Partial networking for conventional and electric vehicles

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For all types of vehicles (conventional with combustion, electric, and hybrid engines), energy savings are important but driven by different aspects. In the conventional car, reductions in CO₂ emissions can be managed by reducing standby power through switching off electronic-control units not in use, which has environmental and tax advantages. Figure 1 shows optional units for this. However, in the electrical vehicles (EV) the operation range is increased by the efficient implementation of its energy management system. This controls the energy flow in the typical system states of the EV (driving, charging, and parked) and state transition.

Energy savings in CAN networks can be realized by “Partial networking” (PN) that introduces the new function “selective wake-up.” PN has been proposed by the Switch group, a group of carmakers and semiconductor suppliers, and is now on its way to become an extension to ISO 11898. Compared to existing products that conform to ISO 11898-5 CAN networks active even when these modules do not contribute to the minimum set of required functions. A mechanism is needed that allows functions to be switched on or off while other functions remain active and exchange data via the network. PN provides the necessary feature for networks to switch off modules to save their standby current and allows these to be quickly reactivated when needed.

Paradigm change in networking from conventional car to EV:

- Safety aspects dominate architecture and network choice (separation of voltage domains).
- Control network becomes an important means of energy management in the vehicle.
- Parts of the control network are always active.

As mentioned, some functions are always active (e.g. battery monitoring) and create bus traffic. This keeps modules in ISO 11898-5 CAN networks active even when these modules do not contribute to the minimum set of required functions. A mechanism is needed that allows functions to be switched on or off while other functions remain active and exchange data via the network. PN provides the necessary feature for networks to switch off modules to save their standby current and allows these to be quickly reactivated when needed.

What are trends in in-vehicle networking when we compare an EV to a conventional vehicle? To what extent can paradigms be sustained, which have been formed based on conventional vehicles?

The following summarizes the system challenges of an EV that have an impact on in-vehicle networking:

- Lifetime and safety – introduction of new safety-relevant embedded systems
- System complexity – new energy sources and new power trains result in new network demands
- Robustness – harsh automotive environment, fast transients in power electronics in electric drive
- Isolation towards human interface – high voltages (far above 60 V<sub>DC</sub>) across the in-vehicle network

The networks of conventional cars shut down when parked. For the EV, the battery charging time adds to the vehicle operation time. Furthermore, EVs have to be alert for critical situations such as failures in the system or in the high-voltage battery, for example, in case of a car crash. Thus the EV never sleeps completely and a minimum level of communication has to be and will be active almost around the clock.

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Figure 1: Units that can be temporarily switched off to save energy
Partial networking advantages

The use of PN in conventional cars is typically seen with comfort modules (functions) that can be switched off in many driving situations (see Figure 1). Moreover, PN also allows functions to be kept available when the ignition of the conventional car is turned off without draining the battery with unnecessary standby currents. Ease of implementation, robustness, and the associated costs are the major aspects to the successfully introduction the PN function in any types of cars.

To operate only a certain part of a network at a certain moment is called PN. See Figure 2, where a green box means a module is switched on, and a gray box means that a module is switched off (right car). In ISO 11898-5 CAN networks, all modules are switched on when at least two modules communicate (left car). Today, exceptions to this have been created by switching off the supply of a selected module or by using dedicated wake-up wires. These setups are hard wired and do not offer any flexibility with regard to their configuration. With PN, modules wake up by receiving a specific message sent via the network. Thus the configuration can be changed by means of a SW update.

Partial networking transceiver architecture

In order to realize the selective wake-up function, the receiving path of a CAN protocol controller including its clock source has to be integrated into a CAN PN transceiver. Since carmakers and Tier-1 suppliers require compatibility with standard transceivers in SO14 package, there is no option to connect an external oscillator, such as a crystal or ceramic resonator, to the transceiver. Such external components would also require more supply current than an integrated oscillator and thus would be in conflict with power-saving targets. Furthermore, it would add to the cost of and space required for a printed circuit board.

If activity occurs on the network that wakes up transceivers conforming to ISO 11898-5, the PN transceiver will not signal a wake-up event on its RXD and INH pins. However, it would activate the receiver, CAN decoder, clock-source oscillator, and message filter and logic comparison. If the bus remains silent for a certain period in time (<1.2 s), these blocks will be deactivated. The wake-up event is signaled on RXD and INH in case the correct wake-up message has been received.

Overall, the major challenge for the hardware implementation of PN is finding an on-chip oscillator design with a certain accuracy, i.e. with perfect compensation for temperature, supply-voltage variation, production spread, and aging in order to comply with automotive robustness requirements, which are even higher in the harsh environment of an EV.

Modifications in the network management

Besides hardware modifications, PN implementations require changes in the network management SW. This impacts different levels of the SW architecture. The related questions have been addressed in subgroup “Efficient Energy Management” of Autosar, and PN control functionality became available with Autosar release 3.2.1.

The CAN network architecture in the vehicle as well as the HW architecture on the module level do not change when PN is intro-

Initiators

German carmakers initiated the formation of the Switch (Selective Wakeable and Interopera-

ble Transceiver in CAN High-Speed) group. Semiconductor vendors (including NXP) and fur-

ther OEMs also joined this interest group. Be-

 tween July and December 2010, the group developed a draft for the extension of ISO 11898 and introduced a selective wake-up function. In short, a valid wake-up message is detected when the received ID matches a predefined CAN-ID, the received data length code matches the predefined data length code, and the received data field correlates to predefined data field content.

Figure 2: Vehicle without (left) and with partial networking (right)

Figure 3: Example transceiver architecture of TJA1145 for partial networking
Energy efficiency

**Summary**
- Partial networking is an excellent means for energy management and savings
- Multiple disciplines are involved in partial networking and standardization of HW and SW
- Robustness and the accuracy of the on-chip oscillator will be the key differentiators among the various PN transceivers
- EV establishes a need for extended energy management
- Partial networking contributes to all operation modes of EVs: driving, charging, and parked
- Paradigm change in networking: the shift from conventional vehicle to EV is from comfort to energy management
- Lifetime aspects in EVs are tremendously important due to embedded safety systems; parts of EV are always active

The PN transceiver with its selective wake-up function is responsible for detecting the wake-up event on the network and controls the activation of the voltage regulators for the entire module. This is identical to the operation of a standard transceiver according to ISO 11898-5.

Figure 4 shows how a standard high-speed CAN transceiver such as the TJA1043 can easily be replaced on a module level by a PN transceiver such as TJA1145. However, since the configuration of the wake-up message is necessary, the PN transceiver features a SPI interface instead of having error (ERRN) and mode-control pins (STBN, EN).

**Relevance of Partial**

![Diagram](Image)

**Networking for electrical vehicles**

Within the next decade, experts expect major improvements with regard to the power density of batteries. Needless to say that each “saved” watt-second directly contributes to the cruising range of an EV. PN makes an excellent contribution with a robust and reliable approach to the energy balance. The industry expects that power savings in a conventional car may add up to 100 watts. What this means for the extended cruising range depends on the EV characteristics and architecture.

In the early days of the Switch group, a decision about the basic wake-up detection mechanism was made. Two options were discussed:
- Detection by a CAN controller that is kept active while the rest of the microcontroller, in which it is nested, stops;
- Add a reduced-protocol engine to the silicon of the transceiver.

The expert community of the carmakers voted for the second option and thus limited changes to the entire system. With this, we anticipate that on the device level the above-mentioned product lifetime extension is applied to only one device, the transceiver, but not to the microcontroller, voltage regulators, capacitors, etc.

While the lifetime requirements for electronic components in EVs have not been concluded yet, a first indication from carmakers is to approximately triple the lifetime requirement. This will add to the product development life-cycle as well as to the final product cost for the device. However, it would be good if we limited the number of affected devices, and the PN draft standard does.

Robustness in vehicle networking is mainly immunity against injected RF energy. The Switch group has already defined dedicated EMC requirements for PN transceivers. The good news is that in the last years big steps in immunity improvement have been made and the acquired knowledge can also be applied to PN transceivers. The bad news is that experts see EVs emitting high voltage and high current transients, leading to hazardous electromagnetic fields. Thus adhering to the impulse immunity during operation in ISO 7637 might become one of the new challenges for the semiconductor suppliers.

What does robustness of PN in EVs mean in detail? Do wake-up messages have different levels of vulnerability than other messages? Yes, and the reasons are the following:
- Potential wake-up messages are received and decoded by a transceiver with an on-chip oscillator, which is likely less precise than the quartz of the attached µC that does the decoding during normal operation;
- Power consumption of the receiver is reduced to a very low value, which decreases the ability to suppress noise.

It is too early to compare robustness of “wake-up message detection in a PN transceiver” in all PN set-ups and implementation concepts, but it is clear that the critical factor is the on-chip oscillator and its resulting stability when confronted with distortions such as electromagnetic fields, ringing, sender-clock tolerances, and cranking pulses on the supply.
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