When cars talk to each other.
Car-to-x – the communication platform of the future.

The key to intelligent driving, which is synonymous with energy-efficient and safe driving, is forward thinking. To help drivers plan ahead, vehicles from the BMW Group are already fitted with a large number of sensors designed to improve safety, comfort and efficiency. Often, however, these sensors have only a limited predictive capability or "horizon". "Car-to-x" communication extends this horizon significantly, and will in future allow drivers to "see" long distances ahead, into areas currently hidden from view, and even around not just one but many corners.

Car-to-x communication means electronic networking of vehicles and roadside infrastructure, with the aim of exchanging information directly both between road users and between road users and roadside infrastructure such as traffic lights. Car-to-x communication is a comprehensive communication network which any road user can take part in.

Car-to-x communication usually operates via WLAN or mobile phone connections. For standard automotive application, car-to-x communication at present uses high-speed WLAN networking based on the high-frequency WLAN IEEE802.11p/ G5A standard, which is designed to allow real-time communication. The protocol allows large numbers of participants to communicate simultaneously without interference. At the same time the performance of mobile phone networks is improving steadily, with an increase in bandwidth and a reduction in data lag – the so-called latency times. Therefore, this type of medium, too, is becoming increasingly important for car-to-car communication, for example as a complement to direct communication via WLAN.

Connectivity brings added value.
Integrated and connected vehicle functions are nothing new within the BMW Group. Connectivity for infotainment applications already made its debut in the 1990s with BMW ConnectedDrive. For some years, the focus of development work in the BMW Group has been shifting increasingly towards integrated and connected comfort and, in particular, safety functions. Here, car-to-x communication opens up completely new potential. In the event of a hazard, extensive connectivity between vehicles allows oncoming and following traffic to be given advance warning of potential dangers, and therefore to react appropriately and in good time. But warnings are only one possible use of this communication platform. Since infrastructure data, too – for example about traffic light phases – can be integrated into this communication system, information is available which allows drivers to easily adapt their driving style for even greater efficiency, thereby significantly reducing vehicle emissions. This technology therefore offers new solutions not only for proactive safety and accident prevention but also for intelligent energy management.

"The more information I have about the rest of my journey – for example, if I know in advance when traffic lights will change, or if I know that an accident has just happened further along the route – the more promptly I can react, which means I have less stress and can either avoid hazardous situations altogether or at least reduce the risk." (Karl-Ernst Steinberg, Head of Information and Communication Technologies at BMW Group Research and Technology).

In combination with existing vehicle sensors, car-to-x communication provides a valuable starting point or enhancement for a wide range of BMW ConnectedDrive driver assistance and information systems of the future. These technologies, combined with the driver's own input, create an extremely high-performance macrosystem capable of ensuring a safe and efficient journey from start to finish.

BMW Motorrad ConnectedRide: active protection for motorcyclists as well.
The BMW Group's ongoing efforts to achieve greater road safety take all road user groups into account. In addition to applications for vehicles of the BMW Group and for protection of pedestrians or cyclists, motorcyclists are a further group whose integration into the car-to-x communication platform is an important priority for BMW. BMW Motorrad ConnectedRide – the motorcycle equivalent of BMW ConnectedDrive – is looking to use car-to-x communication, in addition to handling control systems, driver assistance systems and a motorcycle emergency call function, in order to improve safety for motorcyclists. Motorcyclists face different dangers on the road from car drivers. Certain situations, such as fog, slippery roads or heavy precipitation, are much more of a challenge for these road users than for car drivers. What's more, "single-track" vehicles like motorcycles, with their narrower silhouette, are unfortunately often more easily overlooked.

There are therefore big benefits for motorcyclists in having advance information about special situations. Often, cars play a pivotal role in this system as the original source of the warnings. For example, activation of car fog lamps or the highest wiper setting, or DSC intervention in an otherwise normal driving situation, may indicate adverse conditions in a certain area. This information is then supplied to the motorcycle, keeping the rider promptly and fully informed.

Car-to-x research of value only with industry collaboration.
Car-to-x communication has been an important topic within the BMW Group for almost ten years. But the BMW Group's research is not carried out in isolation. After all, this is a field where teamwork between as many vehicle manufacturers as possible is vital. For example, the BMW Group was one of the first carmakers to join the "Car-2-Car Communication Consortium". Founded in 2003 by a number of European car manufacturers, this consortium is researching potential applications and looking into a harmonised standard for transnational vehicle-to-

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vehicle and vehicle-to-infrastructure communication. That's because this technology can only develop its full potential with a critical mass of participants: the greater the number of vehicles integrated into the system, the greater the amount of data that can be made available and used, and the greater the safety benefits.

The BMW Group is also participating in many other joint research projects in this field, such as "simTD" (Safe Intelligent Mobility – the German Test). The aim of this project is to test the functionality, everyday practicality and effectiveness of car-to-x communication for the first time under real-world conditions. The simTD project is putting into practice findings obtained in earlier research projects. Realistic traffic scenarios are being addressed in a large-scale test environment based on the infrastructure around the city of Frankfurt, Germany. The project is also intended to provide the necessary political, economic and technological foundation for successful implementation of vehicle-to-vehicle and vehicle-to-infrastructure communication. Various companies in the automotive and telecommunication sectors, the government of the German State of Hesse and a number of leading universities and research institutes are partnering in this project and are committed to the above objectives. The project is sponsored and supported by the Federal Ministries of Economics and Technology, Education and Research, and Transport, Construction and Urban Development.

Following three years of intensive research, the groundwork has now been completed for the world's largest car-to-x field trial, which will take place on German roads. On 11 October 2011, the simTD project consortium delivered a current status report at a project presentation in Friedberg, Hesse, at which it summed up the initial results of the first three years' work on this car-to-x project, which began in September 2008.

Car-to-x functions from the BMW Group. Research into car and motorcycle applications.

The Intersection Assistant: greater safety at road junctions.
In Germany alone, a third of all accidents involving personal injury occur at intersections, due to failure to see, or to spot in time, another road user; poor visibility due to buildings or trees; or because drivers are not being sufficiently attentive. If we take a typical everyday driving situation as an example, the system functions as follows: the driver approaches an intersection and prepares to cross. On the road he wants to cross, which has priority, there is a continuous stream of traffic in both directions. At the same time, visibility into the priority road is impaired due to roadside parking. This is a situation for the Intersection Assistant, which detects the data emitted by other road users in the area of the intersection and can reduce the potential risks of the manoeuvre by communicating with other vehicles approaching the junction.

The Intersection Assistant analyses the incoming information about the speed, distance from the intersection and direction of travel of other road users, along with information generated by the driver's own vehicle. If a collision risk is detected, the driver receives a warning in the form of visual and audible signals and gentle deceleration. The warning results in a reduction in vehicle speed so that either a crash can be prevented or at least, if this is not possible, the consequences are mitigated. If driver reactions alone will not be sufficient to eliminate or reduce the risk, the Assistant can intervene by priming the brakes and assisting with braking.

The BMW Motorrad ConnectedRide Intersection Assistant.
To improve intersection safety for motorcyclists as well, the BMW Group engineers have also incorporated Intersection Assistant functionality into the BMW Motorrad ConnectedRide technology for motorcycles, for the first time integrating motorcyclists into vehicle-to-vehicle communication. Car-motorcycle collisions are particularly dangerous for motorcyclists, who are roughly three times more likely to be seriously injured in such a collision than car drivers.

Like the Intersection Assistant for cars, the Intersection Assistant in BMW Motorrad ConnectedRide is a forward-looking active safety system which aims as far as possible to prevent, or at least to mitigate, critical situations at intersections. Based on road data and data about the position and speed of road users approaching the intersection, the system assesses which vehicles have priority in this situation and calculates the likelihood of a collision. It also evaluates the behaviour of the waiting car driver on the non-priority road.

If the Intersection Assistant calculates that there will be a collision if both car and motorcycle continue on their present course, it gives the car driver a graduated series of warnings about the collision risk, starting with visual and continuing with

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tactile and audible signals. An increasing collision risk also prompts a series of actions at the motorcycle: the headlight is gradually modulated, its intensity increased, and additional LED warning lights are activated at the side of the motorcycle to widen its silhouette. If the collision risk becomes acute, the motorcycle horn is sounded too. The aim is to draw the car driver's attention to a potentially critical impending situation at the intersection. On the one hand the warning is issued early enough for the driver still to be able to halt the vehicle before the stop line. On the other hand, the warning is nevertheless issued late enough to avoid alerting the car driver unless there is a very real risk of a collision. It is assumed that emergency braking by the car driver will be able to prevent a collision.

The Traffic Light Phase Assistant – green lights all the way.
The Traffic Light Phase Assistant allows a vehicle to communicate with traffic lights. For example, traffic lights can supply information about their phasing, so that drivers can choose an optimal speed for catching lights on green, or are warned in sufficient time to avoid any risk of going through a light on red.

On board the vehicle, the Traffic Light Phase Assistant analyses a range of incoming data – for example information about current traffic light status and length of the individual green, amber and red phases, along with intersection- and vehicle-specific information. If the traffic light would be red by the time the car driver or motorcyclist reached the intersection if he did not change his current speed, the driver or motorcyclist receives this information early enough to be able to brake gently to a halt. On approaching the light the driver or rider may also, however, be given a recommended speed for reaching the traffic light on green – subject to compliance with traffic regulations, of course.

The Intersection Assistant allows the driver to see a short way "into the future" and to adapt his driving style effortlessly to the traffic light phasing. The result is increased safety and convenience, avoiding any need for sudden acceleration or abrupt braking. The driving style becomes calmer, safer and more fuel-efficient.

Local hazard warnings keep motorcyclists fully informed about fog, congestion etc.

The **bad-weather warning** informs motorcyclists in good time about adverse conditions such as fog, rain, snow or ice on upcoming sections of the route via a visual display in the instrument cluster – and optionally also by a voice message from the BMW Motorrad Communication System. The Assistant also tells the rider approximately where to expect these conditions. The engineers have in mind that the input for this warning would be provided, for example, by a given number of vehicles activating their fog lamps or windscreen wipers. This input, combined with information about the outside temperature in the vicinity of the vehicles affected, could be used to evaluate the likelihood of snow or hail in the affected area. In the event of ice, a warning or bad-weather alert could be

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triggered by the intervention of systems such as Dynamic Stability Control on vehicles in the affected area. Looking at this information in conjunction with outside temperature information and data from other sensors such as the rain sensor or video camera, or from weather reports, the algorithm can generate appropriate alerts in the instrument cluster and a voice message in the BMW Motorrad Communication System.

The **obstacle warning** function warns the motorcyclist – again via a visual display in the instrument cluster and optionally also by a voice message – to expect an obstacle on the road ahead. This could be anything from a stranded vehicle, an accident or roadworks to the end of a tailback. The warning comes with information about approximately how far ahead the obstacle is situated. The warning can be generated in a variety of different ways and by a variety of different systems. For example, it may be generated by a stranded vehicle or by a number of vehicles activating their hazard warning lights or braking at the end of a tailback and so transmitting a warning, and indicating their location, to approaching vehicles.

The **emergency vehicle warning** provides early warning of an emergency vehicle approaching from behind. The warning, which is provided by means of a visual display in the instrument cluster, allows the rider to make way for the emergency vehicle in good time and so avoid a critical situation. A clearly identifiable symbol – for example a blue light – provides an instantly recognisable warning and is combined with an approximate indication of where the emergency vehicle is currently situated. The displayed distance decreases in 50-metre increments, allowing the motorcyclist to adapt his driving accordingly, and if necessary to pull over to the side of the road. In addition to the visual information in the instrument panel, a warning can also be given via a voice message in the BMW Motorrad Communication System. The warning is automatically deactivated as soon as the emergency vehicle has passed. The development team are also looking into ways of integrating the planned route of the emergency vehicle into the warning strategy, so that the system could warn the rider when the emergency vehicle is about to change direction.

The **electronic brake light** is designed with the following hazard in mind: in very dense traffic, the brake lights of a vehicle that is braking sharply may not be visible to vehicles further behind on the road, leading to delayed reactions on the part of these drivers and potentially to rear-end collisions. The electronic brake light provides a way of informing motorcyclists at the earliest possible opportunity that a vehicle further ahead is decelerating sharply, so that they can react in good time. The warning takes the form of a display in the instrument cluster or an audible warning. The motorcyclist therefore knows in good time that he may soon need to brake, and so can react faster if the need arises.

The Left Turn Assistant: anticipation and good planning, for safe turning across traffic.

With the Left Turn Assistant (for left-hand-drive vehicles), BMW Group Research and Technology has developed a system to help drivers making a left turn at intersections by warning them if they have failed to spot another road user and preventing a collision by autonomous braking. The Left Turn Assistant takes into account the special hazards of this manoeuvre both for cars and for motorcyclists.

The Left Turn Assistant, which is currently being tested in the BMW 5 Series, is automatically activated when the vehicle's sensors detect that the vehicle is entering the left-turn lane and the car registers that the driver wishes to turn off. The system detects the left-turn lane in two ways. Firstly, it uses the vehicle positioning function of the navigation system, which allows the location of the vehicle at intersections to be determined to within a metre. And secondly, a mono camera, similar to standard cameras already in use today, detects the turn-off lane markings on the road and also the lane boundaries.

As soon as the Left Turn Assistant has been activated, three laser scanners at the front of the test vehicle scan the area in front of the vehicle over a distance of up to 100 metres. The laser scanners are capable of detecting not only cars and trucks but also motorcycles. If the sensors detect that oncoming traffic is approaching yet the vehicle is still continuing into the intersection, the Left Turn Assistant automatically brakes the vehicle, provided it is not travelling faster than 10 km/h, in order to prevent a collision. At the same time, an audible warning and appropriate warning symbols in the instrument cluster and in the Head-Up Display advise the driver of the reason for the intervention. This automated braking is intentionally performed without prior warning, since fast response is vital in this situation to prevent the vehicle proceeding into the intersection and presenting an obstacle to oncoming traffic. By the time the driver received and reacted to a warning, the vehicle would already be in the collision zone and an accident would be unavoidable.

The Left Turn Assistant is designed to operate at speeds up to 10 km/h. In other words, the Assistant does not slam the brakes on when the vehicle is travelling at speed, but instead should be viewed as a system that prevents the vehicle from starting off, or from continuing to edge forwards. As soon as the driver himself steps on the brake pedal, the vehicle is "authorised" to move forward again and the Left Turn Assistant braking function is released. To maximise safety, the Left Turn Assistant can also be overridden at any time. For example, if the driver needs to clear the way for an emergency vehicle coming through the intersection, he can do so with a further brief press of the accelerator.

Left Turn Assistant: car-to-x communication further enhances safety

The functionality of the Left Turn Assistant can be extended by combining it with vehicle-to-vehicle communication. As well as the laser scanners and camera, the

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BMW 5 Series Sedan test car is therefore also equipped with a WLAN car-to-x communication system. This specification not only increases the range over which the vehicle is able to detect other vehicles – to 250 metres – but also allows similarly equipped road users to be detected even when they are not visible to the turning vehicle.

The additional potential offered by a car-to-x system is illustrated by a second test scenario involving the Left Turn Assistant, on the test car, and a motorcycle equipped with car-to-x communication. The BMW Motorrad test motorcycle is currently a BMW R 1200 GS. Again, fused sensor data from a camera-based image recognition system and laser scanners detects the lane markings and the left-turn arrow, along with the distance from the centre line and stop line – if these markings are present. As soon as the direction indicator is operated, the vehicle registers the driver's wish to turn left and the assistance system is activated. "As the motorcycle approaches, the car and motorcycle communicate with each other via their car-to-x systems. They exchange information about vehicle type, position and speed, as well as dynamic data such as the current steering angle and whether the direction indicator is activated," explains Udo Rietschel, development engineer in BMW Group Research and Technology's Left Turn Assistant project.

From this information, the motorcycle is aware that the car wishes to turn left. Based on the data communicated between car and motorcycle, an algorithm projects the future trajectories of both vehicles and identifies any risk of collision. If a critical situation is detected, the motorcycle draws attention to itself in order to warn the car driver, in the same way as with the Intersection Assistant. These warnings are progressively extended as the collision risk increases – the motorcycle's headlight is gradually modulated, its intensity increased, and side- and mirror-mounted flashing lights and LEDs are activated to give the motorcycle a broader silhouette. If the collision risk becomes acute, the motorcycle horn is sounded too. If the car continues to move forward into the intersection regardless, the Left Turn Assistant automatically brakes it to a standstill. Again, during and after the automatic braking, the system also generates an audible warning and appropriate warning symbols are displayed in the instrument cluster and in the Head-Up Display, to inform the driver of the reason for the intervention.

"Ko-FAS" research initiative – successor to the "AMULETT" project.
The aim of the "Ko-FAS – Cooperative Vehicle Safety" research initiative is to significantly increase traffic safety through efficient and reliable sensing of the traffic environment using cooperative sensory and perception systems, and through comprehensive scenario assessment to precisely evaluate collision risks, with subsequent activation of appropriate advance protection systems where necessary.

Ko-FAS comprises three joint projects: Ko-TAG, Ko-PER and Ko-KOMP. The Ko-TAG and Ko-PER projects are being managed by BMW Group Research and Technology.

The focus of the joint project Ko-TAG is on transponder systems for precise object location-sensing and classification using cooperative sensory systems (car-to-TAG communication). In the future, this technology will be used to help protect vulnerable road users (pedestrians and cyclists) and to enhance vehicle-vehicle safety. Engineers from BMW Group Research and Technology already developed a first pedestrian protection system based on car-to-TAG communication as part of the earlier project "AMULETT". This system was used in a test vehicle which wirelessly exchanged data with an active RFID-type tag, at a frequency of 2.4 GHz. This tag would be capable of being fitted in such everyday articles as school satchels or walking sticks. Cooperative sensor technology makes it possible even to detect people who are not visible to the car driver at the time of the hazard, and to classify them as vulnerable road users. The results of the AMULETT project are now feeding into the Ko-TAG project and the work is continuing – now with the accent on enhancing car-to-x communication with transponder-based location-sensing functions. The researchers are particularly interested in how this technology can be extended to more complex scenarios involving large numbers of participants. "In future applications, this location-sensing technology will provide data from which we can draw very precise and very reliable conclusions. This will allow us to achieve a further substantial improvement in road safety," says Daniel Schwarz, Ko-TAG project spokesman for BMW Group Research and Technology.

The Ko-PER project – which is again based on car-to-x communication – is researching cooperative perception systems for use in both "parallel" traffic and at intersections. "We are incorporating into this project the results of the successfully concluded EU research project 'PReVENT', and are also seeking an active exchange of information with the national research project 'simTD – Safe Intelligent Mobility – the German Test'. The various research activities all have a common goal: greater safety on our roads," says Dr Felix Klanner, Ko-PER Project Manager at BMW Group Research and Technology. In the Ko-PER project, the BMW Group researchers are studying ways of using cooperative sensor networks to scan the traffic environment. The aim is to use vehicle-to-vehicle communication, and fusion of data from a variety of vehicle environment and roadside infrastructure sensors, in order to generate a complete picture of this environment. A particular focus is on detecting currently concealed road users and on tracking traffic dynamics over time. This will provide a basis for continuous and comprehensive evaluation of collision risks.

The focus of the joint project Ko-KOMP is on researching vehicle protection systems that can be activated when a collision risk arises and that are intended to help prevent an accident or at least mitigate its consequences. In particular, the systems being investigated include expanding the vehicle's external shell or

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timely automatic activation of autonomous emergency braking functions. Also planned is the development of a virtual test environment for simulating communication interactions in a wide variety of traffic scenarios.

Initial findings from the Ko-FAS research initiative were presented to the public in late September at presentations in Alzenau and Aschaffenburg.

If you have any questions regarding this press release please contact:

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