Partial Networking for CAN bus systems: Any saved gram CO_2/km is essential to meet stricter EU regulations.

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Different governments around the world are calling for massive reductions of CO_2 emission. In the EU by the year 2020, the average CO_2 emissions per passenger car should fall to 95 g/km. Hard measures and challenging technological advances are required.
The imposed EU limits are not achievable only with the optimization of conventional technologies. New methods dealing with an efficient and flexible power management are an urgent need.
Partial networking is one of these methods. It is intended to make it possible for a node or a sub-network to be woken individually by means of dedicated and predefined messages. When its tasks are not required it is in selective sleep mode. With this approach, a saving of almost one gram CO_2 per km is a realistic estimation for a middle-range car.
Since the beginning of 2010 a working group called SWITCH has been working to make partial networking for CAN bus systems an environmental and commercial success. The outcomes documents specified in the framework of this working group are currently in the ISO process.
Different concepts for partial networking as well as the achievements and standardization activities taken over by the SWITCH group will be presented in this speech.

Situation – CO_2 emissions from passenger cars in EU

After power generation, road transport is the second biggest source of CO_2 emissions in the EU. It contributes with more than 20% of the EU's total emissions.

In general the emissions from other sectors are decreasing, but road transport is one of the few sectors where emissions are still rising. Between 1990 and 2008 the emissions from road transport increased by 26%. This increment breaks the progress in cutting the overall emissions of greenhouse gases, which fell by 7%.

Passenger cars alone are responsible for around 12% of EU CO_2 emissions. Even though there have been significant improvements over recent years in vehicle technology and fuel efficiency, these improvements have not been enough to balance the effect of increases in traffic and vehicle size.

For that reason the EU proposed in 2007 and adopted in April 2009 by the European Parliament and the Council, the current regulation to improve the fuel economy of cars and ensure that average emissions from new passenger cars in the EU do not exceed 120gCO_2/km.

Regulation – Target based on the fleet average mass

Each manufacturer gets an individual annual target based on the average mass of all new cars registered in Europe in the given year. The limit value of this curve is set in such way that a fleet average of 130 grams should be achieved for the EU as a whole.

It is important to point out that only the fleet average is regulated, so manufacturers will still be able to make vehicles with emissions above their targets if these differences are compensated by other vehicles which are below the targets. The limit curve formula for the permitted specific emissions of CO_2 is:

130 + a × (M – M0)

M = mass of the vehicle in kilograms
M0 = 1289.0, average mass of new passenger cars in the previous 3 years
a = 0.0457

Emissions from heavier cars will have to be reduced by more than those from lighter cars.

The 130 grams target will be phased in between 2012 and 2015.
As of 2012, manufacturers must ensure that 65% of the new cars registered in the EU have average emissions that are below their respective targets. The percentage rises to 75% in 2013, 80% in 2014 and 100% from 2015 onwards.

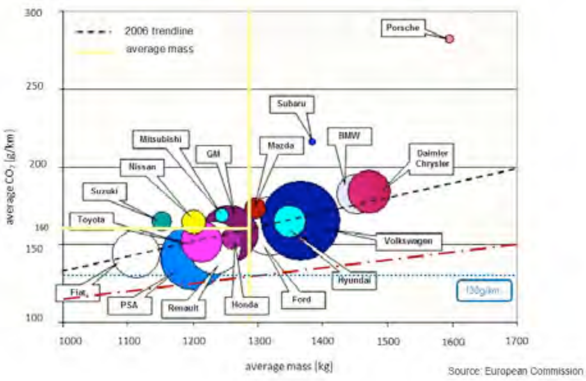

Figure 1: Position car manufacturers in 2006 – CO_2 emissions of new cars

The Figure 1 shows the position of the car manufacturers of the new cars produced in 2006, the year on which the Regulation's impact assessment was based.

The average mass in 2006 was slightly below 1300 kg and the average emission was about 160g CO_2 per km.
The 2009 report disclosed that more brands reached the (now expired) 2008 140 g/km goal: Fiat (127.8 g/km), Toyota (130.1 g/km), Peugeot (133.6 g/km), Renault (137.5 g/km), Citroen (137.9 g/km) and Ford (140.0 g/km). Fiat, however, was the only brand to reach the 2015 goal of 130 g/km, 6 years in advance. The Fiat Auto Group (including the Fiat, Alfa Romeo, Lancia, Abarth, Ferrari and Maserati brands) averaged to 131.0 g/km.

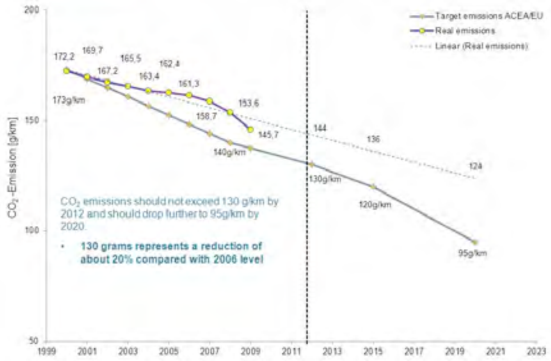

Figure 2: Targets, real emissions and trend

In the Figure 2 we can see the evolution of the different targets, real emissions till 2009 and a linear trend based on real emission from 2000 to 2020.

A voluntary agreement between the European Automobile Manufacturers Association (ACEA) and the European Commission was signed in 1998 to achieve an average of 140 g/km of CO_2 by 2008.

The target was not achieved; the average for the whole car market for 2008 was 153.6 g/km.

In the current EU Regulation the average CO_2 emissions from cars should not exceed 130 grams CO_2 per km phased in between 2012 and 2015 and should drop further to 95g/km by 2020.

If the average CO_2 emissions of a manufacturer's fleet exceed its limit value in any year from 2012, the manufacturer has to pay a penalty for each registered car. This premium amounts to €5 for the first g/km of exceedance, €15 for the second g/km, €25 for the third g/km, and €95 for each subsequent g/km. From 2019, already the first g/km of exceedance will cost €95.

Necessary measures for a sustainable CO2 strategy

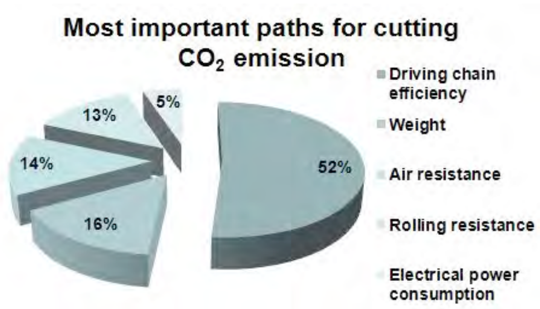

Figure 3: Most important paths for cutting CO_2 emissions

The most important paths to cutting CO_2 emissions are: engine parameters, weight, aerodynamic drag, and rolling resistance.

For example, reducing a car's weight by 100 kg leads to lower CO_2 emissions in about 8.5 g/km. A continuous growth of the use of plastic in automotive parts (chassis, exterior and engine) is observed, having a strong impact on the weight decrease.

As rule of the thumb, reducing a car's power consumption by 10A leads to lower CO_2 emissions in about 3.5 g/km.
More efficient energy management system has a great saving potential. This includes regenerative braking systems as well as thermo-electrical generator, especially if we consider that almost 35% of the thermal energy from exhaust-gas gets lost in heat.

Hard measures and challenging technological advances are required. The first conventional optimizations start with weight reduction, reduction in tire rolling resistance or improvements in aerodynamics and start-stop systems plus a gradual electrification of new vehicle fleet.

Increment of automotive electronics

Automotive electronics is still a strong growth market. The trend of the world demand of automotive semiconductors estimates a growth of 11.2 % per year, from 2010 to 2015. This trend is confirmed by:

- Average power requirement today is approx. 3 kW; a quadruplication in the last 10 years.
- Customer requirements in the areas of safety, increased comfort and easier handling are still intensifying this trend; the number of ECUs is still increasing.
- As with other forms of propulsion the significance of electronics is increasing rapidly.
- Many mechanically based functions will in the medium term be replaced by software-based mechatronic functions in mechatronic products.

The higher the increment of automotive electronic, the higher the power consumption and the more significant are more efficient power management systems.

Partial networking – The idea and motivations

Many ECUs consume power even if they are not needed; several ECUs are not required 95% of the travel time and each inactive unit, which is only waiting for an eventual request, consumes around 2 W.

With partial networking the ECU or the cluster can remain in selective sleep mode without wasting energy when the respective tasks are not required.

Partial networking is a method intended to make it possible for a node or for a cluster to be woken individually by means of dedicated and predefined CAN messages instead of woken by any activity on the bus as defined in ISO11898-5.

The adoption of this method does not require modifications of the existing network architecture neither external crystals nor additional components.
Potential candidates for partial networking include parking assistance systems which will not be used with a speed exceeding 20 km/h. Also, seat control modules are actively used only in very rare occasions, and even mirror, door and roof control modules will not often be used and can

remain in selective sleep mode for the rest of the time.

Partial networking – Potential CO2 savings

Figure 4: Modern cars may have > 70 ECUs.

With this approach, a saving of almost one gram CO_2 per km is a realistic estimation for a middle-range car assuming fifteen potential ECUs and considering an average current consumption of 250 mA in active mode and 50 µA in selective sleep mode.

This saving is significant keeping in mind that stricter penalties will be introduced from 2019 with each exceeding gram costing the manufacturer 95 EUR.
Ricky Hudi, managing E/E director at Audi, has public announced in favor of this technology at an automotive conference held in Ludwigsburg, Germany, in June 2011.

“CAN Partial Networking is an area where we see great potential for energy saving…” “In addition, intelligent wake-up concepts improve the lifetime of ECUs and increase the operating reach of electrical vehicles. Audi and Volkswagen corporations have therefore started to introduce Partial Networking into the next generation of car models. Audi estimates a mid-term reduction potential on CO2 emissions of about 2.6 g/km and fuel savings of 0.11 litres/100km, when using CAN Partial Networking.”

In addition, partial networking offers different advantages in several application areas:

1. Reduction of CO_2 emission and energy consumption
   - Unused ECUs remain in sleep mode during driving cycle
   - Increased cruising range for electric and hybrid-vehicles

2. Shorter operating time of ECUs
   - Avoidance of higher lifetime requirements for ECUs in electric and hybrid-vehicles no needed during charging cycle.

3. Optimizations of operational strategy during “ignition-off”
   - Improving on the one hand the comfort functionalities and on the other hand reducing the strain on the battery during “ignition off”.

Partial networking – Basic principle

Existing transceivers compliant to ISO 11898-5 could be split mainly into two different modes of communication:
- A low-power sleep mode and
- A normal mode.

If the transceiver is in sleep mode, it will interpret any CAN communication as a wake-up event and will leave the sleep mode. Therefore it is not possible for the device to stay in sleep mode while CAN communication is ongoing.
That is the gap which is filled by the new transceiver generation having selective wake-up functionalities. There is the conventional low-power sleep mode while no communication is present and there is a new low-power mode that allows to stay asleep even in case of ongoing CAN communication.

Figure 5 shows the difference between the new transceiver and the transceiver according to ISO 11898-5.

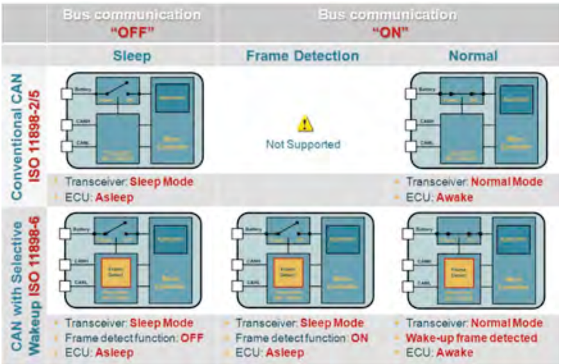

Figure 5: Transceiver modes

If the new transceivers are in the new low-power modes, wake-up events will be detected by occurrence and detection of dedicated CAN messages.
This implies for the transceiver state diagram a new low-power mode with the new wake-up behavior.
There is the conventional sleep mode with wake-up pattern as wake-up sources and the new selective wake-up mode with dedicated wake-up frames as wake-up source.
Figure 6 depicts a potential transceiver state diagram with implemented new low-power mode with selective wake-up function.

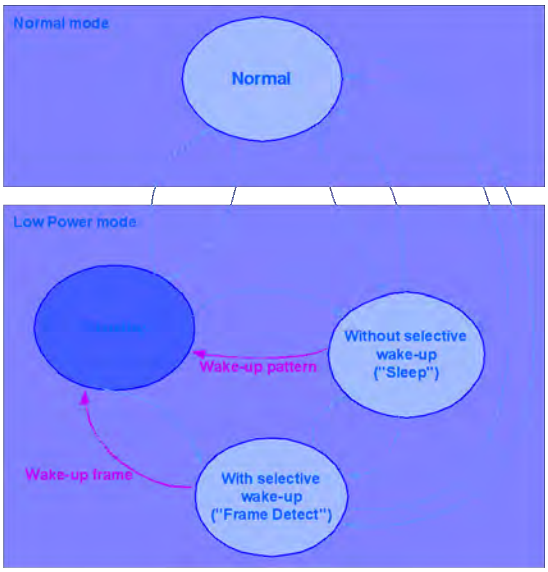

Figure 6: Potential transceiver state diagram

New functions have to be added to the transceiver to realize the new behavior. The following potential sequence shall describe the interaction of the different new transceiver parts:

- If the transceiver is in low-power mode with configured selective wake-up a decoding unit using an internal oscillator will decode the CAN communication.
- A compare logic compares the decoded frame with the configured frame.
- If the decoded frame matches to the configured frame a wake-up event occurred which will result in a change of the transceiver state.
- Furthermore there could be erroneous communication on the bus or frames could be decoded with errors. This can be detected by an error management which is responsible for the receive error counter.
- In case of a receive error counter overflow the transceiver will wake-up.

The biggest challenge is the implementation of the internal oscillator which fulfills the further below explained requirements.

SWITCH group – A success story

To define all necessary requirements unambiguously, a group of experts was founded in 2010.
This group is called SWITCH group which stands for „Selective Wake-up and Interoperable Transceiver in CAN High Speed.

The outcomes of the group are:

- The draft for the ISO 11898-6 which defines the CAN physical layer for partial networking.
- The draft for the ISO 16845-2 which defines the conformance tests according to the ISO 11898-6
- the OEM hardware requirements for partial networking (v 2.1) which completes the requirements for transceiver for partial networking
- the single device and system interoperability tests according to the OEM hardware requirements

The SWITCH group is composed of experts of the OEMs: Audi, BMW, Daimler, Porsche, PSA and Volkswagen; as well as of experts of the semiconductor suppliers: Elmos, Freescale, Infineon, NXP, and STM and C&S as the chairman of the group.

The SWITCH group concluded its work in the middle of 2011 by consigning the drafts of the new ISO specifications to the corresponding ISO task force for the further ISO standardization process.

Key features of the new requirement documents (draft for ISO 11898-6 and OEM Hardware requirements)

The draft for the ISO 11898-6 could be split mainly into four different main aspects:

- the definition of the enhanced biasing during reception of an wake-up pattern
- the transceivers CAN bus decoding capabilities
- the validation criteria when does a frame shall be seen as a valid wake-up event
- and the definition of an error counter

Enhanced biasing:
The biasing is enhanced compared to the definition of the ISO 11898-5. When the biasing of the device is turned off and CAN communication takes place on the bus, a detailed definition of the different states during the reception of a wake-up pattern are defined including its timing restrictions.

CAN decoding capabilities:
Once the biasing is turned on the device shall decode the CAN bus communication to detect wake-up frames. As it is mentioned above one main challenge for the semiconductor suppliers is to implement the internal oscillator. The decoding of the CAN communication is simplified because requirements are not as strict for a receive-only-device and to make internal oscillator solutions possible. The draft of the ISO defines the limits for a correct decoding.

Wake-up frame validation:
The draft of the ISO 11898-6 defines what parts of a decoded frame are relevant for detecting a wake-up event and what are not relevant. The transceiver can be configured via a host interface with the ID (standard and extended), the DLC and the data bytes.
With help of an ID mask, relevant bit positions can be set and used for the ID validation. This allows defining groups of IDs to be valid for wake-up frames.
The DLC has to be equal in configured and received DLC. For the data field bytes, at least one logic 1 bit must be equal in the configured and received frame. This enables the masking of wake-up groups (or clusters).

Not relevant for considering frame as a valid wake-up condition are the ACK slot and the End of Frame field.

Error counter:

To be robust against communication with errors or decoding failures an error counter is implemented. This deals as a fall back strategy that at least, if there is too much erroneous communication on the bus, the ECU will wake-up and the µC will take over the error handling.

The OEM hardware requirements concentrate on the definition of different status flags that can be read out by the host as well as the definition of the different transceiver modes.

To bring backward compatibility the transceivers are pin compatible regarding the communication related pins.
This implies as well lower migration costs.

Conformance testing procedures

The test system and test philosophy are based on an OSI layered test approach and follow further requirements of the ISO 9646.

The test cases of the draft of the ISO 16845-2 could be split mainly into two groups. The parameter tests for the physical layer parameters which are static test cases and the protocol related test cases covering the ability to decode CAN frames correctly, as well as to check the wake-up condition correctly and the operating of the error management.

The test cases of the OEM hardware requirements test specification could be split into two groups of tests as well. On the one hand there are the single device tests covering the correct implementation of the host interface, the mode control and the status flags. On the other hand are the interoperability tests following a system test approach in a defined network. Goal of the system tests are the backward compatibility to ISO 11898-5 and 11898-2 transceiver devices as well as the observation of system behavior including stress scenarios.

Several devices were already tested by C&S group.

Ongoing ISO process for international standards

After the acceptance of the New Work Item Proposals (for ISO 11898-6 and ISO 16845-2), submitted last year by the SWITCH group, a group of international experts have joint the Task Force 6, of the Working Group 1 of the ISO standardization entity to discuss the proposals. Technical issues are here under discussion. Figure 7 shows the different stages of an ISO standardization process.

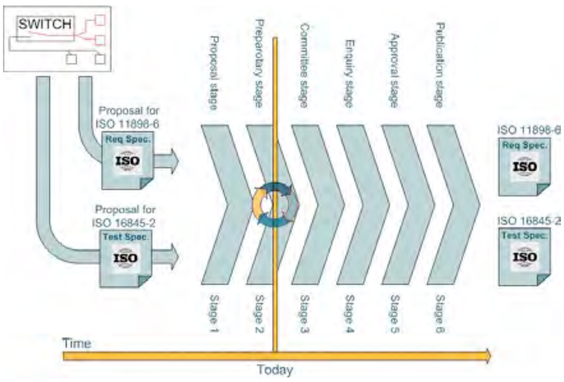

Figure 7: ISO standardization process

The proposals of the ISO 11898-6 and 16845-2 are on a good way to enter soon in the next standardization stage.

Conclusions

The car manufactures are faced with the dilemma that on the one hand there are hard regulations calling for continuous and massive reductions of CO_2 emissions and on the other hand there is a continuous increment of electronics and demand of electrical power consumption.

The imposed EU limits regarding the maximum allowed CO_2 emissions per km are not achievable only with the optimization of conventional technologies. New methods dealing with an efficient and flexible power management are an urgent need; technical improvements are required to avoid strict penalty payments.

One concept of improving the energy management and dropping the electrical power consumption is partial networking. With partial networking the ECU or the cluster can remain in selective sleep mode without wasting energy when the respective tasks are not required. Calculations lead to a potential saving of up to 2.6g CO2 /km. The adoption of this method does not require modifications of the existing network architecture neither external crystals nor additional components.

The necessary enhancements, to make partial networking possible for the CAN networks, were drafted and defined within the SWITCH expert group. Now the outcomes documents specified in the framework of this group are in the ISO process to develop international standards.
Several transceivers of different semiconductor manufacturers were tested by C&S and are already available on the market.

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