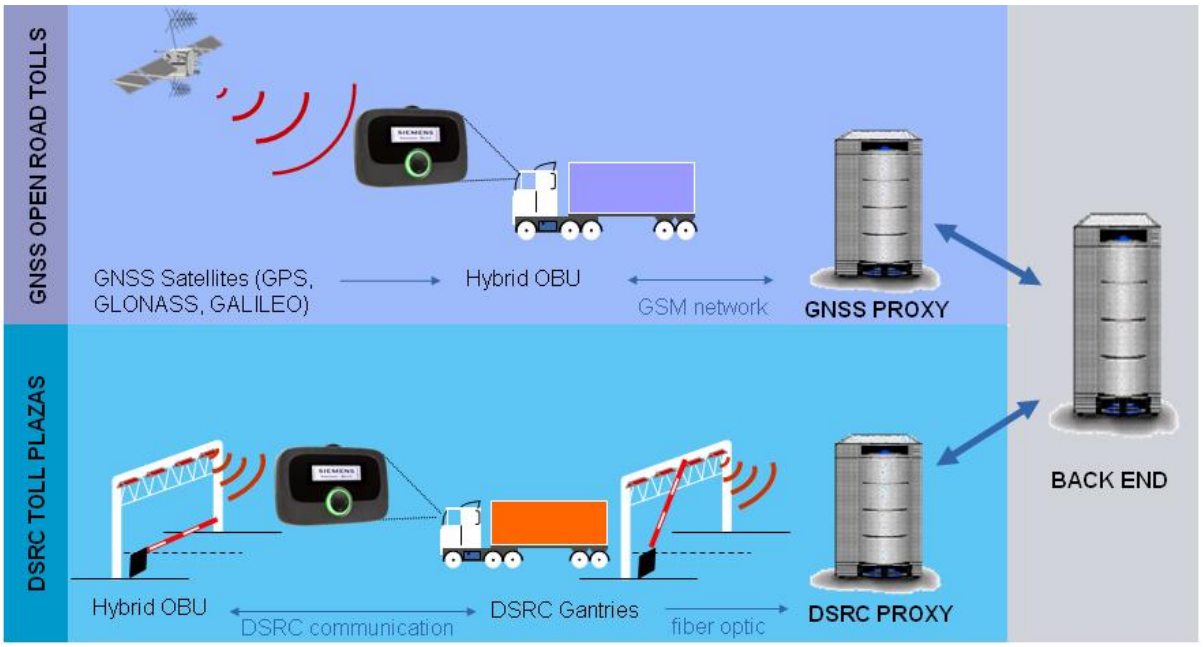

Figure 2. The new Hybrid OBU works in both the GNSS Open Road Tolling environment (above) and the DSRC Toll Plaza environment (below).

Other unique advantages of the Siemens Hybrid approach for France:

- Hardware and software specially developed to handle all new GNSS-based toll domains for Open Road Tolling on all major national roads;
- The ability to operate on all future toll domains based on new DSRC standards, as well as on existing toll domains based on the proprietary French "dialects" of DSRC;
- The DSRC interface is fully compatible with the Spanish VIA-T microwave standard;

- Data security during updates of the Hybrid OBU is much higher than with traditional DSRC tags and conforms to international cryptographic recommendations;
- Ample headroom is provided in the OBU hardware to tackle new toll domains and value-added services without any need to physically access the OBU;
- Local Augmentation Communication is implemented via the DSRC interface to enhance position accuracy of the OBU in the GNSS domain in areas where GNSS signals are not sufficiently available;
- The DSRC interface enables automatic electronic enforcement to be performed in both DSRC and GNSS domains, so that recent toll transactions can be read directly out of the OBU;
- Full remote control of toll domain capabilities: the OBU never needs to be returned for upgrading when new toll domains are added; all the necessary software and settings are updated over-the-air. This enables OBUs to be distributed directly from the factory to the Toll Service Providers. When the OBUs are installed in the vehicles, the personalization of the units is performed remotely at the push of a button in the toll provider's back office system;

3. ADVANTAGES OF EXTENDING DSRC SYSTEMS TO GNSS SYSTEMS

France has a long tradition of concession-based tolled motorways, and the new *écotaxe* GNSS system will be operated in parallel to and in combination with the existing toll-plaza based tolling systems. The advantages that the new GNSS-based extension of the tolling environment will bring include:

- Quick and easy changes to the tolled road network by simply updating the map information via air interface to the OBU;
- No additional or unexpected infrastructure costs if roads are upgraded and widened, or for road maintenance work, since roadside infrastructure is no longer required;
- The entire spectrum of "intelligence" can implemented on the Siemens Hybrid OBU, from very thin to very thick clients - in which, for example, the actual fees being charged for the travelled tolled sections can be shown in real-time;
- The deployment of any tolling paradigm considered appropriate for the task at hand, not only the "section-based" or "closed" approaches which are typically used in toll plaza environments or in ORT systems;
- Tracking the transportation of livestock or of dangerous goods;
- Traffic warnings (e.g. for adverse weather conditions in certain areas) can be issued via the Hybrid OBU;
- Real-time traffic information, road closure or accident announcements can be sent to the Hybrid OBU;
- Traffic safety features, such as an Emergency Breakdown Call feature, can be built into the Hybrid OBU platform;

- Pay As You Drive (PAYD) solutions for car rentals or insurance policies can be integrated into Hybrid OBU platform;
- The OBU platform can act as a navigation systems with integrated real-time traffic information and alternative routes, potentially saving time and money for drivers;
- External displays can be connected to the OBU via Bluetooth interface.

4. DATA SECURITY

The French *écotaxe* system requires a very high level of data security. In the new Siemens Hybrid OBU platform, reliability, confidentiality and integrity are ensured end-to-end through the application of cryptographic mechanisms at the level of message transfer between the OBU and the Proxy. The following technologies are used:

- encryption (for data for which privacy is required)
- hashing (for data for which integrity is required)
- signing (for data for which non-repudiation is required)

These measures are applied to data in both directions (from the OBU to the Proxy, and vice versa). At the transport layer, the following data security measures are employed:

- Within the GSM network, a private Access Point Name (APN) is used to ensure that no IP packets are forwarded between this address range and any other. Thereby, it is not possible for intruders to inject malicious data from the outside.
- Within the GSM network, a private Access Point Name (APN) is used. The resulting private Internet Protocol (IP) address range ensures that data packages sent either to or from the OBU can be clearly identified, thus ensuring the accuracy of the data transmission. Thereby, it is not possible for intruders to inject malicious data from external sources either to the OBU or the proxy.
- Between the termination point of the GSM network and the Proxy, a Virtual Private Network (VPN) is used, resulting in the same characteristics as described for the intra-GSM transfers above.

5. OBU HARDWARE

The main task of the OBU is to capture Road Usage Data from every vehicle liable to pay tolls, and to transmit the data to the back office for further processing. The Hybrid OBUs can be installed by the drivers within a few minutes; they are connected to the windshield by means of a glued holder. The OBU is permanently connected to the vehicle's power supply, either through a cigarette lighter connection or by fixed cabling. Once installed, the OBU operates completely on its own, establishing a communication link to the Proxy. The OBU is automatically switched on and off either through the connection to the ignition or by a

movement detector (when the power connection is made via the cigarette lighter). A built-in backup battery ensures that the OBU remains functional in case the main power connection is interrupted (either advertently or inadvertently). An illustration of all hardware components integrated into the OBU is provided in Figure 3.

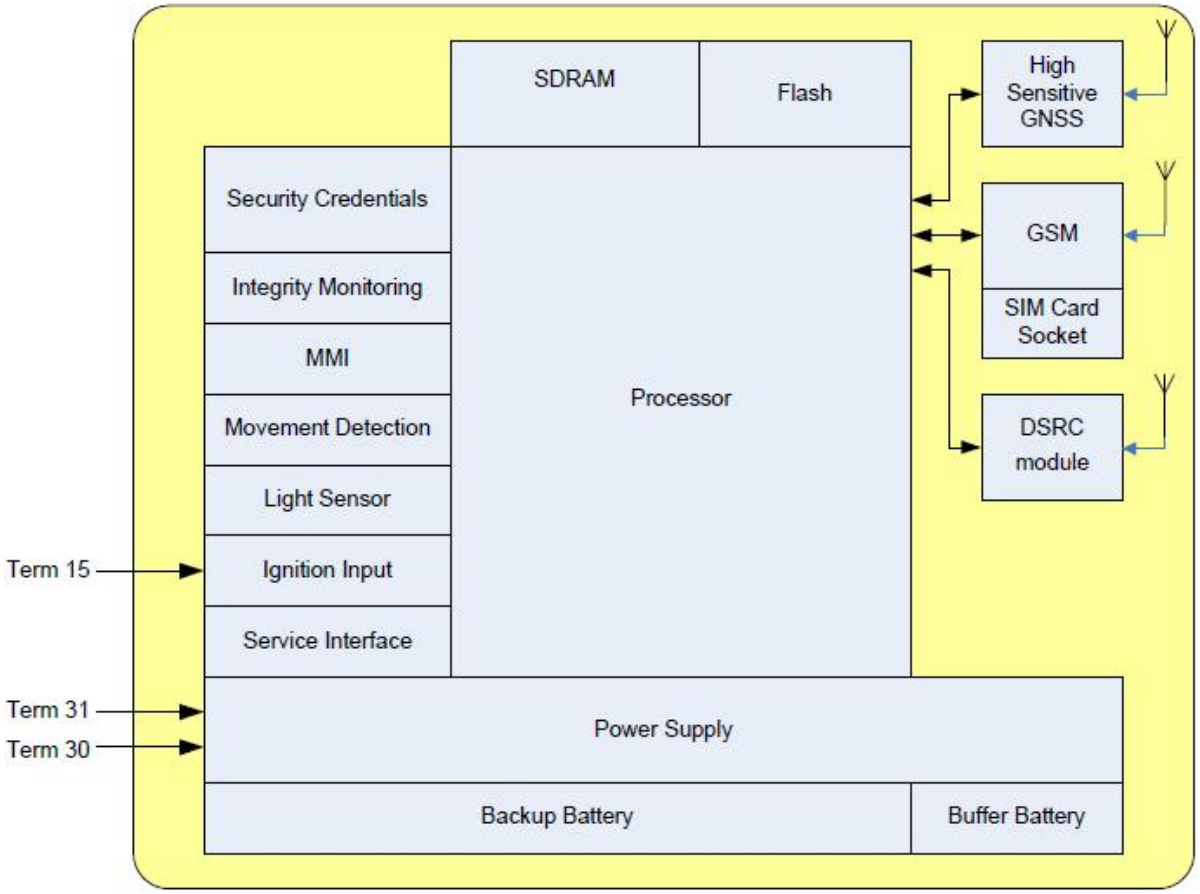

Figure 3: Block Diagram of the OBU Hardware Components

6. OBU APPLICATION ARCHITECTURE

The OBU software consists of two main parts:

- the basic software including the operating system, Java virtual machine, and low-level drivers;
- the toll application software.

All levels of software, including the firmware of the individual hardware components on the Hybrid OBU, can be updated remotely from the Proxy, over the air (via the GSM cellular network). This unique capability enables a significant flexibility of the tolling environment throughout the course of tolling operations, and helps to minimize operational costs. Furthermore, thanks to the overall system architecture, full remote control of the toll domain – as well as any additional services provided – is possible via the Proxy.

An application programming interface (API) provides all functionality required by the applications to make use of the hardware features of the OBU. The underlying Java technology (J2ME) assures a high degree of flexibility, maintainability and portability. Figure 4 gives an overview of the software architecture and its layers.

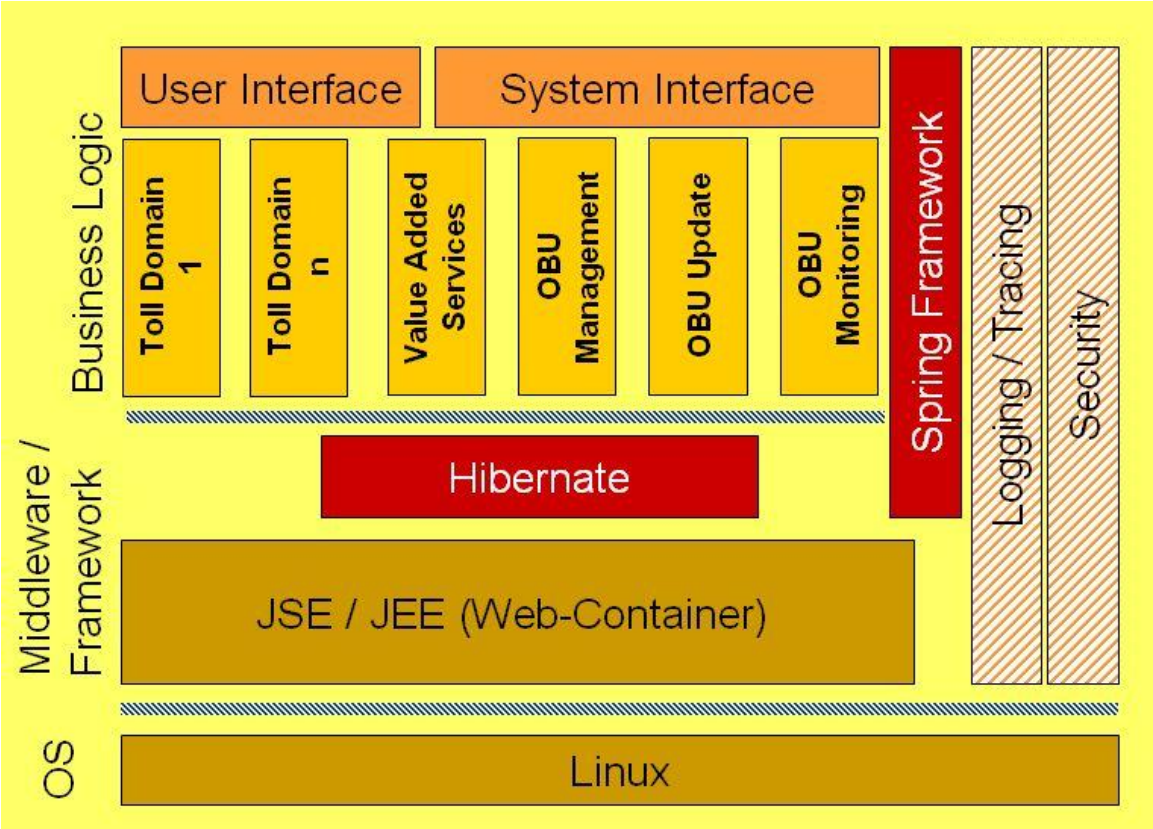

Figure 4: OBU Software Architecture

7. ADDITONAL SERVICES

The Hybrid OBU can be configured to send positioning data. This configuration could, for example, include:

- transmission of data depending on the location (i.e. data sent at specific locations of interest);
- transmission of data depending on certain events (e.g. when the driver presses a button on the OBU);
- configuration of the granularity of recorded positioning data.

Furthermore, information can be provided that can be used for other services, such as events recorded or determined by the front-end which can be used for:

- detecting accelerations exceeding certain limits (e.g. resulting in crash warnings);

- monitoring of GSM coverage for detection of blind spots.

Information provided by the OBU can be used as the basis for individual or global services. Depending on the service definition and the agreements of the affected persons, these services may be based on personal or anonymous data. Aggregation of information may open up a range of services in the interest of the public.

In order to be able to perform a clear separation of data, an architectural approach could be implemented as outlined in Figure 5.

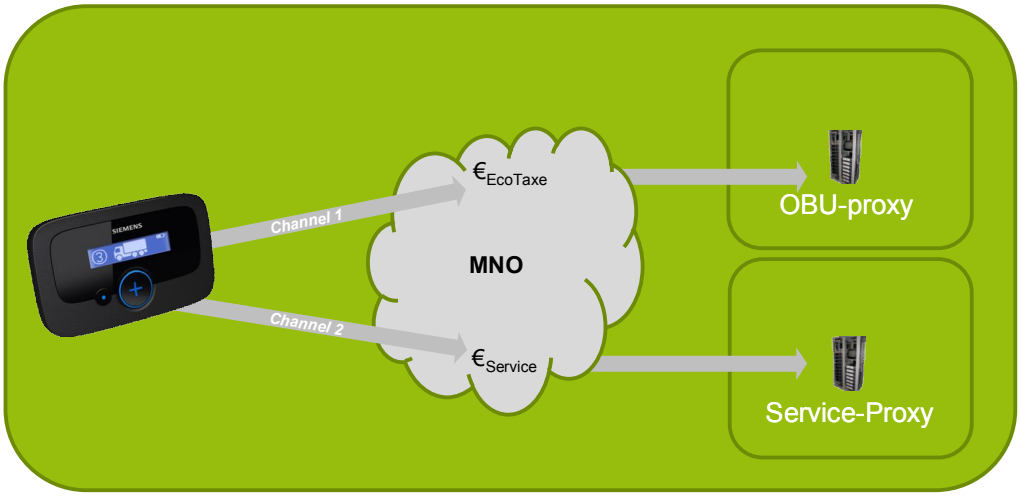

Figure 5: Potential Service Proxy Architecture

The service proxy can be deployed at the facilities of the Toll Service Provider or at the premises of a particular service provider. The independent logical data channel for data communication allows for clear separation from tax functionality.

8. CONCLUSION

France is implementing an innovative and comprehensive new tolling system that is interoperable with the existing tolling technology used for legacy toll systems (based on DSRC) and with the new tolled network of roads (based on GNSS). The French *écotaxe* system also supports the ability of multiple service providers to offer the tolling service to truck drivers and to truck companies, as required by law, as well as other "value-added" services. All current toll operators will now have the opportunity to participate in the *écotaxe* system with their own interoperable solutions. The Siemens hybrid solution is thus able to meet the multiple demands of the truck drivers as well that of the operators which need a highly reliable and secure mode of operation in order to ensure their revenue.