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# *RoJAE*

## Romanian Journal of Automotive Engineering

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**SIAR**

*The Journal of the Society of Automotive Engineers of Romania*  
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# RoJAE Romanian Journal of Automotive Engineering

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Society of Automotive Engineers of Romania  
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Founded in January 1990 as a professional association, non-governmental, SIAR's main objectives are: development and increase the exchange of professional information, promoting Romanian scientific research results, new technologies specific to automotive industry, international cooperation.

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In order to help promoting the science and technology in the automotive industry, SIAR is issuing 4 times a year rIA - Journal of Automotive Engineers (on paper in Romanian and electronically in Romanian and English).

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## CHASSIS OPPORTUNITIES FOR THE FUTURE – UNIQUE ACTUATORS & APPLICATIONS SOLUTIONS MADE BY SCHAEFFLER

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**Abstract:** *The actual technologies in terms of driver assistance and the future technologies of autonomous driving, brings forward the need of mechatronic chassis systems. In the 1990s Schaeffler began development of mechanical actuators (ball screw drive, small planetary gear, cylindrical gear units and the bearing support for the entire module) for electromechanical brakes. Nowadays the Electromechanically Active Roll Stabilizer already defined his presence on the market. Within this paper are presented Schaeffler's unique solutions for all this challenges in the area of vehicle roll stabilization , ride height adjustment, steering, damping and wheel bearings.*

**Key-Words:** *Electromechanical actuator, chassis system.*

### 1. INTRODUCTION

When it comes to developing chassis, today's challenges go far and above the traditional conflict of having a comfort-based and sportive set-up.

A whole host of benefits is associated with electrification of the chassis.

The actual technologies in terms of driver assistance and the future technologies of autonomous driving, brings forward the need of mechatronic chassis systems.

Above that, the emission regulation calls for energy efficient systems.

From this point of view the electromechanical actuator comes with the advantage of power on demand and higher efficiency compering with electro-hydraulic systems.

Last but not least cost efficient systems is nowadays a big challenge of the market.

In the 1990s Schaeffler began development of mechanical actuators (ball screw drive, small planetary gear and cylindrical gear units and the bearing support for the entire module) for electromechanical brakes. Nowadays the Electromechanically Active Roll Stabilizer (emARS) already defined its presence on the market.

Figure 1 shows the technologies and their penetration in the individual vehicle segments.

#### 1.1. Requirements of chassis of the future

Stringent requirements regarding CO2 reduction also mean that chassis technology will have to utilize the potentials provided by lightweight construction, friction reduction and more efficient actuators [1].

This is accompanied by the use of new materials or existing materials with optimized characteristics in terms of rigidity and strength.

What's more, many chassis systems are also used as a way of making vehicles stand out within a platform. Figure 2 shows an overview of the current trends.

Nowadays, buzzwords such as connectivity, autonomous or semi-autonomous driving have a considerable bearing on chassis development [2].

Related to this development is, ultimately, a modified safety strategy; for instance extended latency periods requiring the basic mechanical function to be protected.

This protection may also necessitate enhanced or additional redundancy/safety state. In light of these possibilities, new requirements will be demanded of existing actuators.

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Characteristic	Function	Segment				
		A Sub A	B B-SUV	C C-SUV	C/D CD-SUV	D D-SUV
Lateral dynamics	Electric steering	S	S	S	S	S in future
	Anti-roll system				O	O
	Rear-wheel steering				O	O
	Superimposed steering				O	O
	Torque vectoring					O
Vertical dynamics	Variable dampers		O	O	O	S
	Air springs				O	S/O
	Level control		O <sup>2)</sup>	O <sup>2)</sup>	O <sup>2)</sup>	
	ABC (active body control)					S/O
Longitudinal dynamics	Electronic parking brake		S/O	S	S	
	Electronic brake booster	S <sup>1)</sup>	S <sup>1)</sup>	S <sup>1)</sup>	S in future	S in future
Driver assistance system	Lane departure warning			O	O	O
	Emergency braking assist		O	O	O	O
	Traffic jam assist			O	O	O
	....					
Self-driving vehicles						2017/18 <sup>3)</sup>

S = standard feature  
 O = optional feature

<sup>1)</sup> will be standard feature on electric vehicles  
<sup>2)</sup> SOP = 2017 onwards

<sup>3)</sup> Semi-self-driving

Figure 1. Chassis technologies and their penetration in various vehicle segments

Drivers	Urbanisation		Product differentiation	
Trend	Reduction in CO <sub>2</sub> emissions	Affordable travel	Comfort and safety	Driving pleasure
Measures	e-mobility/hybridisation	Platform strategy	Self driving vehicles	Extension of platform strategy functions
	Friction reduction	New chassis layouts/concepts	Network/connected driving	New chassis applications
	Lightweight design	Cost optimised solutions	New vehicle concepts	New vehicle concepts
	Demand-based control	Car sharing	New chassis applications	
	Energy recuperation		Technology aimed at older drivers	

Figure 2. Trends in chassis technologies

What's more, actuators, sensors and systems are increasingly networked to generate new overarching functions, to increase availability and to improve safety.

This could be achieved, for instance, by a mutual plausibility in the context of a safety concept according to ISO 26262. Key elements of the future thus include cameras, sensors, antennas, as well as corresponding software for networking in the vehicle and with the environment [3].

Of key importance is the increase in the use of camera and radar-based as well as laser-based systems. These systems include polarizing and infra-red cameras, in addition to stereo ones. Used in combination with information regarding temperature and humidity, it is possible to detect aquaplaning and black ice.

## 2. CURRENT SCHAEFFLER SOLUTION

### 2.1. Weight reduction products

In the wheel bearing area, the market has seen a gradual introduction of lightweight construction solutions with face spline and weight-optimized flange design.



The technology is becoming increasingly popular and is well on the way to setting a new industry standard in the foreseeable future – a standard that Schaeffler will have created. Figure 3 shows a comparison of a third-generation wheel bearing in its previous design and one with face spline.

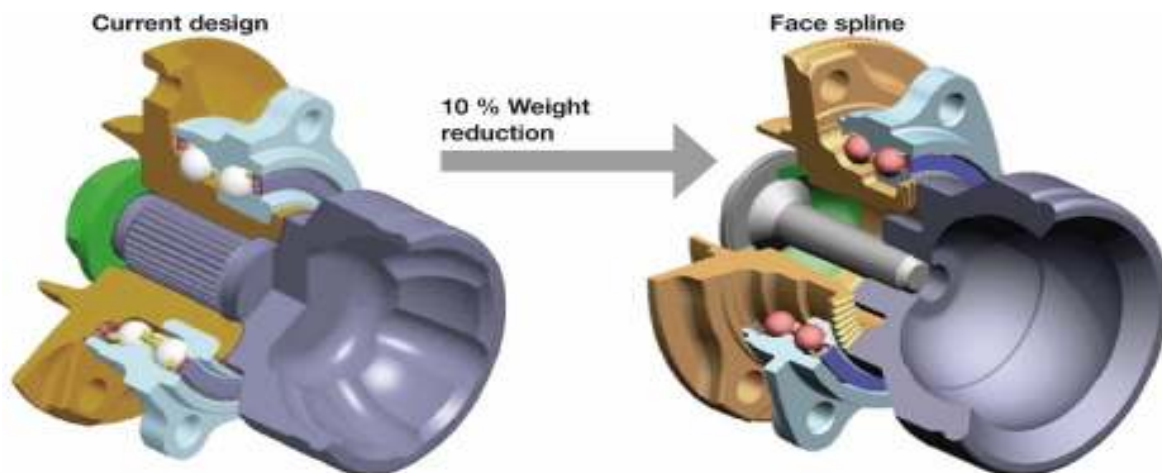


Figure 3. Wheel bearing with face spline design compared with actual internal gear teeth design

The benefits from this technology, such as 10 % rigidity increase, 10 % weight reduction, 50 % higher transferable torque as well as a reduction in unsprung mass yet still with simple assembly process, have been utilized in series applications since 2009.

An additional measure for reducing weight comes about by cutting the bearing flange weight while maintaining its rigidity.

By applying numerical procedures, it has already been possible to make weight reductions of 20 % without compromising the axial rigidity.

Figure 4 shows a wheel bearing with a weight-optimized flange compared with a conventional bearing flange. The result is optimized tension curves, which have also been used as a basis for an enhanced fiber flow of the flange. It is feasible to use driven and non-driven axles.

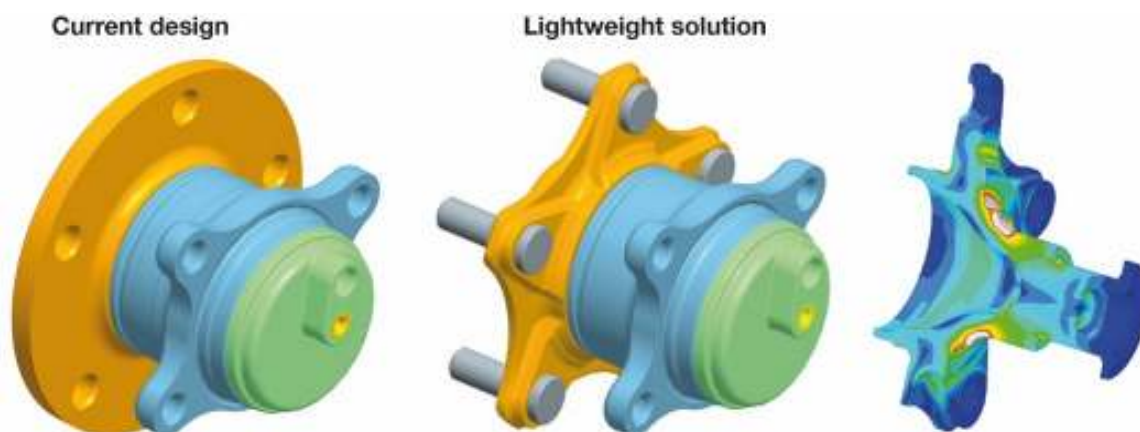


Figure 4. Comparison of a current wheel bearing with weight-optimized flange

## 2.2. Friction reduction products

Seal friction determines wheel bearing friction to a great extent, which is why it makes sense to start there with measures designed to reduce friction.

The wheel bearings offered by Schaeffler can be fitted with low-friction seals, which reduce friction by around 50 % compared to seals offered by competitors.

This 50 % reduction thus makes it possible to cut CO<sub>2</sub> emissions by around 1 g/100 km.

It is worth mentioning that the sealing effect is still the same compared with today's conventional two and three-lip seals (Figure 5).

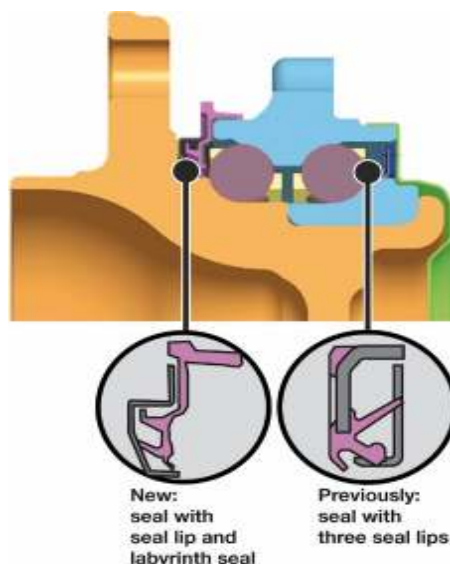


Figure 5. Comparison of conventional seal with a friction-reduced seal

### 2.3. Mechanical actuators with ball screw drive for chassis applications

Many linear actuators are equipped with a ball screw drive as a mechanical actuating element. Schaeffler launched a ball screw drive for electromechanical power-assisted steering on the market as far back as 2007. This steering ball screw drive is designed along the lines of the principle of modular design and can cover a wide range of applications. It provides a virtually constantly high degree of efficiency of more than 90 % over the entire temperature range and is supplied together with a four-point support bearing. Ball screw drives and support bearings designed to meet customer requirements of minimized backlash can be provided. In parallel to this, a compact ball screw drive with a pitch diameter of up to 4 mm has been developed; this compact version has been used by Continental in its electric parking brake since 2011. Other applications based on this design are currently in the development phase — for instance, application in the electromechanically operated brake booster.

Figure 6 shows other potential applications for the compact ball screw drive.

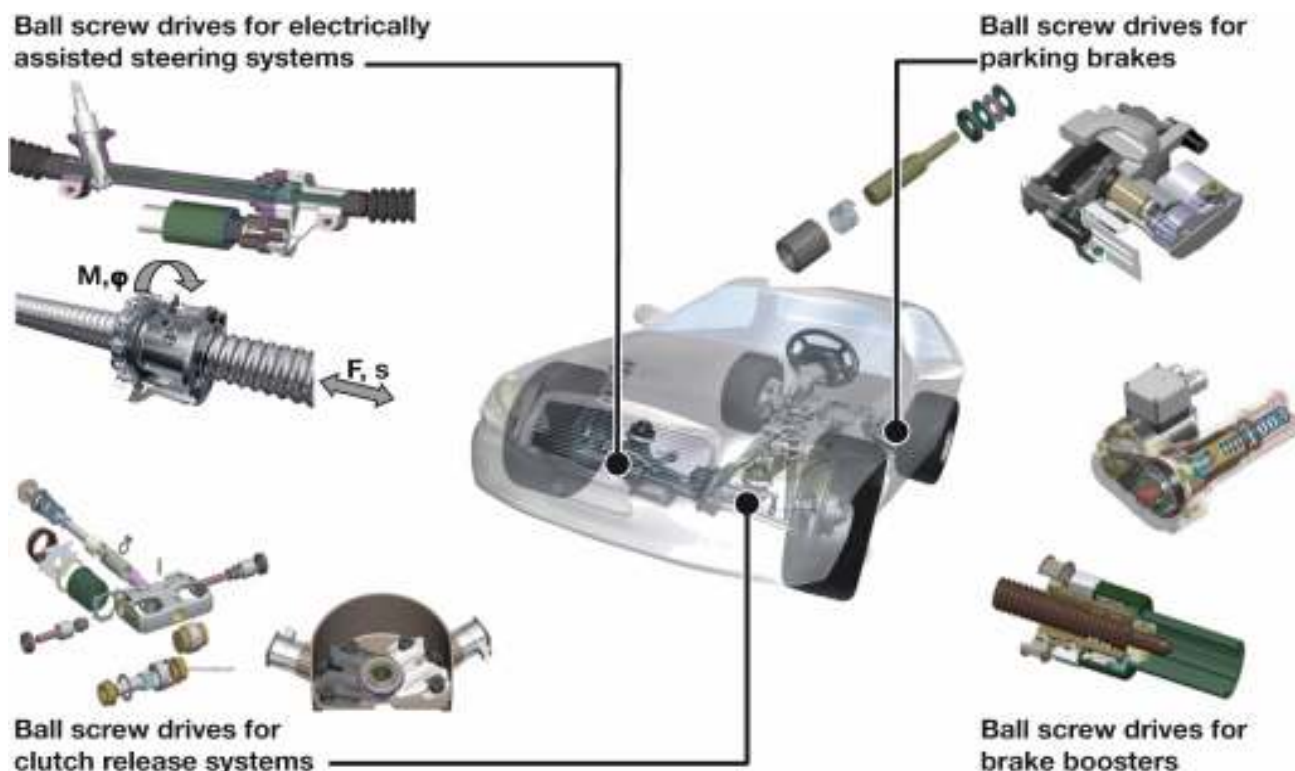


Figure 6. Overview of ball screw drive applications



## 2.4. Electromechanical active roll stabilizer – emARS

Over the last few years, Schaeffler has played its role in driving the replacement of hydraulic with electromechanical systems thanks to developing an electromechanical anti-roll system. Series production of this system started in 2015.

The benefits offered by the system are:

- Little or no tilting of the vehicle when cornering as a function of the present lateral acceleration
- More accurate steering behavior, improved agility and stability
- Enhanced system dynamics compared to hydraulic systems
- Simple installation and easy maintenance
- Reduction in the number of field complaints by up to 30 % compared to hydraulic systems
- Installation in hybrid vehicles possible
- Reduction in fuel consumption of up to 0.3 liters compared to hydraulic anti-roll systems, and
- Weight neutral compared to hydraulic systems

The system comprises a brushless direct current motor with control system, transmission, torsion bars and a decoupling unit (Figure 7). The E/E architecture is shown in Figure 8.

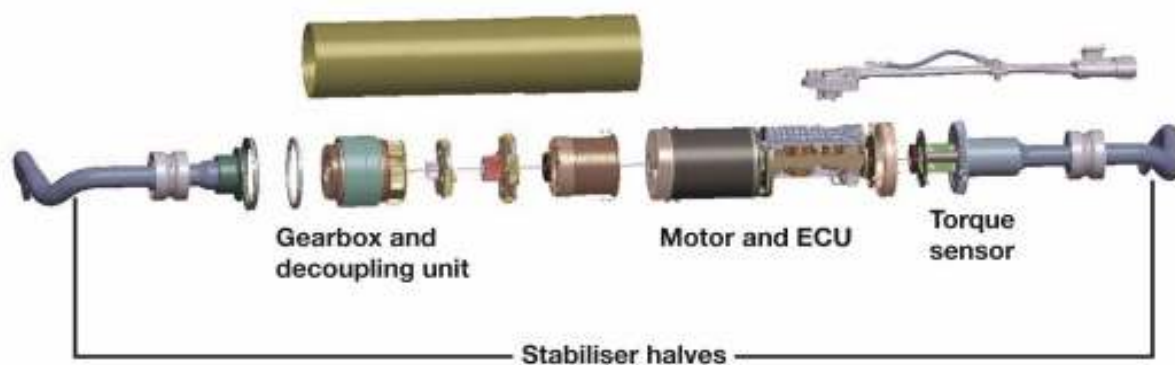


Figure 7. Design of the anti-roll system

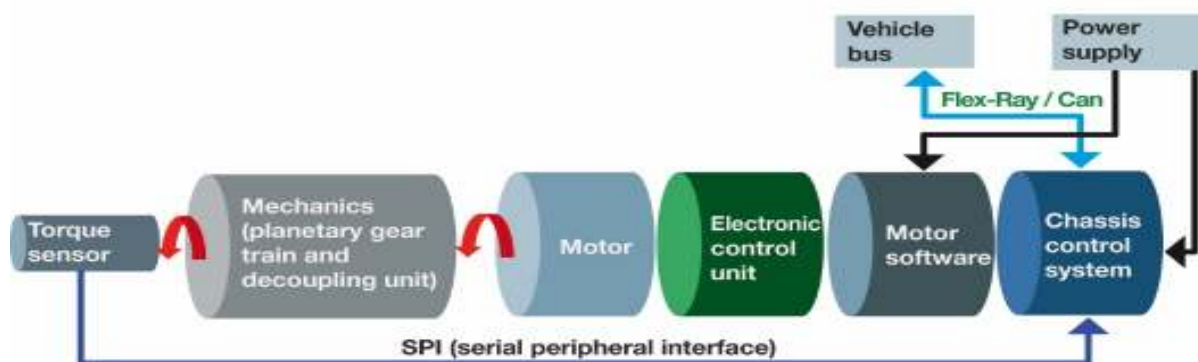


Figure 8. System Architecture

To complement a pure rotary actuator and to enhance comfort, the Schaeffler solution features a decoupling element, which enables one-sided disruptions in the road surface to be absorbed.

Transmitting pulses to the body is thereby also reduced as well as strong vertical motion caused by one-sided disturbance excitation.

Design and function of the anti-roll system are explained in detail in [4] and [5].

The effect of the decoupling unit for small disturbance excitations is shown in Figure 9.

The decoupling unit demonstrates excellent efficiency particularly for small disturbance excitations with an amplitude of up to 5 mm.

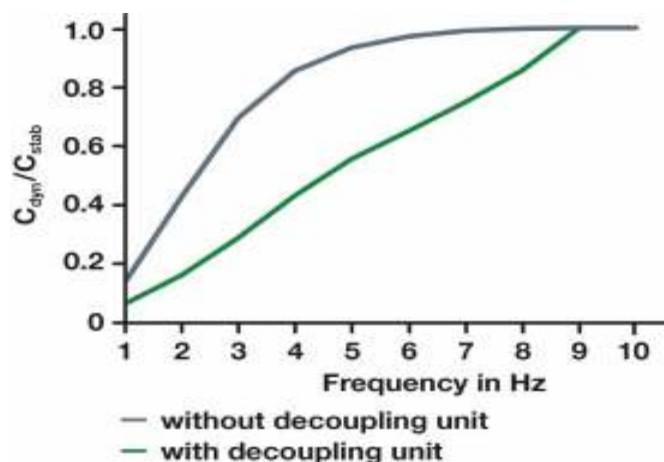


Figure 9. Dynamic system as a function of the frequency of the one-sided disturbance excitation for systems with and without a decoupling unit

Larger disturbance excitations can be corrected by the disturbance controller.

As the input parameter, this controller requires different functions, including the torque in the anti-roll system and the vertical displacement of the wheels.

The overall controller structure is shown in Figure 10.

The interference can be corrected up to a frequency of approximately 8 Hz.

The maximum frequency depends on the amplitude.

If the information about the road surface collected by a stereo camera is available as the input signal and information from the navigation system about the route can be used, the disturbance controller can be improved still further by means of anticipation.

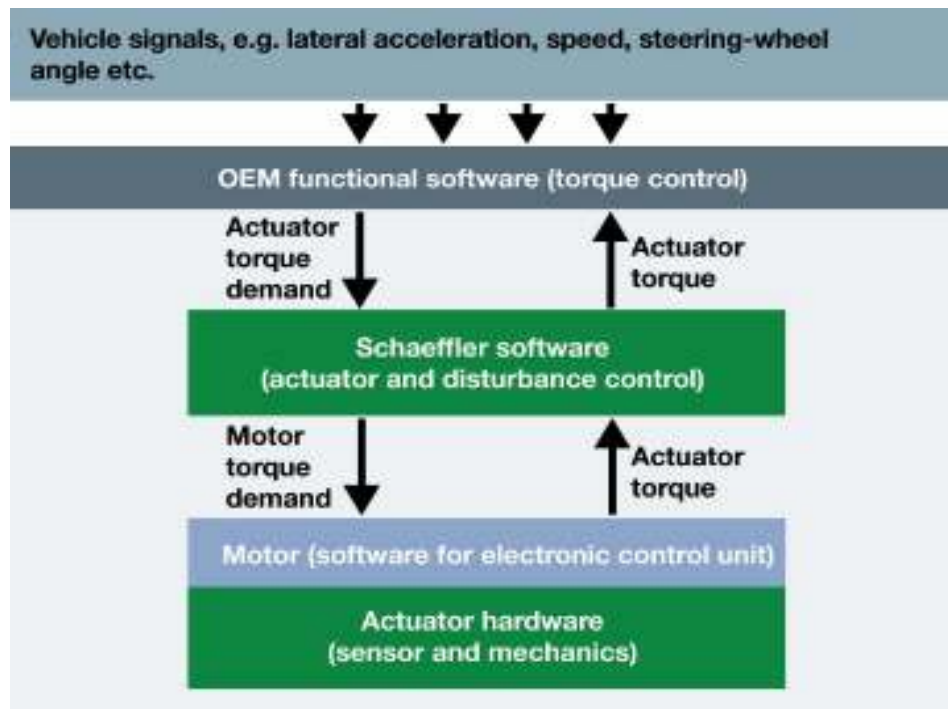


Figure 10. Block diagram of the emARS

Alternatively, the body tilt and the effect of one-sided disturbance excitation on the body can also be prevented by hydraulically adjustable struts on each wheel. In addition to the anti-roll motion, this kind of system also prevents a pitching motion during braking and accelerating.

However, this does not apply to air-sprung systems on account of the compressibility of air.

### 3. FUTURE SCHAEFFLER SOLUTION

#### 3.1. Sensor layer for measuring wheel force

Schaeffler is currently developing a sensor layer for measuring wheel force; this layer can be applied to two or three-dimensional components such as bearing components.

Figure 11 shows several examples of applications.

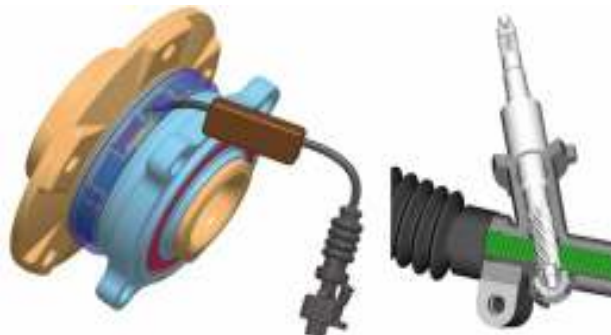


Figure 11. Sensor layer for measuring the wheel force at the wheel bearing (on left) and for measuring the steering moment in the steering gear

Application to the wheel bearing enables the wheel force to be measured and thus record the forces acting on the wheel, including the brake forces generated during braking. These forces can be used as an input signal for various chassis control systems. The wheel force measurement being developed at Schaeffler also enables accurate recording of the vehicle weight, which may be of interest for light commercial vehicles. The measurement principle is based on the arrangement of strain gauges on a two-dimensional or three-dimensional tensioned surface. The strain gauges are attached using thin-film technology. The basic layer design is shown in Figure 12. The geometry of the strain gauges is “cut” into the sensor layer using laser, with a top cover attached to protect the sensor layer. To illustrate the technology, Figure 13 shows an applied sensor layer using a bearing outer ring as an example. As proof of the measurement accuracy, it is helpful to compare this layer with a laser extensometer.

Experiments with planar samples, which were stretched on a traction engine and their elongation in synchronously recorded with the sensor layer as well as using the laser extensometer, have provided fairly good correlation (Figure 14).

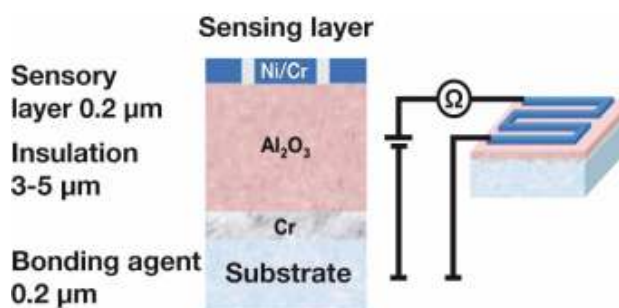


Figure 12. Sensor layer design



Figure 13. Sensor layer on a bearing outer ring

The past few years have seen that the process reliability of the individual process steps has been systematically demonstrated and increased.  
 Currently, preparations for winning projects and customers are being ramped.

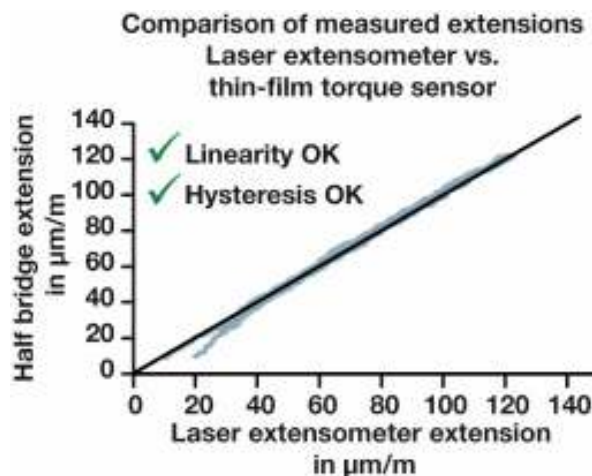


Figure 14. Comparing the elongation of planar samples with the sensor layer

### 3.2. Ride height control

In today's vehicles, air suspension is used to adjust the ride height to various driving and load conditions. This suspension system can inherently absorb very poor lateral forces and is therefore not well-suited to McPherson strut axles. In addition, the costs for air springs are another reason the system has not become established in the B and C segments. Hydraulic height adjustment systems are used in the sports car sector, in particular on the front axle to make it easier to drive over ramps [6]. The tendency of markets towards potentially failure sensitive hydraulic actuators is to oppose further proliferation of this technology. There is therefore a need for electromechanical systems designed to adapt the ride height. The following functions can be supported by this kind of system.

- Lowering the vehicle to reduce aerodynamic drag either on all four wheels or only on the front axle to bring a laden car back into the trim position
- Raising the vehicle to make it easier to get in
- Raising a sports car to protect the spoiler when driving over car park ramps
- Raising vehicles for light off-roading, as well as
- Lowering the vehicle to make it easier to load the luggage compartment

The solution developed by Schaeffler is shown in Figure 15.

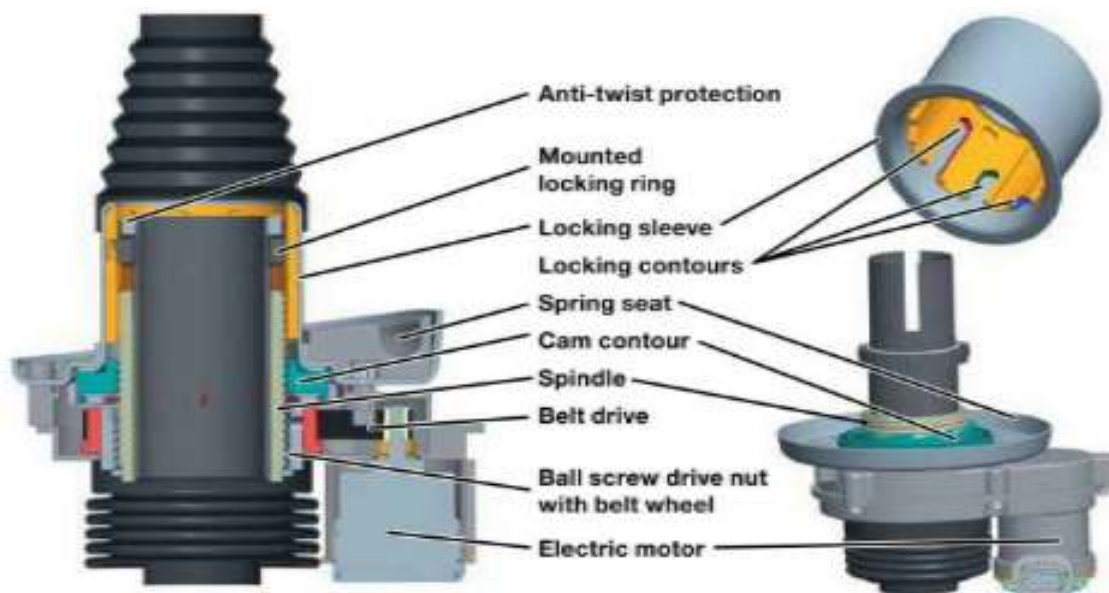


Figure 15. Ride Height Control actuator for front axle



The actuator essentially comprises a ball screw drive, a belt drive, an electric motor and a locking assembly. In this case, the vehicle load is not supported on the ball screw drive but on the locking assembly, which locks the vehicle's ride height. The ball screw drive itself is only used to adjust the different heights. Figure 16 shows a detailed view of the locking assembly.

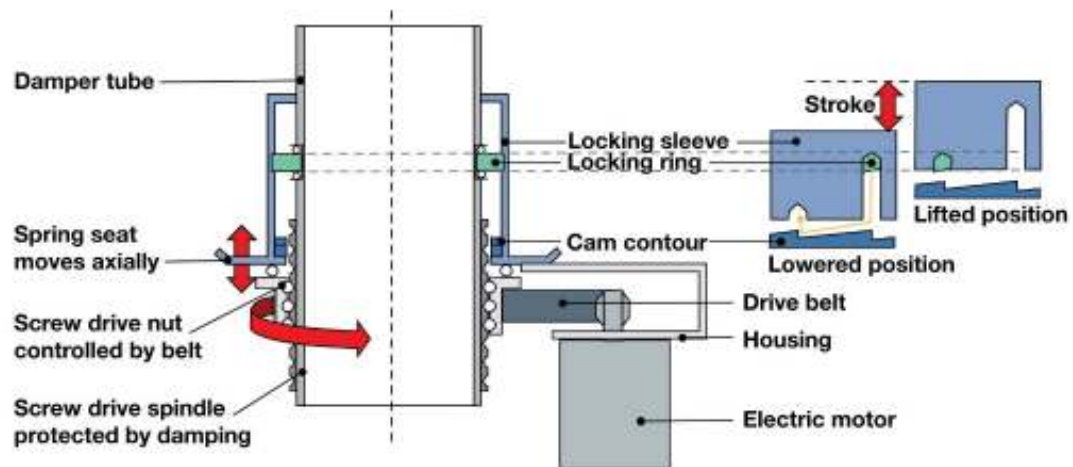


Figure 16. Locking assembly in detail

The spindle is fixed on the damper to raise and lower the vehicle, while the nut is driven by a belt. The nut rotating leads to an axial displacement of the unit comprising the nut, control contour, motor, housing and spring seat, and this is what changes the ride height. To lock the height, the locking ring engages in different locking contour grooves depending on the position when lowering. This action maintains the vehicle at the required level.

As the vehicle is offset in any position on the locking ring, the drive and spindle lock remain load-free in the locked state (Figure 17).

To aid a better understanding, the three different ride heights and resulting design positions of the actuator are summarized in Figure 18.

The number of grooves determines the possible ride height. A third groove means that a central position can also be realized. The current engineering knowledge enables adjustment ranges of 40 mm, which can be extended even further depending on the available space.

The selected design also allows installation on the rear axle, where dampers and springs are often arranged separately. The only action needed to accommodate this installation is to merely rotate the motor by 180° (Figure 19).

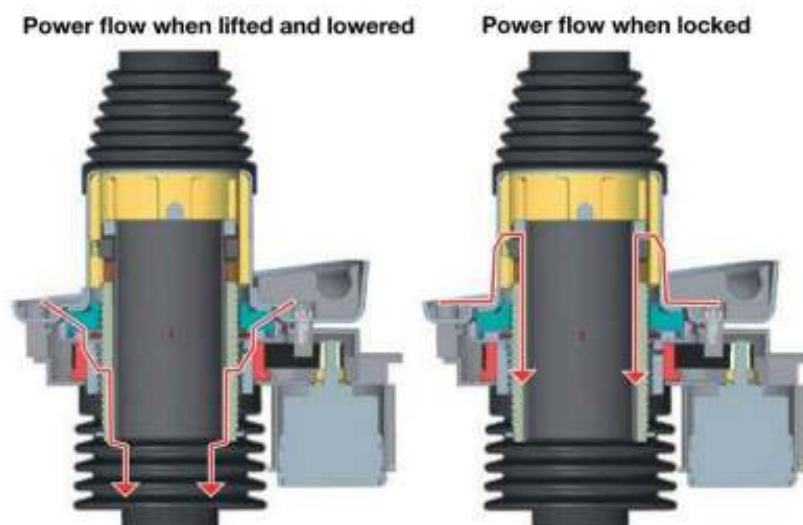


Figure 17. Power flow during raising, lowering and locking



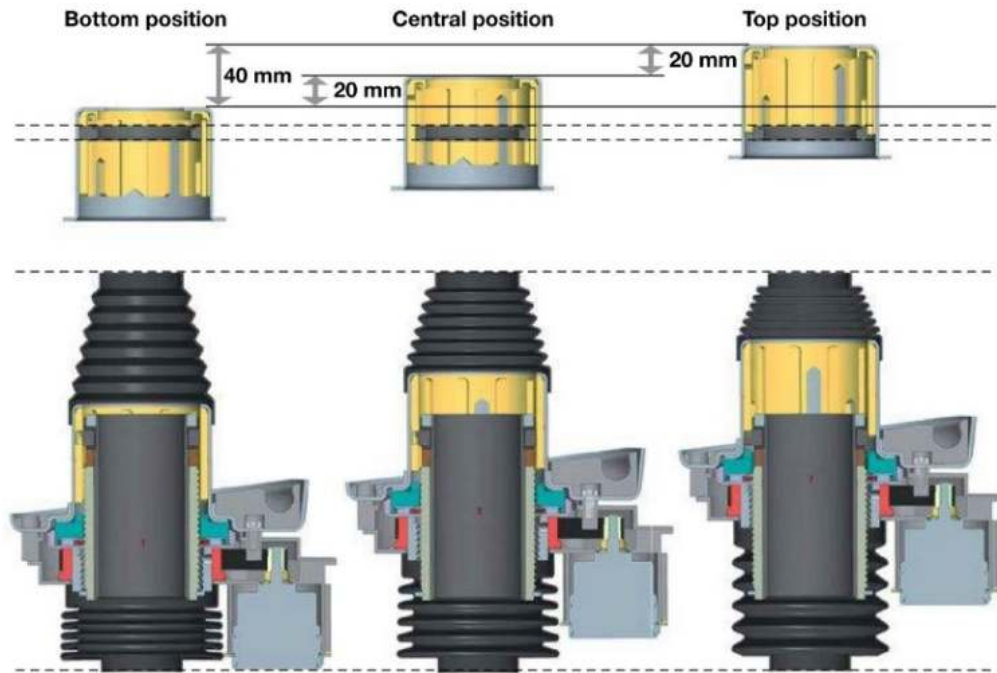


Figure 18. Position of the actuator at different ride heights

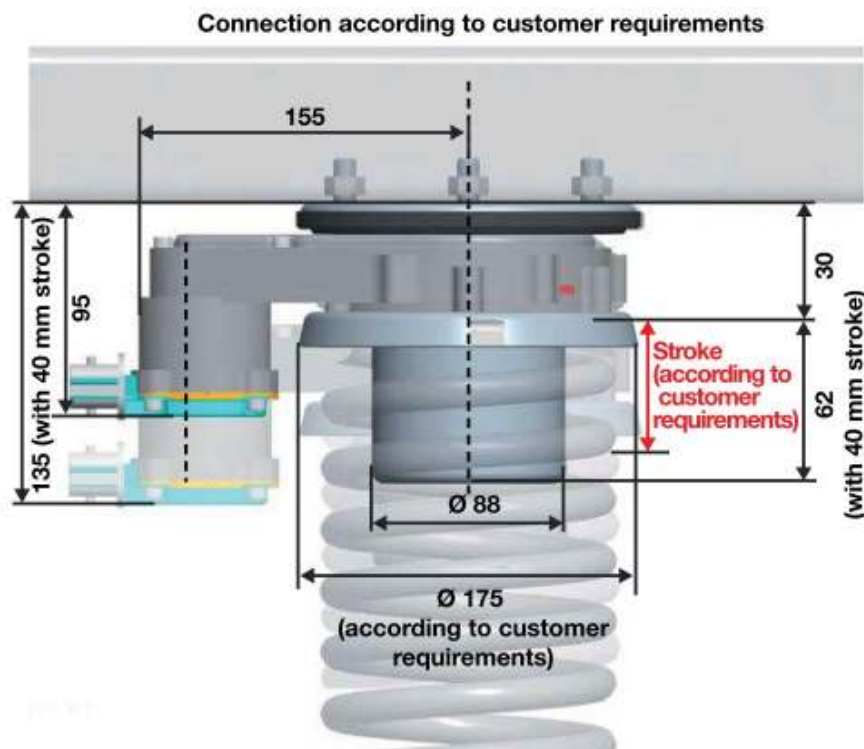


Figure 19. Installation position of the actuator on rear axle

For E/E implementation, E/E components are already available on the market. Selected ECU includes two power stages, they can control two electric motors simultaneously. The resulting system architecture is shown in Figure 20. The proposed system configuration can be seen in Figure 21. By virtue of the actuator design, selected system architecture and proposed system configuration, the market is filled with diverse and promising applications. Preparations are currently underway to construct test vehicles this year.

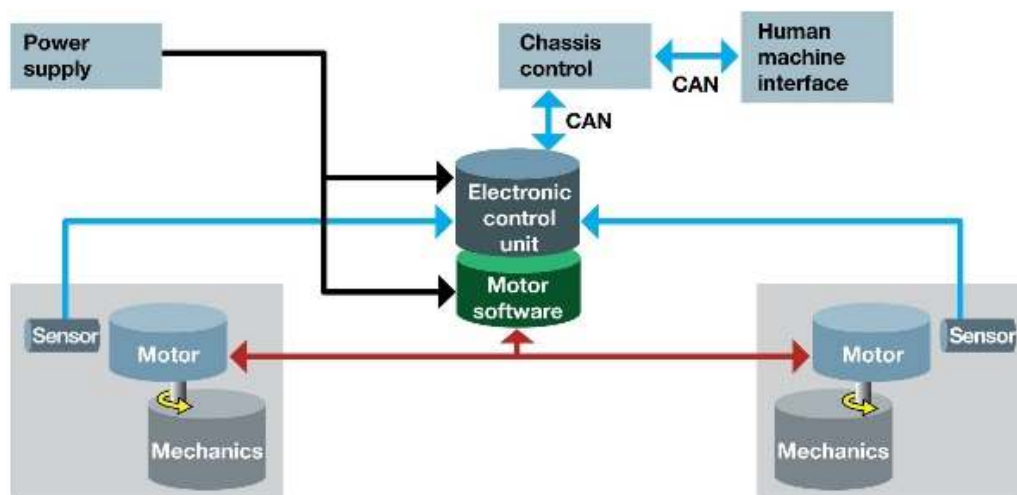


Figure 20. System architecture

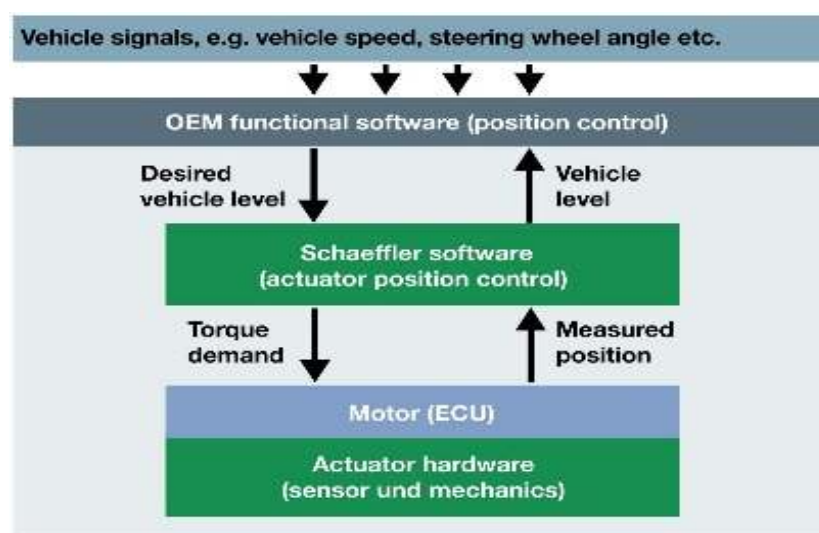


Figure 21. System architecture

### 3.3 Camber and Toe-in Actuator

The approach taken by Schaeffler for camber and toe-in actuation is based on an eccentric drive, which is mounted to the rear axle carrier that can be designed as an individual wheel actuator [7].

Figure 22 shows the mechanical concept.

The axle-side actuator provides actuation of the toe-in and/or support arm. The actuation speed and force are based on the power of the selected drive. The actuation travel is a function of the underlying eccentric feature. The E/E architecture uses the E/E components familiar from the level adjustment system with two integrated power stages to control two electric motors. This results in the following actuator characteristics:

- Actuation travel = 6 mm in the case of this eccentricity of 3 mm,
- Maximum actuation time < 2 s
- Maximum actuation load 5 kN
- Actuator diameter < 65 mm

To reduce the engine speed, a worm wheel or planetary gear train can be used. Another feature of the drive is its overload clutch, as well as mechanical short circuit to protect the bearings.

Furthermore, the actuator can be integrated into an elastomer metal cartridge on request

Previous customer feedback indicates that the market is looking for an alternative to the linear actuator on the rear axle. This alternative does not always need highly dynamic actuation.

The stated actuation time of 2 seconds for toe-in actuation with a noticeable reduction in turning circle is usually sufficient. Current plans are to kit out a prototype vehicle this year.

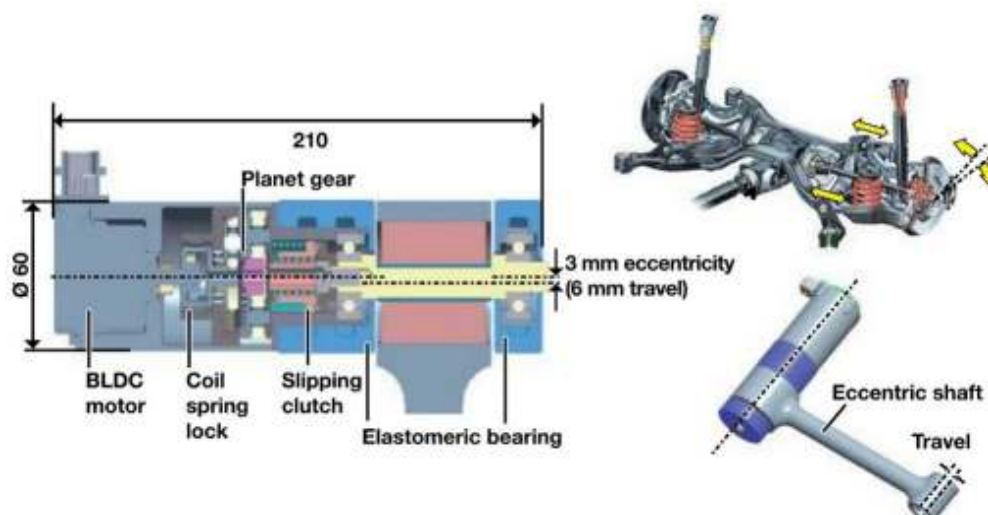


Figure 22. Design of the eccentric actuator for use on the rear axle carrier

### 3.4 Stabilizer disconnect

In the course of developing the anti-roll system further, a Stabilizer bar is opened for driving in a straight line and closed when cornering. Thus, a quasi-static tension state is produced when cornering. When driving in a straight line, however, the stabilizer is open and rolling movements of the bodywork for the reciprocal disturbance excitation through the road to the opposite side of the vehicle are suppressed.

In order to significantly reduce the vehicle's rolling angle when cornering, the stabilizer rigidity is increased by more than 20 % compared to a passive stabilizer. The design for this type of anti-roll system is shown in Figure 23. In this design, the clutch is actuated via electromechanical linear actuator (consisting of electric motor, ball screw), such as depending on the steering angle and vehicle speed and other vehicle status parameters. The functional principle of the clutch is based on a locking device developed at Schaeffler, the design of which is also shown in Figure 23. The current engineering knowledge has a weight of 6.5 kg without stabilizer halves. Compared to the design used in series production, this equates to a weight reduction of more than 50 %. If the stabilizer halves are not designed as steel pipes, but in glass fiber reinforced plastic, this produces a potential total weight of the entire actuator of around 7 to 7.5 kg.

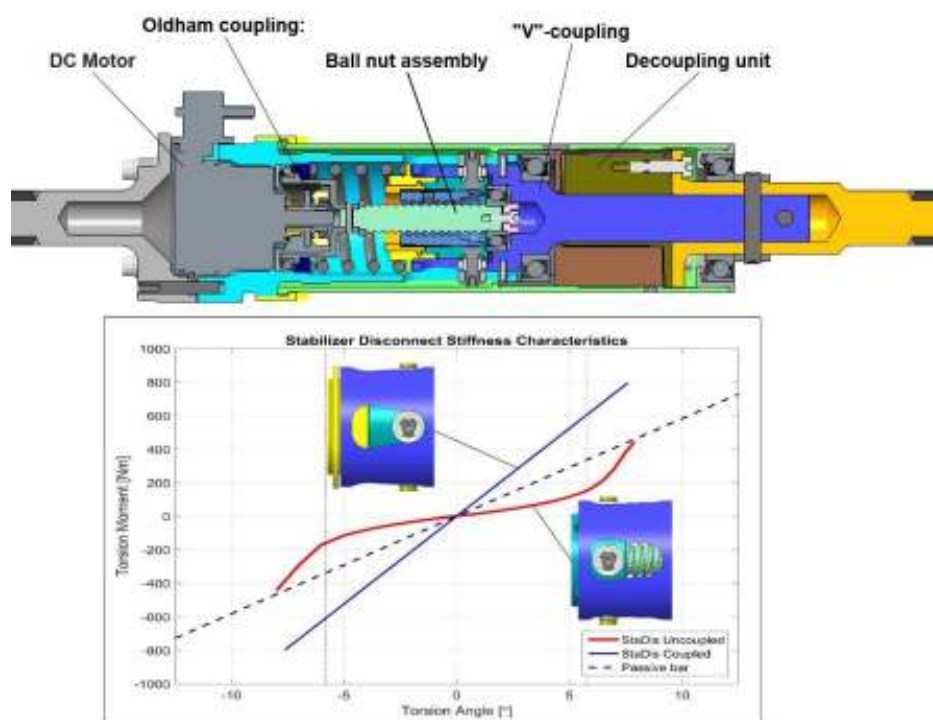


Figure 23 Stabilizer Disconnect

### 3.5 Switchable wheel bearing

Schaeffler has developed a triple row wheel bearing to reduce friction compared to the tapered roller bearings used in general and for higher wheel loads. This bearing features two equally tensioned rows of balls. To further reduce friction, the bearing can be designed such that only the outer rows of balls are used when driving in a straight line, and the central row is engaged when cornering. This is done by specifically changing the bearing preload, as shown in Figure 24.

Only the outer rows of balls are loaded when driving in a straight line; the central row is not loaded. When cornering, the central row (which is designed a four-point contact bearing) is engaged in order to support the drive performance in the bend by providing the required high level of rigidity. To this end, only a few oversized balls are fitted in the four-point contact bearing, which means that the remaining balls in the cage have clearance and reduce friction when driving in a straight line. When cornering, these balls are in contact and then absorb the required forces.

Initial simulation results show an additional reduction in friction of more than 25 %.

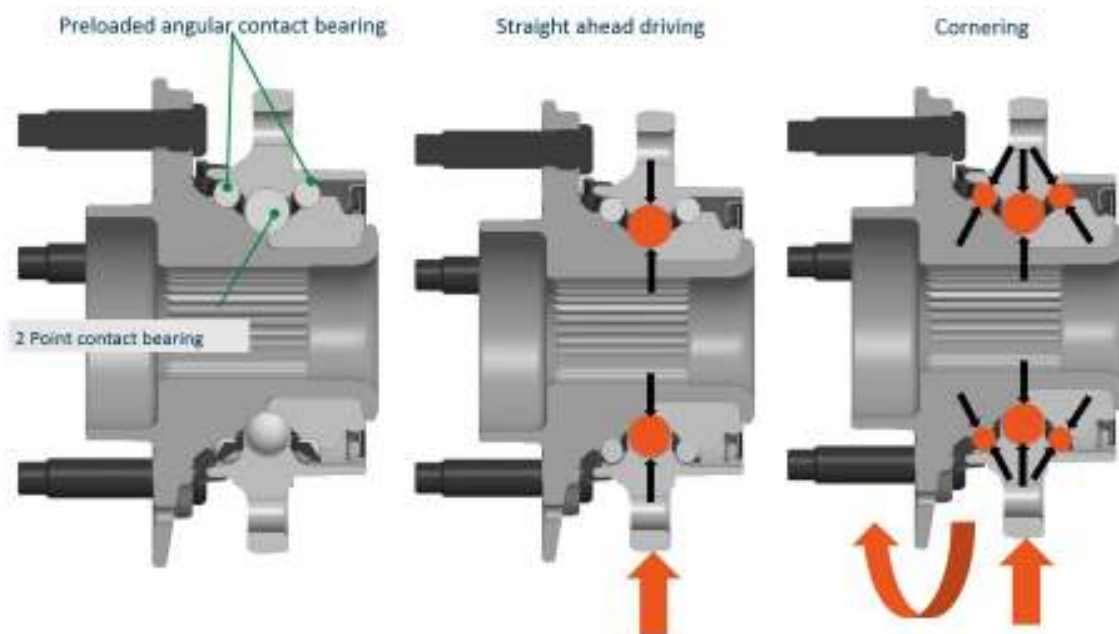


Figure 24. Switchable wheel bearing with offset outer row of balls

### 3.6 e-Suspension

One possible approach of realizing an active, or at least partially active, chassis is produced by using an electromechanical damper; this damper simultaneously works as an actuating element and actively feeds forces into the chassis. The idea of being able to utilize the lost energy of vehicle damping has been explored for over 20 years; the result is to use a brushless direct current motor using a ball screw drive to transfer the vertical motion of the wheel in a rotational motion of the rotor, thereby recuperating the damping energy [8].

What's more, this kind of damper provides the prerequisite for optimizing the damping characteristic curves beyond the options offered by the hydraulic system [9]. At the same time, it forms the basis for realizing a (partial) active suspension. Previous solutions show an unfavorable cost-benefit ratio and are also difficult to integrate into the space available. In addition, other requirements, such as overload capability or the response characteristic for small excitations, have prevented further development in this field.

Schaeffler is continuing to develop an actuator, which will fit as far as possible in the existing space of a hydraulic damper that offers a better cost-benefit ratio than previous solutions as well as improved overload capacity. The basic configuration of the damper comprises a brushless direct current motor, a ball screw drive with bearing arrangement and a damper pipe (Figure 25).



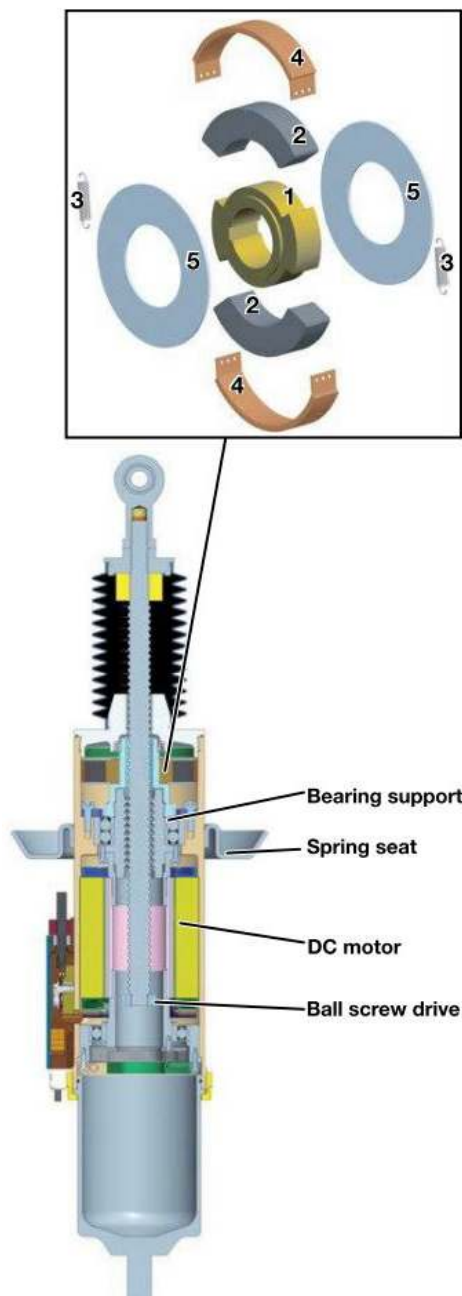


Figure 25. Design of e-Suspension

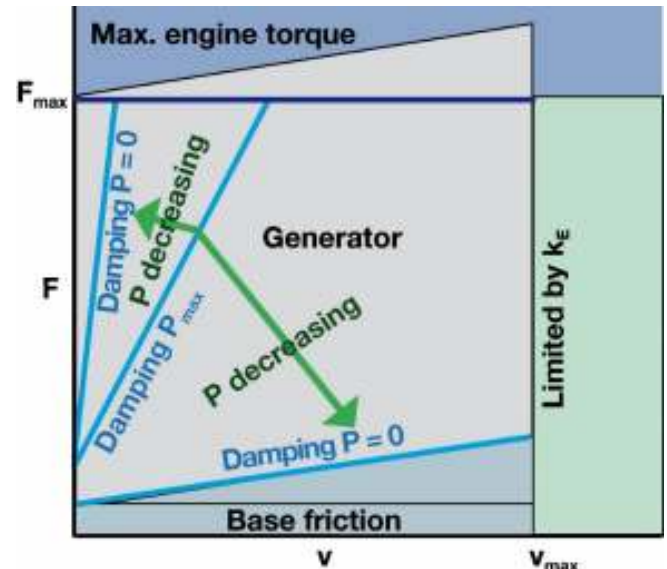


Figure 26. Characteristic curve and application area of e-Suspension

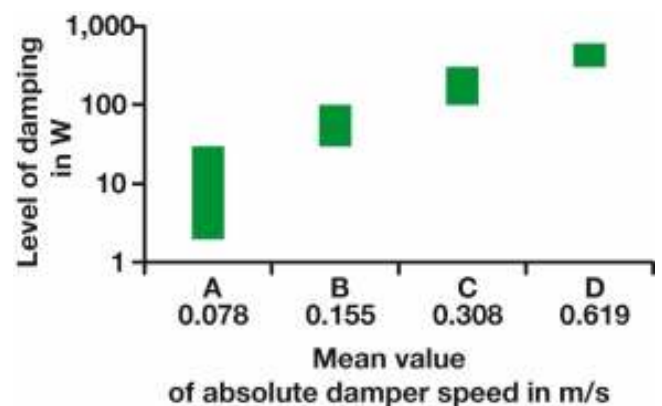


Figure 27. Measured power generated function of damping force

The wheel module with McPherson strut is excited vertically through the road surface. This translation is converted in the damper to a rotation and dampened by the regenerative operated electric motor. A centrifugal brake is used to slow down the rotor rotation in the electric motor in the event of large pulses. The design of the electric damper is based on the characteristic curve of the damper during a suspension and rebound of a hydraulic damper as well as being based on the physical limits of the electric motor in generator mode (Figure 26).

To obtain basic findings, Schaeffler designed an electric damper (identical to the one seen in Figure 25) and tested it on the test rig. The findings for four different road surfaces (A, B, C, D) are shown in Figure 27; the amplitude and speed increase in alphabetical order. Significant regenerative power is achieved with excitation profile C and D, but is more likely to be achieved on poor roads or when off-roading.

If one assumes “normal” amplitudes of 10 to 30 mm in accordance with profile A and B, the resulting regenerative power ranges from 20 to 30 W. This is too little power to justify high volume production purely on the grounds of energy regeneration. Another option is if the damper can also be used in the chassis as an actuating element [11].



The derivation of the underlying function equations of the damper is performed using the quarter vehicle model [10]. The installed electrical output of around 1.9 kW per wheel enables active engagement in the chassis. The characteristic diagram of the electromechanical damper is shown in Figure 28. The overload capability is a result of the centrifugal brake function.

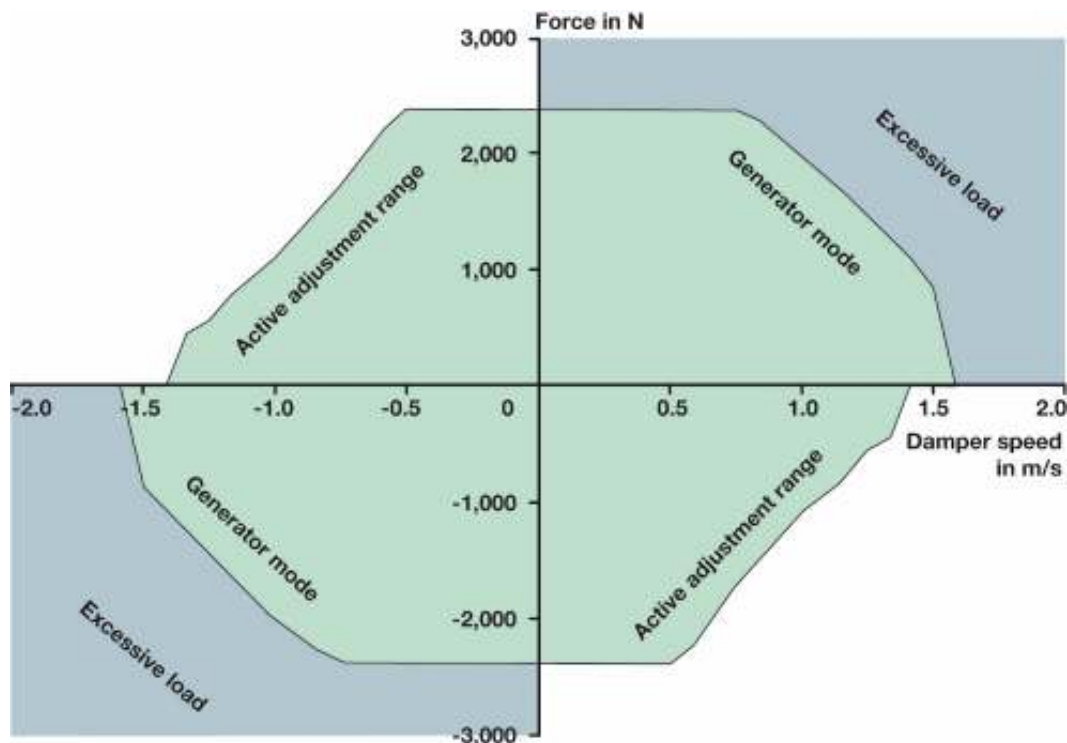


Figure 28. Characteristic diagram of the active electromechanical damping with generator mode and active adjustment rang

With the active electromechanical damping, the entire range [12] of a possible influence on the driving dynamics can be extended, thereby significantly boosting the benefit for customers. The series production use of technology now depends on customer acceptance, which is to be studied over the coming months.

#### 4. OUTLOOK

The range of the chassis applications offered by Schaeffler requires a multi-pronged approach when developing new products. Firstly, customers in an extremely cost-driven and competitive market should be provided with added value when it comes to bearing applications; this can be achieved by offering innovative developments. Secondly, mechanically oriented innovations form a sound basis for designing new mechatronic chassis systems. In addition, the task for Schaeffler engineers is also to create and realize added with new and trend-setting concepts. The objective of all these efforts is to generate function added value particularly in terms of power density, energy efficiency, weight and functional integration as well as to create cost benefits compared to today's technology. To do this, the broad knowledge and experience held within the Schaeffler Group as well as that experience of selected cooperation partnerships will be used in a specific manner.

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## ASYMMETRIC ENCRYPTION FOR THE AUTONOMOUS VEHICLE

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**Abstract:** *The future of the vehicle is of cars, roads and infrastructures connected in a two way automated communication in an holistic system. It is a mandatory to use Encryption to maintain Confidentiality, Integrity and Availability in an ad hoc vehicle network. Topology of the network produces its structure and key distribution. Both Star and ad hoc (Manet) topologies were investigated as a solution for autonomous/smart vehicle system. As a conclusion a combined topology was developed, as the nature of the vehicle and infrastructure allows combined solution, that benefits from both topologies advantages, with low number of Keys, real time performance of the Vehicle to Vehicle (V2V) and strong reliable encryption on the Infrastructure to Vehicle (I2V) as well as easy integration of old (dumb) vehicles.*

**Key-Words:** *Connected car, asymmetric encryption, key exchange, real time communication.*

### 1. INTRODUCTION

Not too long ago, security of automotive was equal with theft prevention. However as computerization in the modern vehicle is growing quickly to enable the implementation of autonomous driving and the connected car safety has become synonymous with security. It is clear that the autonomous car is unique in the requirement for operation with zero tolerance for failure in availability, continuity and security. Farther more current demonstrations by research groups have proven that vehicles can be penetrated remotely through their communication units and ordered to run malicious code that permits the intruder to control remotely the vehicle. Therefore, it has been confirmed that automobiles breaches in security already have severe safety effects. As safety is always the primary concern of every car manufacturer, automobile manufacturers must make security the same priority as safety. As automobiles open to peripheral networks, they become potential targets of malicious hackers. New embedded computers and external communication interfaces create even more treats and bring new attack surfaces. Communication interfaces not only suffer from classical IT weaknesses but from the fact that vehicles by nature have to rely on wireless communication with no wired back up. One of the clear difficulties in massive implementation of the connected car are the opposite demands of strong, reliable, encryption and description while keeping real time operation in a moving vehicle with low computer resource environment. It is known that a key advantage of Asymmetric Encryption over Symmetric Encryption is that no secret channel is required for the transfer of the public key. Furthermore the benefit of simple key management in asymmetric encryption in V2I (Vehicle to Infrastructure) and even more in V2V (Vehicle to Vehicle) communication allowed us to develop and demonstrate through software simulation, an holistic model of multilevel authorization in communication, even in the case of ad hoc V2V network. Multilevel authorization network is guaranteed in the V2I communication, expanding it to the V2V case allows stronger read and write permits for a part of the fleet, for example emergency and security vehicles.

### 2. VEHICULAR COMMUNICATION INFRASTRUCTURE TOPOLOGY

In the near future the majority of new automobiles will be equipped with two way radio systems for car to car and car to Infrastructure communication.

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A comparison between the Vehicle and Infrastructure of computer and connectivity foundations (Table 1) shows a contradiction between the demands to capability of the vehicles and infrastructure. Vehicles by nature are mobile, require real time multi party wireless communication with limited computer communication and bandwidth access on the other hand infrastructure is on a fixed location, backed up by wired communication with almost unlimited computer, memory and back up availability. Furthermore wireless towers are by design redundancy.

Table 1.  
 Vehicle vs. Infrastructure : computer and connectivity foundations

Heading level	Vehicle	Infrastructure
Location	Mobile	Fixed
Computer power	Low	High
Communication	Wireless	Wired/Fast - I2I Wireless I2V, V2I
Memory	Low/Limited	Large/expandable
Band width	Low	High
Back up	Local/limited	Large/Cloud
Availability	Part time	Always On

The wireless network topology structure is defined from the functionality required by the different parties. By nature I2V and V2I is of a central address (Infrastructure) that communicates with multi parties (Vehicles), in other words star network topology. In this topology all components connect to a central Infrastructure. The vehicles are not linked to each other and it does not allow direct traffic between devices. The active star network has an active Infrastructure central node that usually has the means to prevent security problems.

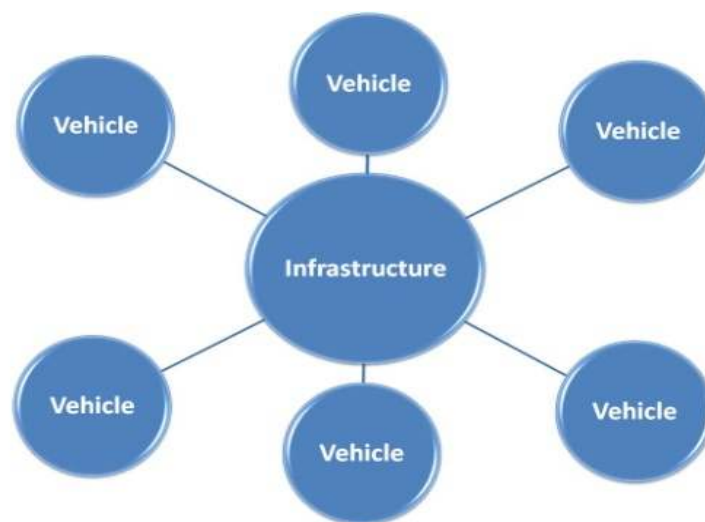


Figure 1. Star topology [1]

Star topology advantages Easy to diagnose network fault, Good performance, Scalable, easy to set up and to extend on the other hand. Star topology main disadvantage is that it totally depend on a single hub.

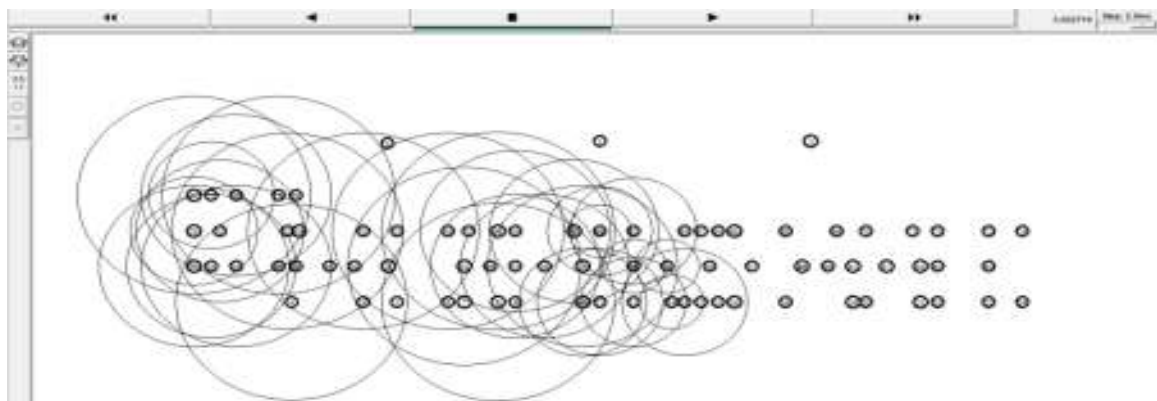


Figure 2. Ad hoc network [2]

On the other hand V2V, requires multi channel interaction between mobile, moving and changing parties to insure the full benefit from data sharing and real time decision making, a network of such users referred as mobile ad hoc network (MANET) A survey of secure Mobile AD HOC.

A Mobile Ad-hoc Wireless Network (MANET) is a collection of autonomous nodes that communicate with each other by forming a multi-hop network, maintaining connectivity in a decentralized manner. It consists of a set of mobile hosts communicating amongst themselves using wireless links, without the use of any other communication support facilities, such as base-stations.

The nodes in a MANET can be any device that is capable of transmitting and receiving information.

Each node in such a network acts as a host or end system (transmitting and receiving data) and simultaneously as a router.

The nodes in a MANET are generally mobile and may go out of range of other nodes in the network [2].

### 3. AD HOC NETWORK PERFORMANCE SIMULATION

In order to evaluate the performance of Ad Hoc networks in a changing conditions a simulation of different Ad Hoc protocols was performed on multiple number of mobile nodes.

We have examined three common routing protocols for MANET.

DSDV is a proactive protocol, every mobile station maintains a routing table with all available destinations along with information like next hop, the number of hops to reach to the destination, sequence number of the destination originated by the destination node, etc.

DSDV uses both periodic and triggered routing updates to maintain table consistency.

Triggered routing updates are used when network topology changes are detected, so that routing information is propagated as quickly as possible [3].

DSR is a reactive routing protocol which allows nodes in the MANET to dynamically discover a source route across multiple network hops to any destination. In this protocol, the mobile nodes are required to maintain route caches or the known routes.

The route cache is updated when any new route is known for a particular entry in the route cache. AODV is a reactive routing protocol instead of being proactive. It minimizes the number of broadcasts by creating routes based on demand, which is not the case for DSDV.

When any source node wants to send a packet to a destination, it broadcasts a route request (RREQ) packet. The neighboring nodes in turn broadcast the packet to their neighbors and the process continues until the packet reaches the destination [2].

For the simulation of the developed system ViSim 1.0 has been used, ViSim calls ns-2 simulations in a Windows environment, to allow rapid configuration for any MANET routing scenario [2].

All three protocols were compared in a 20,40,60,80 and 100 mobile nodes in random four traffic lanes as can be seen in Figure 2.

The following performance metrics were evaluated to understand the behavior of DSDV,DSR and AODV, Max throughput, Goodput (In terms of Packet Size in Bytes), Routing Load (In terms of Bytes).



Table 2.  
Simulation Parameters

# Define options		
set val(chan)	Channel/WirelessChannel;	# channel type
set val(prop)	Propagation/TwoRayGround;	# radio-propagation model
set val(netif)	Phy/WirelessPhy;	# network interface type
set val(mac)	Mac/802_11;	# MAC type
set val(ifq)	Queue/DropTail/PriQueue;	# interface queue type
set val(ll)	LL;	# link layer type
set val(ant)	Antenna/OmniAntenna;	# antenna model
set val(ifqlen)	50;	# max packet in ifq
set val(nn)	20/40/60/80/100;	# number of mobilenodes
set val(rp)	DSR/AODV/DSDV;	# routing protocol
set val(x)	2000;	# X dimension of topography
set val(y)	1000;	# Y dimension of topography
set val(stop)	150;	# time of simulation end

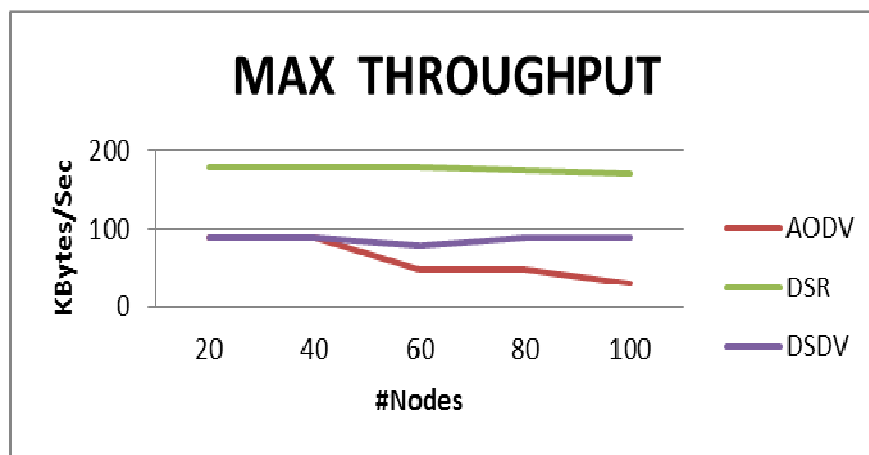


Figure 3. MAX Throughput results (Simulation results)

Max Throughput is the max bytes received by the destination node per second (Data packets and Overhead). Routing Load (in terms of Packet Size in Bytes) is the ratio of the total bytes of routing packets that are sent within the network to the total number of bytes that are transmitted within the network to reach the destination.

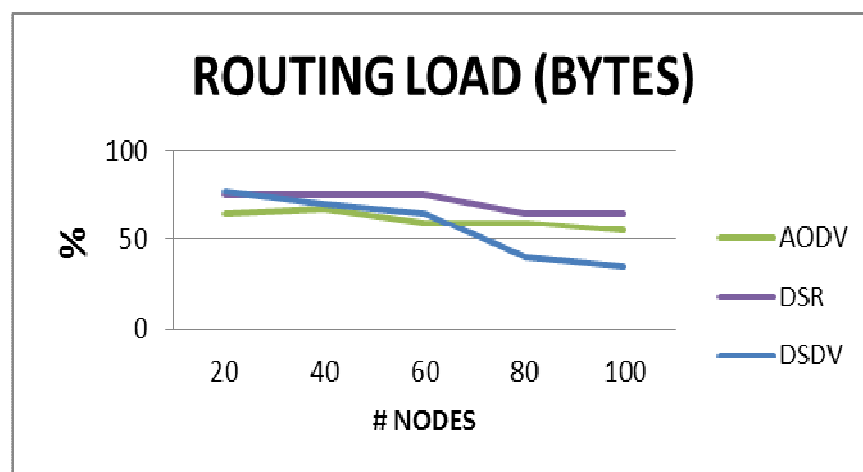


Figure 4. Routing Load results – Bytes (Simulation results)

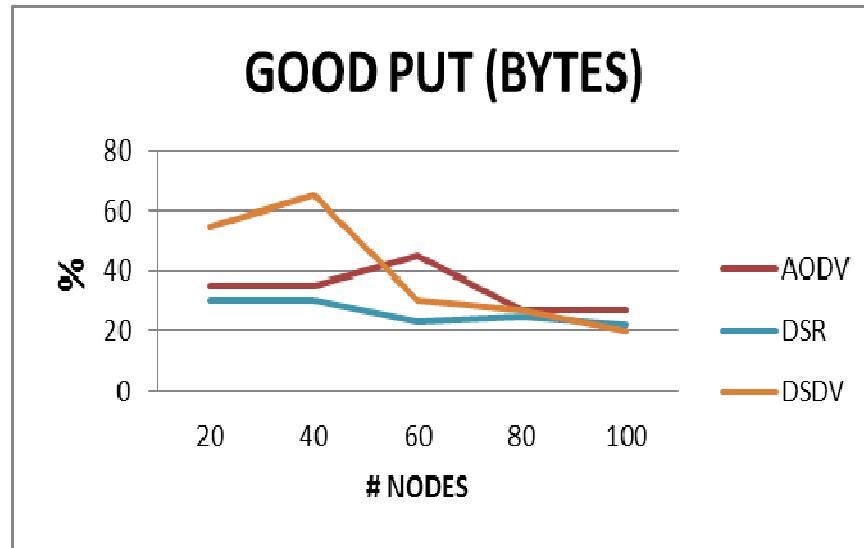


Figure 5. Goodput results – Bytes (Simulation results)

Goodput (In terms of Packet Size in Bytes) is the ratio of the total bytes of data that are sent from the source to the total bytes that are transmitted within the network to reach the destination. It is clear that in terms of performance of throughput and routing load DSR protocol has a clear advantage, and even in the Goodput parameter is similar to the AODV and DSDV protocols in the high node number mode.

#### 4. HYBRID NETWORK ASYMMETRIC ENCRYPTION

The most important challenge that MANET is facing is the security issue. Some of the issues that cause that is that there is no centralized administration control, that the wireless channel is unprotected [4]. However in the case of connected /autonomous vehicles most of the weakness of a classic ad hoc network can be migrated due to the hybrid nature of the network that allows V2I and I2V is a trusted secure star topology and V2V in an ad hoc model. ARAN [5] or Authenticated Routing for Ad hoc Networks detects and protects against malicious actions by third parties and peers in an ad hoc environment. ARAN introduces authentication, message integrity, and non-repudiation. It is composed of two distinct stages. ARAN makes use of cryptographic certificates for the purposes of authentication and non-repudiation. Stage 1 contains a preliminary certification stage and a mandatory end to end authentication stage. ARAN requires the use of a trusted certificate server T.

$$\begin{aligned}
 A &\rightarrow * : \{ \text{RDP}, X, N_A \}_{K_{A-}}, [\text{cert}_A] \\
 B &\rightarrow * : \{ \{ \text{RDP}, X, N_A \}_{K_{A-}} \}_{K_{B-}}, [\text{cert}_A, \text{cert}_B] \\
 C &\rightarrow * : \{ \{ \text{RDP}, X, N_A \}_{K_{A-}} \}_{K_{C-}}, [\text{cert}_A, \text{cert}_C] \\
 X &\rightarrow C : \{ \text{REP}, A, N_A \}_{K_{X-}}, [\text{cert}_X] \\
 C &\rightarrow B : \{ \{ \text{REP}, A, N_A \}_{K_{X-}} \}_{K_{C-}}, [\text{cert}_X, \text{cert}_C] \\
 B &\rightarrow A : \{ \{ \text{REP}, A, N_A \}_{K_{X-}} \}_{K_{B-}}, [\text{cert}_X, \text{cert}_B]
 \end{aligned}$$

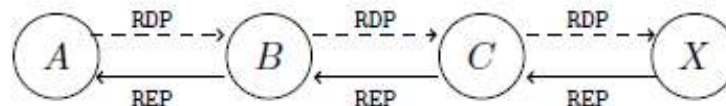


Figure 6. The ARAN protocol (an example with four nodes-Simulation results)[6]

Before entering the ad hoc network, each node requests a certificate from the trusted server. The certificate contains the IP address IPA of the node, the public key of the node, a timestamp, of when the certificate was created, and a time at which the certificate expires.

These variables are concatenated and signed by the trusted server. All nodes must maintain fresh certificates with the trusted server and must know the trusted server public key.

The goal of Stage 1 is for the source to verify that the intended destination was reached. In this stage, the source trusts the destination to choose the return path.

Stage 2 is performed only after Stage 1 has been successfully executed.

This is because the destination certificate is required in Stage 2.

This stage is primarily used for discovery of shortest path in a secure fashion.

Since a path is already discovered in Stage 1, data transfer can be pipelined with Stage 2's shortest path discovery operation.

## 5. CONCLUSIONS

It is known that a key advantage of Asymmetric Encryption over Symmetric Encryption is that no secret channel is required for the transfer of the public key. Furthermore the benefit of simple key management in asymmetric encryption in V2I and even more in V2V communication allowed us to develop and demonstrate, an holistic model of Combined network topology consist of Star topology for I2V communication, with strong encryption and ad hoc topology for V2V and V2I communication with ARAN topology encryption, therefore implementing multilevel encryption in an holistic system.

The combined topology model allows real time performance in V2V network due to with asymmetric encryption. Furthermore as Asymmetric encryption allows easy public key delivery to allow read permission for a 3<sup>rd</sup> party communication without compromising the network, the combined topology permits easy integration of older system including regular (dumb) vehicles that can benefit from the network knowledge through one way communication.

*This work was presented at the International Congress of Automotive and Transport Engineering CONAT 2016, Brasov, Romania and it was published in Proceedings of the Congress (ISSN 2069-0401).*

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## SKILLS AND COMPETENCES DEVELOPMENT FOR THE PROFESSIONALS OF THE FUTURE TRANSPORTATION SECTOR – THE SKILLFUL PROJECT

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**Abstract:** The transport industry accounts for 4.5% of total employment, and represents 4.6% of Gross Domestic Product (GDP). This paper analyses the future needs to be gained concerning the training and expertise of the professionals in transportation field mainly because of the continuous and dramatic development of technology and more specifically the development and penetration in the transportation sector of intelligent systems. Furthermore, this paper proposes the introduction of some new business roles in the transport sector and more particular in the education and training chain that would help to achieve European wide competence development and take-up in a sustainable way, according also to the European project SKILLFUL that aims to perform a structured foresight into the vocational and academic qualifications in the Transportation sector of the future, as well as to enhance employability and sustainable industrial development in the transportation sector in Europe.

**Key-Words:** ITS, automation, employability, transport professionals, skills, competences, future requirements, training tools, lifelong training.

### 1. INTRODUCTION

The transport industry of Europe employs over 10 million people representing the 4.5% of total employment, as well as the 4.6% of the Gross Domestic Product (GDP) [1].

This fact, combined with the continuous technological developments and the ongoing growth of the transport sector, increases the need for seamless education, training and qualification improvement of professionals in this sector.

National and regional authorities have traditionally been responsible for the development and evolution of the educational standards, curricula, training tools and methods addressing mainly the needs of national and regional labour-markets.

Nevertheless, during the last years a trend concerning the globalization of the transport professionals' competences has been witnessed, regarding though mainly fields with a more international range of cooperation, such as ITS [2].

The European Commission places great importance on the role of academic and vocational qualifications having a direct impact on employability [3] and this is also a crucial element of the Europe 2020 strategy.

The Bologna Process [4] and Lisbon Strategy [5] in Europe are, among others, the clearest examples of international engagement, for more comparable, compatible and coherent systems of higher education, as well as for the development of a dynamic and competitive knowledge-based economy in Europe.

Given this, some international initiatives have already been developed for educational and vocational programmes regarding transport professionals, such as joint University degrees based on cooperation between Universities from different countries.

However we are still a long from even Europe-wide common qualifications and standards.

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Part of this effort is also the SKILLFUL project, whose vision is to analyse the emerging trends, to identify the skills and competences required by the Transport workforce of the future and define the training methods and tools to meet them.

SKILLFUL will focus on employability for all transportation modes and for multimodal chains (which by themselves constitute a key transport of the future trend), as well as for all levels/types of workers (blue collar, white collar, managers, operators, researchers, etc.).

## **2. THE DEVELOPMENT OF ADVANCED TRANSPORT SYSTEMS AND THEIR IMPACT ON EMPLOYABILITY**

The Intelligent Transport Systems and Services (ITS) make the transportation of people and goods more efficient, economical and thus smarter.

They resulted from the combination of information and telematics technologies and their applications in the transport area and cover all modes of transport and all kinds of parameters associated with driving.

Intelligent Transport Systems (ITS) can be used in order to make transport safer, more efficient and more sustainable, tackling Europe's growing emission and congestion problems for all modes of passenger and freight transportation.

As the digitization of transport is moving forward, through the rapid development and evolution of the ITS sector, the European Commission is already working with Member States, industry and public authorities to find common solutions to the various barriers and difficulties that have already occurred and will occur in the future.

The employability of the transportation sector is also directly affected by the development and deployment of intelligent systems.

As these systems are establishing in all transportation areas, jobs in the sector are rapidly changing.

For example, as the driver's cabin of a high-speed train becomes increasingly similar to an aircraft cockpit, train drivers are required to have additionally other skills than they used to, usually more advanced technical and analytical skills [6].

While the transport sector offers a wide variety of jobs with different skills requirements due to ongoing technological developments, in combination with social and economic trends, new pressures and needs are arising for highly skilled workers throughout the sector.

The need of better and more specialized education and training becomes even more urgent considering also that the trend to automation features all employment sectors and continues to be driven by a corporate focus on cost competitiveness, outsourcing of engineering functions, thus increasing quality requirements and rising wage inflation across emerging markets [7].

According to the Oxford Martin Programme on the Impacts of Future Technology, nearly half of U.S. jobs could be susceptible to computerization over the next two decades and the jobs in transportation, logistics, and office/administrative support are at "high risk" of automation [8].

Thus, the issue of employment in the Transport sector is a major social phenomenon that affects the life of millions of people and requires sound and effective handling.

This purpose and effort can be reinforced and promoted by the SKILLFUL project, through the development of new training/educational schemes, programs and tools taking under full consideration the existing needs but also those which will be derived in the future.

On the expected innovation of the SKILLFUL project is the best practices and knowledge transfer in various technologies (i.e. in automation from air to road transport; in operator monitoring and vigilance support across all modes; in electrification from rail to maritime and road sectors, etc.) performed within the project with the focus on interdisciplinarity in automated maintenance application using extensively IT technologies.

## **3. ENHANCING EMPLOYABILITY OF THE TRANSPORTATION SECTOR OF THE FUTURE**

### **3.1. Future trends in transport systems and their job impact assessment**

The development of the employment sector and its alignment with the current and future requirements is an issue of great importance for the EU.

Providing people with the right skills for employment, as well as matching these skills with the labour market requirements remains a challenge [9].



For the above purpose to be achieved, emphasis needs to be given to the intelligent transport systems and services (ITS) and supporting technologies which have been developed to such an extent that they constitute an integral part of the transport sector.

Advances in the Internet of Things (IoT), Networking and Connected Car technologies are transforming almost its overall context.

For the promotion and further development of the transport sector proper education and training of professionals is required, in order to be able to cope with the introduction of new technologies and automation in all transport areas and modes.

Proper education and training is also essential for safety reasons as the incorrect use of such systems or the misuse of technologies of this kind by professionals not adequately qualified may lead to accidents or even to loss of lives.

During the SKILLFUL project, the most critical emerging technologies will be identified and analysed, in order for the connections between those technologies and future employment demands to be determined.

Among the key technologies that are going to be analysed are the following:

- Information technologies and telematic applications.
- Cooperative Systems and V2X interfaces.
- Radars, lidars, machine vision and innovations in object recognition.
- Traffic big data handling methods.
- Pro-active traffic and incident management algorithms.
- Gamification concepts.
- Affective and Persuasive interfaces.
- Augmented Reality interfaces.
- New materials and processes.
- Logistic tracing and tracking.

Additionally, as the Transportation sector moves steadily from products to services, emphasis will also be devoted in the identification of relevant emerging novel service concepts and bundles.

The most important service concepts will be recognized, as well as their impact to existing and emerging requirements of new jobs.

Relevant key services and service concepts include:

- Mobility-as-a service (MaaS) enabling services (carpooling, carsharing, DRT and FMS schemes, etc.).
- Personalisation of services.
- Mobile services on the cloud.
- Context aware services.
- Support for on-the-fly decision making.
- Multimodal trip planners and routers.
- Payment mechanisms to facilitate easy transfers across different modes.
- Integration of social media into Public Transport.
- Novel tourism/recreational services, incorporating travel and mobility services.
- Integration of infrastructure-based and in-vehicle services.

Even more than technologies, new business schemes that accompany them will change the working ecosystem of transport.

So, MaaS will push users from ownership to usership; thus creating a number of connected jobs and business opportunities to it.

As major relevant business schemes the following ones are going to be analysed:

- Do-It-Yourself (DIY) schemes that changed the home furniture area some decades ago and are now migrating to the choice of vehicle and infomobility services sectors.
- Crowdfunding schemes that allow new transport related applications to emerge.
- Transport on demand schemes that adapt flexibly to the kind and number of objects to be transported.
- Fuel availability schemes that offer energy for transport vehicles available at the concrete time and the distinct localization.
- Retail and (e)commerce development.
- Transport workplace flexibility.
- Transport workforce flexicurity.

The identification, designation and analysis of all these technologies, services and business schemes is going to be the first and most crucial step that will trigger the procedures for the determination of required qualifications and competences for the future professionals of the transportation sector.

During the SKILLFUL project these skills and competences are going to be prioritised, as well as gaps in the current and foreseen levels are going to be identified, in order to lay the foundations that will lead to the development of appropriate educational/ vocational system and program, accompanied by the relevant curricula, tools and methods.

This whole procedure will, of course, take under consideration the current educational and training systems for workers in the transport sector (all modes).

### 3.2. The introduction of new business roles in the future transportation sector

Another factor that could contribute to the development and evolution of the future employability in the transport sector and which is a key element and objective of the SKILLFUL project is the creation of new business roles that will cover some of the new needs emerging by the overall change in the field of education and training of transport professionals.

Some of these roles are the following:

- **“Knowledge aggregators”**: The technological advancements are so rapid that traditional players (i.e. VET organization and Universities, let alone Transport infrastructure or fleet operators) can’t follow them.

On the other hand, Research Centers and performers that possess the relevant knowledge do not focus so much on training; especially as low to middle level skilled personnel is concerned.

“Knowledge aggregators”, may thus be established as coalitions, spin-offs or other collaboration schemes between Research Institutes and Transport Associations or Universities/VET operators; to cover this need and become the Centers of Excellence on developing training material, tools and curricula, training the trainers and certifying the training processes.

- **“Training promoters”**: The need for the appropriate training to be continuous and make use of advanced tools (primarily ICT related, but also simulation ones) leads to a procedure that is more and more costly.

And although “it pays off on the long run”, it may be difficult to be financially supported by individual SME’s or other entrepreneurs in the transport sector.

Thus, alternative schemes may be established, utilizing existing or emerging stakeholders Associations but also PPP’s, in order to promote, guide and co-finance the necessary training schemes.

- **“Training certifiers”**: New courses and trainee/trainer competences need to be certified and accredited correspondingly at a Pan-European scale.

In such a context, methodologies and policies should be implemented, in order to reach excellence and quality in education provision and harmonization throughout EU countries.

Along with trainee requirement and trainer competences, trainer and education providers would meet criteria for excellence through accreditation or other attests, agreements or certifications.

A higher education institution at the EU level (similar to the European Consortium for Accreditation in Higher Education, ECA) may be mandated to assess requirements fulfilment and recognition of accreditation decisions.

The definition and analysis of new actor roles, such as ones described above may dramatically change the future training provision and become the catalyst for its sustainability.

#### 4. CONCLUSION

Europe, potentially, will face a major skills problem in the near future.

Over 20 million new jobs are expected to be created between 2006 and 2020.

Expansion of high- and medium level skilled occupations is expected to continue over the next decade, while an increase is also anticipated for some jobs requiring lower level skills, like jobs that consist of simple and routine tasks and require basic education to carry them out [10].

The current paper deals with this important issue directly related to the sustainability of the transport sector, such as the proper and continuous education and training of its component members, so that they can meet the new and constantly alternating needs of the transport sector that are mainly deriving by the development of technology and of intelligent transport systems and services.

The SKILLFUL project is a new project which aims to utilize existing and emerging training/education methodologies, tools and knowledge, to design novel training/education schemes and pilot several of them, in order to prove their usefulness and assess their impact.

SKILLFUL will also propose best practices, training application guidelines and policy recommendations to promote the novel training/learning schemes and their Europewide adoption.

#### ACKNOWLEDGEMENT

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# RoJAE Romanian Journal of Automotive Engineering

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## The Scientific Journal of SIAR A Short History

The engineering of vehicles represents the engine of the global development of the economy.

SIAR tracks the progress of the automotive engineering in Romania by: the development of automotive engineering, the development of technologies, and road transport services; supporting the work of the haulers, supporting the technical inspection and of the garage; encouraging young people to have a career in the automotive engineering and road haulage; stimulation and coordination of activities that promote an environment that is suitable for continuous education and improving of knowledge of the engineers; active exchange of ideas and experience, in particular for students, master students, PhD students, and young engineers, and dissemination of knowledge in the field of automotive engineering; cooperation with other technical and scientific organizations, employers' and socio-professional associations through organization of joint actions, of mutual interest.

By the accession to FISITA (International Federation of Automotive Engineering Societies) since its establishment, SIAR has been involved in achieving an overall professional community that is homogeneous in competence and performance, interactive, dynamic, and competitive at the same time, oriented towards a balanced and friendly relationship between people and the environment; this action will be constituted as a challenge worthy of effort and recognition.

The insurance of a favorable framework for the initiation and the development of cooperation of the specialists in this field of activity allows for an efficient and easy exchange of information, specific knowledge and experience; it supports the cooperation between universities and between research centers and industry; it speeds up the process of implementing the new technologies, it simplifies the identification of training and specialization needs of the personnel involved in the engineering of motor vehicles, transport, and road safety.

In order to succeed, ever since its founding, SIAR has considered that the stress should be put on the production and distribution, at national and international level, of a publication of scientific quality.

Under these circumstances, the development of the scientific magazine of SIAR had the following evolution:

### 1. RIA – Revista inginerilor de automobile (in English: *Journal of Automotive Engineers*)

ISSN 1222 – 5142

Period of publication: 1990 – 2000

Frequency: Quarterly

Total number of issues: 30

The above constitutes series nr. 1 of SIAR scientific magazine.

Format: print, Romanian

Electronic publication on: [www.ro-jae.ro](http://www.ro-jae.ro)

Type: Open Access

### 2. Ingineria automobilului (in English: *Automotive Engineering*)

ISSN 1842 – 4074

Period of publication: as of 2006

Frequency: Quarterly

Total number of issues: 45

(including the December 2017 issue)

The above constitutes series nr. 2 of SIAR scientific magazine (Romanian version).

Format: print and online, Romanian

Electronic publication on: [www.ingineria-automobilului.ro](http://www.ingineria-automobilului.ro)

Type: Open Access

### 3. Ingineria automobilului (in English: *Automotive Engineering*)

ISSN 2284 – 5690

Period of publication: 2011 – 2014

Frequency: Quarterly

Total number of issues: 16

(including the December 2014 issue)

The above constitutes series nr. 3 of SIAR scientific magazine (English version).

Format: online, English

Electronic publication on: [www.ingineria-automobilului.ro](http://www.ingineria-automobilului.ro)

Type: Open Access

### 4. Romanian Journal of Automotive Engineering

ISSN 2457 – 5275

Period of publication: from 2015

Frequency: Quarterly

Total number of issues: 12 (December 2017)

The above constitutes series nr. 4 of SIAR scientific magazine (English version).

Format: online, English

Electronic publication on: [www.ro-jae.ro](http://www.ro-jae.ro)

Type: Open Access

### Summary – on December 31, 2017

Total of series: 4

Total years of publication: 23 (11=1990 – 2000; 12=2006-2017)

Publication frequency: Quarterly

Total issues published: 75 (Romanian), out of which, the last 28 were also published in English

