The method comprises the steps of: the mobile node 19, 20 comprising at least two communication interfaces 15, 16 operates 701 in an interleaved fashion, so that when one first interface 15 is carrying an active communication with the present communication node 11, at least one second interface 16 at the same time is trying to establish a communication link with one of the available following communication nodes 12, 13, 14, the mobile node 19, 20 uses 702 a directed graph that suggests which one or ones of the available following communication nodes 12, 13, 14 that the second communication interface 16 should primarily search for when trying to establish a communication link, the state system 29, 30 being arranged on the vehicle 27, 28 determines 703 vehicle state information, relating to the movement of the vehicle 27, 28, the mobile node 19, 20 receives 704 the vehicle state information from the state system 29, 30 and distributes said information to the server 26.
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TITLE
Handover of mobile node in a wireless cell-based communication network.

TECHNICAL FIELD
The invention relates to a method for sharing vehicle state information in a wireless local area network. It also relates to a state system, a mobile node, a collision avoidance system, a vehicle control system and a vehicle.

BACKGROUND ART
IEEE 802.11x is a set of standards for Wireless Local Area Network (WLAN) computer communication. IEEE 802.11x is one example of a communication network suitable for wireless cell-based communication, wherein cell-based relates to the fact that there are cells covered by a base station, a communication node or similar. These stations or point enables radio communication between a mobile node and the network through the grid of communication nodes in the network.

IEEE 802.11x is developed by the Institute of Electrical and Electronic Engineers (IEEE) in the 5 GHz and 2.4 GHz public spectrum bands. The WLAN is normally designed using a number of independent base stations ("Access Points", AP's) that are geographically placed within the area where communication shall be granted at positions so that a moving unit in any position of this area will have a required level of communication using at least one AP.

The standard defines a Medium Access Control (MAC) sub-layer and a Physical (PHY) layer in the lowest part of the protocol stack. The MAC layer in IEEE 802.11 provides access to control functions such as addressing, access coordination, and frame check sequence generation and checking.

Since the first release, three extensions to the physical layer have been made; 802.b, IEEE 802.11g and IEEE 802.11n. These are amendments to
the original standard IEEE 802.11a. IEEE 802.11b was the first widely accepted one, followed by IEEE 802.11g and IEEE 802.11n.

The upcoming IEEE 802.11r is a proposed amendment to the IEEE 802.11 standard which permits connectivity aboard vehicles in motion, with fast handoffs between base stations. Handover is supported in IEEE 802.11a/b/g/n, but insufficient. The handover delay is too long to support applications like voice and video and is problematic for implementing (high speed) safety applications. The primary application currently envisioned for the IEEE 802.11r standard is Voice over IP (VoIP) via mobile telephones designed to work with WLAN instead of common cellular networks. IEEE 802.11r refines the transition process when a mobile terminal moves between Access Points (AP's) - called handover. The protocol allows a wireless client to establish connection to a new Access Point before making a transition, which leads to minimal connectivity loss and application disruption.

An ordinary WLAN communication network consists of a large number of WLAN AP's. A WLAN network interface is installed in the mobile unit and hands over from one AP to following AP as it moves through the WLAN area. A problem with WLAN is that latency occurs when switching from one Access Point (AP) to another. When leaving the area of a present AP and entering the area of a following AP, the network interface must do a scan to obtain a new signal. This causes a latency time when the receiving unit does not have a wireless connection. Typical performance for "switch-over" measured, and documented by many, is in the range of one following AP. This is achieved as mobile unit that is leaving one AP is communicating "as long as possible", thereafter starts listening for any other AP to switch to. When a candidate is found (by means of evaluation received signal strength or other method), a "registration process" is performed, where after communication can proceed.

When WLAN communication networks are used for moving vehicles, such a latency time can cause interruptions. This is very problematic for applications such as voice and video. Typical figures for a (worst-case) car travelling a
test-track site at 300 km/h, communicating with optimal AP's, each covering, say 300m radius, total (maximal) length of travel within reach being 600m, will result in a communications channel that is dead 1 second every 7 seconds.

In order to solve this problem in WLAN, there is a known proposal of using dual antennas in order to shorten the latency time in ordinary IEEE 802.11b/g/n networks. The latency time is when no packets can be sent or received. This is presented in the publication "Wireless LAN Access Network for Moving Vehicle". Authors T. Okabe, T. Shizuno and T. Kitamura. Proceedings of the 10th IEEE Symposium on Computers and Communications (ISCC 2005). The same proposal is also presented in the Internet Draft "Smooth Handover over IEEE 802.11 Wireless LAN". Author Masatako Ohta. Published June 2002.

In the proposal, switch-over schemes for WLAN are discussed and their use with fast-moving vehicles. Each moving unit is equipped with multiple communications units. These are operated in an interleaved fashion, so that one unit is establishing the "next communications path" at the same time as communication is still operational using another unit. Switch-over from one operational channel to next operational channel can be in the range of 50 ms or better.

Figure 1 illustrates the network architecture for any wireless cell-based communication networks, for instance a wireless local area network. The communication network 10 comprises Access Points 11,12,13 connected to a common (backbone) Network 26. The cloud 26 illustrates all nodes and entities in such a backbone network and the fact that the Access Points communicate with the same Network. This means that handover can be performed between the Access Points connected to the Network. The Network 26 is responsible for the authentication of the mobile node 19.
The mobile node 19 is installed in a moving vehicle and comprises two wireless cell-based communication interfaces 15,16. One of the interfaces 15 is used for data communication 24 with a present Access Point 11 while the other one 16 is used for searching 25 for and connecting one of the other available Access Points 12,13. The roles are switched alternately and as a result the mobile node can perform data communication while performing switch-over.

To find suitable Access Points when moving in a certain direction 18 the mobile node 19 sends a probe request every 5 ms and receives the response to the probe. The Access Point 12 that returns a response and where the power level is sufficiently high is chosen as the next Access Point 12, 13 to which switch-over is performed. In the next step of the switch-over, an air link is established. Thereafter, authentication and location registration is performed. When this is done, data communication can start. When switch-over is performed to a new Access Point 12,13 the access to the Access Point 11 is disconnected. Since there are two interfaces, the switch-over can be performed at the same time as data communication is running. Thereby, the latency time is significantly reduced.

To shorten the authentication and registration time of the switch-over, the Network 26 authenticates a mobile node 19 to the next Access Point 12,13 of the communication network 10 on behalf of the radius server (not shown) in the Network when the mobile node switches over from one Access Point 11 to another 12,13. Shortly, in order to do this, the Network checks a local challenge word received and compares it with an earlier received word to confirm if the mobile node is identical. If they are identical, the Network indicates authentication success to the mobile node with no Radius Server involved. The Server is located in the Network 10.

The IEEE 802.11b/g/n works with a channel frequency distribution divided into a number of possible channels. Several of these channels are overlapping and among these some channels do not overlap. Each of the
Access Points 1,12,13 uses one of these channels for communication. The problem with the proposal by Okabe, Shizuno and Kitamura with switch-over schemes in WLAN is that the handover also comprises a step of searching for available Access Points.

The mobile node 19 still has to look though all the available channels when searching for new available Access Points for switch-over. If WLAN is used as wireless cell-based communication network this procedure may take up to 300 ms. Due to the long time, the Access Points 11,12,13 has to overlap significantly so that the mobile node 19 is the fast-moving vehicle has enough time to search for Access Points. Using a mobile node with two antennas the overlap needs to be 35 - 100 meters. This means that more Access Points are needed to cover a certain area. For instance, if the coverage of the Access Point is 300 meters (diameter) and the area is 900 meters long, four Access Points are needed.

Similar problems occur also for other wireless cell-based communication networks. Such networks are for instance mobile networks, WiMAX, Bluetooth and systems developed for a particular consumer/use such as the Swedish bluelight system RAKEL. They all comprise communication nodes, such as access points or base station, for enabling wireless communication with the mobile node. The communication nodes operate on different frequencies within the band, and consequently an overlap is needed for the mobile node searching of available communication nodes.

Each communications path between the communicating peers (two mobile nodes or one node and a backbone network) can be viewed as a set of link communications paths, each between two peers. Figure 2 shows an example of link communication paths between nodes X and Y. In fig 2 communication between peers X and Y is said to be indirectly connected using the set of directly connected communications paths links (X - A, A - H, H - Y), see example in middle picture in figure 2. In this example the in theory possible communications path B - H is not used. The problem addressed is regarding
performance of data transfer when the communications path link X-A is broken, but a new candidate communications path link X-B is available, i.e. transmission between X and Y shall be handed over from the communications link X-A to communications link X-B, see example in lowest picture in figure 2.

One of the problems with this handover procedure in a cell-based communication network is the time required to fulfill the procedure of handover. This procedure mainly comprises of the method of scanning all channels available to all used interfaces when searching for an available following communications nodes 12, 13, 14 in the communication network and the method of establishing communication using the following communications nodes 12, 13, 14.

For instance COTS (Commercial Of The Shelf) WLAN-interfaces according to IEEE 802.11a/b/g works with a channel frequency distribution divided into 14 a number of possible channels. Scanning all these channels typically requires in the range of up to 300 ms. Due to this time, the communication nodes have to overlap significantly. The required minimum overlap distance is calculated by a product of the movement speed of a vehicle based mobile node and the total time required fulfilling the hand-over procedure. For example, a scanning time of 300 ms used in a vehicle based mobile node under movement at 250 km/h (approx 70 m/s) requires 21 m of overlap to cover for the scanning part of a hand-over procedure.

A directed neighbouring graph for reducing the scanning time and therefore the handover time is presented in the publication "Global Path-Cache Technique for Fast Handoffs in WLANs" PUB-Computer Communications and Networks", ICCCN 2007. Authors Weetit Wanalertak and Ben Lee. Proceedings of 16th International Conference on 20070801 (XP031136840). This graph is preferably used together with the multiple communication units proposed by Okabe, Shizuno and Kitamura in order to reduce the handover time even further. These communication units are operated in an interleaved
fashion, so that one unit is establishing the "next communications path" at the same time as communication is still operational using another unit.

SUMMARY OF THE INVENTION
The object of the present invention is to use the solution for improved handover in a vehicle management system to allow vehicles to run simultaneously on a common driving area without colliding.

The object is solved by means of a method for sharing vehicle state information in a wireless cell-based communication network. A mobile node being arranged on a vehicle is adapted for wireless communication with communication nodes arranged in the network. The network further comprises a server being connected to the communication nodes. The method comprises the steps of:

the mobile node comprising at least two communication interfaces operates in an interleaved fashion, so that when one first interface is carrying an active communication with the present communication node, at least one second interface at the same time is trying to establish a communication link with one of the available following communication nodes.

the mobile node uses a directed graph that suggests which one or ones of the available following communication nodes that the second communication interface should primarily search for when trying to establish a communication link.

the state system being arranged on the vehicle determines vehicle state information relating to the movement of the vehicle,

the mobile node receives the vehicle state information from the state system and distributes said information to the server.

The object is also solved by means of a state system suitable for sharing vehicle state information in a wireless cell-based communication network. A mobile node being arranged on a vehicle is adapted for wireless
communication with communication nodes arranged in the network. The network further comprises a server being connected to the communication nodes. The state system being arranged on the vehicle is particularly characterized in that it is adapted to determine vehicle state information relating to the movement of the vehicle. The state system further being adapted to distribute the state information to the mobile node according to any of the claims 11 - 13 and/or the collision avoidance system 31,32 according to claim 14.

The object is also solved by means of a mobile node suitable for sharing vehicle state information in a wireless cell-based communication network. The mobile node being arranged on a vehicle is adapted for wireless communication with communication nodes arranged in the network. The network further comprises a server being connected to the communication nodes. The mobile node comprising at least two communication interfaces is adapted to operate in an interleaved fashion, so that when one first interface is carrying an active communication with the present communication node, at least one second interface at the same time is trying to establish a communication link with one of the available following communication nodes. The mobile node is further adapted to use a directed graph that suggests which one or ones of the available following communication nodes that the second communication interface should primarily search for when trying to establish a communication link.

The mobile node is particularly characterized in that it is adapted for receiving the vehicle state information from a state system according to claim 10 and distribute said information to the server.

The object is also solved by means of a collision avoidance system suitable for sharing vehicle state information in a wireless cell-based communication network. A mobile node being arranged on a vehicle is adapted for wireless communication with communication nodes arranged in the network. The network further comprises a server being connected to the communication
nodes. The collision avoidance system being arranged on the vehicle is particularly characterized in that it is adapted to predict the future positions of at least one vehicle on the basis of the vehicle state information received from the state system according to claim 10 and/or vehicle state information received from the mobile node according to any of the claims 11 - 13.

The object is also solved by means of a vehicle control system comprising the state system according to claim 10, the mobile node according to any of the claims 11 - 13 and/or the collision avoidance system according to claim 14. The object is finally solved by means of a vehicle comprising the vehicle control system according to claim 15.

Preferred embodiments and advantages of the invention will emerge from the dependent claims and the detailed description below.

BRIEF DESCRIPTION OF THE DRAWINGS
The invention will now be described in greater detail below with reference to the embodiment shown in the accompanying drawings, in which:

Figure 1 shows the physical topology of a wireless cell-based communication network together with a mobile node.

Figure 2 shows an example of link communication paths between nodes X and Y with examples of link communication paths between nodes X and Y, both for path communication link X-A and after it has been handed over to X-B.

Figure 3 shows the directed graph for a wireless cell-based communication network.

Figure 4 shows the physical topology of the wireless cell-based network according to figure 3.
Figure 5 shows the physical topology of a wireless cell-based communication network with vehicles comprising a state unit, a collision avoidance system and a mobile node.

Figure 6 shows a flowchart of the collision avoidance system and part of the state system according to figure 5.

Figure 7 shows a flowchart of the method according to the present invention.

DETAILED DESCRIPTION

The invention will now be described in detail with reference to embodiments described in the detailed description and shown in the drawings.

The mobile node uses a method for handover of a mobile node from a present to a following communication node in a wireless cell-based communication network, for instance a wireless local area network. The mobile node is adapted for performing the method steps in the embodiments here described. The method allows for handover of a mobile node 19 from a present 11 to a following 12,13,14 communication node in at least one wireless cell-based communication network.

The mobile node 19, see figure 1 (a communication peer) comprises at least two communication interfaces 15,16 operating in an interleaved fashion so that when one first interface 15 is carrying an active communication with the present communication node 11 (directly connected), at least one second interface 16 at the same time is trying to establish a communication link with one of the available following communication nodes 12,13.

The communication interfaces 15,16 may for instance be interfaces according to some IEEE 802.11 standards. The interfaces may be either physical or virtual. Other interfaces for other types of wireless cell-based communication networks are also an option, for instance cell-phone networks, WiMAX, Bluetooth and systems developed for a particular
consumer/use such as the Swedish emergency service communication system RAKEL.

The multiple communication interfaces 15,16 can, for instance in the case of data transfer speed requirements being less than the aggregated physical available data transfer speed of the actual physical interfaces, be virtual interfaces implemented by for instance time division of at least one physical communication interface.

During operation the two interfaces 15,16 are switched alternately, e.g. when one of the interfaces is communicating with the present communication node the other one is scanning the frequency channels to find other available following communication nodes 12,13. When found, this interface handles the switch-over from the present to the following communication node, the switch-over including authentication and location registration. With this overlapping procedure, the switch-over time can be significantly reduced, compared to a one-interface solution. This solution was also described in the background art.

As mentioned earlier, one of the problems with this handover procedure in a cell-based communication network is that this procedure comprises of the method of scanning all channels available to all used interfaces when searching for an available following communications nodes 12, 13, 14 in the communication network. For instance COTS (Commercial Of The Shelf) WLAN-interfaces according to IEEE 802.11a/b/g works with a channel frequency distribution divided into a number of possible channels (local regulations). Scanning all these channels typically requires in the range of up to 300 ms. In order to compensate this time, each cell has to overlap the neighbouring cells.

In order to solve the above-mentioned problems the mobile node 19 uses a directed graph that suggests which one or ones of the available following
communication nodes 12,13,14 that the second communication interface should primarily search for when trying to establish a communication link.

The main advantage using a directed graph is that a high communication quality can be achieved for communication between communication nodes where connectivity is constructed by use of communication links that frequently occur and vanish, enabling an almost continuous data transfer between for instance a mobile node 19 and an infrastructure. Another advantage is that less infrastructure communication nodes 11,12,13,14 are needed to cover an area for mobile nodes 19. This consequently leads to fewer handovers, which also increases the quality of the data communication.

A particular advantage is that high quality communication can be implemented using COTS (Commercial Of The Shelf) products. For example defines IEEE 802.11 a very common COTS technique used by professionals and public. The popularity of the products makes the price low and the accessibility high. It is a widespread technique and the development proceeds quickly with increasing performance. The performance has increased from 1 up to 54 Mbit/s in a few years time and will most likely continue to increase.

In commonly used scanning methods, after transmittance of a request message whose destination is all communication nodes 11,12,13,14 (see fig. 1), the mobile node 19 has to wait for possible reception for a specific time because it does not know how many communication nodes that will send a response message. This has to be repeated for every available channel. This technique is called broadcast. Another possible scanning method is to address a subset of the set of all communication nodes. This technique is often called multicast.

Having a directed graph provides the alternative to instead of broadcast or multicast use unicast. In unicast a request message is only sent towards one
or several potential following communication nodes 12,13,14, see fig. 1. Provided that a unicast is directed towards a valid communication node that is in reach from the actual position of the mobile node 19, this technique will not have to include any waiting for potential answers. A pre-requisite of the unicast technique is the availability of a method to select, from every possible position of a mobile node 19, which communication node 12,13,14 (one or several) to address a request message to. The use of unicast-technique reduces time consumed to locate transmission path to a following communication node significantly when compared to a broadcast technique.

The use of a directed neighbouring graph reflects an implementation of the method for selecting which communication node a request message should be addressed to. The communication node is selected by means of a directed graph as the only following communications path indicator. As an alternative the directed graph is included as part of a communications path indicating method.

A general directed graph consists of a set \( V \) of elements called nodes together with a set \( E \) of ordered pairs of the form \( (i,j) \) where \( i,j \in V \), called nodes arcs or directed edges of \( G_D \). Node \( i \) is called the initial node and node \( j \) the terminal node of \( (i,j) \). The arc \( (i,j) \) is directed or oriented from node \( i \) to node \( j \). The case of non directed arc is a sub-case of a directed graph where each non directed arc can be fully described by a pair of two directed arcs.

An example of a directed graph is shown in Figure 3. It is based on a one-way road with four communication nodes 11,12,13,14 surrounding it (see fig. 4). Each node \( A,B,C,D \) of the directed graph represents a communication node 11,12,13,14. Furthermore, each (directed) arc 22 from one node \( A,B,C,D \) (node \( i \)) to another node \( A,B,C,D \) (node \( j \)) in the directed graph represents a suggested following communication node 12, to proceed the present communication node 11.
The task of the directed graph is to provide the mobile node 19 with information regarding the following communications link based upon both the information of which communication node that is the current communication node and other information, for instance information about which communication node that is the previous communication node or information regarding available data communications quality for a candidate communications path.


However, it is preferred to use a directed graph. This is illustrated by the arrows in figure 3. The reason is that additional time is saved when a directed graph is used to suggest one or several communication nodes 12, 13, 14, in this case the only node is 12, to follow the present communication node 11. The example directed graph in figure 3 shows communication nodes 13 and 14 as candidates to be following node 12, whereas an undirected graph describing the same network would indicate communication nodes 11, 13 and 14 as candidates to be following node 12.

The mobile node may use other techniques, for example traditional broadcast scanning to suggest the following communication node, in the case when the following node 12, 13, 14 suggested by the directed graph is not applicable. There are a variety of alternative techniques which can be used.

Construction and maintenance of the directed graph can be performed using several different methods and is not dependant upon which method that is used to construct or maintain the directed graph. It is however remarked that these methods can act upon both static information of the network design and/or dynamically received information regarding the actual network design.
A simple example for a possible communication node placement is shown in figure 4. The communication nodes A, B, C, D are placed on a one-way road 24. As illustrated, the geographical area coverage 23 of each communication node overlaps. As mentioned earlier, the use of the directed graph gives the result that the overlap can be reduced and thereby the number of communication nodes needed to for instance cover the track is reduced. A vehicle provided with the mobile node 19 can travel along the road 24 at high speed with continuous data communication within the network.

In the example high communication quality for moving vehicle and the non-disruptive data flow is achieved also in a situation when communication links that builds up the total communications paths are alternating frequently. The non-disruptive data flow might utilize the full transfer capacity of present communications interfaces undisturbed of interruptions due to the inevitable hand-over procedure.

When describing the communications flow within a wireless cell-based communication network, the discussion can be limited to communication between any two nodes. In the real communication networks several such communications can be taking place simultaneously. In networks commonly used by the public, communication is limited to be between a host, which may be moving, and the infrastructure, which usually is implemented by stationary base stations. Moreover, several independent wireless cell-based communication networks can be used sequentially or simultaneously for data transfer. The different wireless networks are interconnected using other networks (wired or wireless) in order to form one or several aggregated communications paths between the communications peers.

The above-described solution for improved handover is in the present invention used in a vehicle management system to allow vehicles to run simultaneously on a common driving area without colliding. The invention therefore relates to a method for sharing vehicle state information in a wireless cell-based communication network, for instance a wireless local
area network. The invention also relates to a state system, a collision avoidance system, a mobile node, a vehicle control system and a vehicle being adapted to perform these method steps. Therefore, even though the detailed description only describes method embodiments, the person skilled in the art realizes that the systems and the node adapted to perform these method steps are disclosed in the description.

The mobile node 19,20, see figure 5 is arranged on a vehicle 27,28 and is adapted for wireless communication with communication nodes 11,12,13,14 arranged in the network. The network further comprises a server 26 being connected to the communication nodes 11,12,13,14. The mobile node performs two steps for improved handover:

1. The mobile node has two communication interfaces 15,16 searches for 701, see figure 7, communication nodes in an interleaved fashion to enable improve handover.

2. The mobile node uses a directed graph that suggests 702 which communication nodes to search for.

These two method steps have already been described more in detail earlier. What particularly characterizes the method according to the present invention is the steps of, see figures 5 and 7:

3. A state system 29,30 being arranged on the vehicle 27,28 determines 703 vehicle state information relating to the movement of the vehicle 27,28.

4. The mobile node 19,20 receives the vehicle state information from the state system 29,30 and distributes 704 said information to the server 26.

These method steps enable a possibility for autonomous operation of vehicles. Step 3 and 4 of the method steps allows for vehicle state information to be shared between vehicles. This allows for management of
several autonomous and non-autonomous vehicles that uses a driving area, such as a test track or any other defined area, simultaneously while maintaining adequate safety. The method should be a cost efficient solution for positioning, collision avoidance, communication, and surveillance of vehicles.

The possibility of autonomous operation means that test vehicles or any other vehicles run within the driving area can be operated without a driver (autonomous vehicles). The main benefit is that there is no need to consider the working environment or the driving capacity of the driver. The vehicle can therefore be operated at much harder working conditions. On a test track this enables for the test team to try the vehicle at very tough conditions. On a loading place (harbour, mining, truck reloading place) this enables for more vehicles to operate on a restricted area. This improves the loading capacity of the loading place.

The possibility of assisted non-autonomous operation of the vehicle means that the driver can be assisted when driving the vehicle (non-autonomous vehicles). For instance, the system will take over the driving autonomously change the driving direction or speed is a nearby vehicle is detected (active safety). This will for instance improve the safety for the driver and also enable an improved capacity for the area. There are other advantages for non-autonomous vehicles that are also obvious for the person skilled in the art.

The environment of the driving area, such as a test-track, is similar to the standard traffic environment as well as the basic functions of a collision avoidance system. The major differences between these situations are that the test track has more physical restrictions, more restricted traffic rules, limited number of vehicles, etc, and the advantage of providing the vehicle with suitable equipment for a specific scenario. The test track is also a closed area and does not allow any unknown vehicles. These specific test track features simplifies the implementation of the collision avoidance system.
On the test track an endurance circuit may be built with the purpose to expose the vehicles tested to general wear and tear. The drivers are exposed to very hard working conditions primarily because of heavy vibrations when driving repeatedly numbers of laps on the endurance track. Long time exposure to these conditions is not suitable for the human physique. The drivers' working environment would benefit from a decrease of the exposure to vibrations. With the solution as much measurement data as possible can be obtained without causing the driver harm. With an autonomous vehicle, it is possible to repeat the path on the track with a higher precision than a human driver can achieve.

Using WLAN in the present invention will give the advantage that standard components can be used to build the system according to the present invention.

Figure 5 shows an example of a physical topology of a wireless cell-based communication network with vehicles comprising the state unit, a collision avoidance system (will be described later) and the mobile node. The state unit, the collision avoidance system and the mobile node are all part of a vehicle control system in the vehicle.

The mobile nodes 19,20 are arranged on the vehicles 27,28 and are adapted for wireless communication 25,26 with communication nodes 11,12,13,14 arranged in the network 10. The interfaces 15,16 enables the improved handover (described earlier). The network further comprises a server 26 being connected to the communication nodes 11,12,13,14. The state systems 29,30 determines vehicle state information and distributes it to the respective mobile nodes 19,20 and the respective collision avoidance systems 31,32, which will be described later.

The first mobile node 19, which is arranged on the first vehicle 27 may receive vehicle state information distributed by the server 26. The information relates to the movement of a second vehicle 30. This information was
determined by a second state system 30 arranged on the second vehicle 30 and distributed to the server 26 by a second mobile node 20 also arranged on said second vehicle 30.

With these optional steps, the vehicle information can be shared between vehicles for enabling distributed collision avoidance management. The collision avoidance will be described in the following. Vehicle management systems of today only allow a centralized management with a central network-based control unit and a defined number of communication nodes (Access Point). With this sharing procedure, the management system can not be moved between different driving areas. New communication nodes can be introduces and vehicle route conflicts are avoided.

The vehicle state information may comprise information about an ID tag, track and/or information messages on which basis the collision avoidance system 31,32 obtains the vehicle status. The vehicle state information may also comprise information about time, position, speed, heading, yaw rate, velocity and/or longitudinal acceleration of the vehicle 27,28. The vehicle state information may be gathered in a vehicle state message which is distributed to the server 26.

The vehicle state information can be used to specify the vehicle, discard non-relevant vehicles, and obtain vehicle status (running autonomously, brake down, hazard situations, etc.).

A state system 29,30 includes different means for generating the state information, such as an accelerator and different sensors. It may also include means for tracking ID and information data. Added to this, the state system may include means for position determination. Figure 6 shows such a state system distributing such information to the collision avoidance system 31,32.

Figure 6 also discloses the communication system (including the mobile nodes 19,20) and means (Route and Vehicle State Interpreter) for distributing vehicle state information to the collision avoidance system. This information
is as described, distributed by the server 26 and relates to the state of other vehicles 27, 28. The communication system may be a Self organizing Time Division Multiple Access (STDMA) or Wireless Local Area Network.

As disclosed in figure 6, vehicle state information may be generated by Differential Global Positioning System (DGPS) or Interial Navigation System (INS) information distributed via a controller area network (CAN). A person skilled in the art understands that there are a variety of systems for position determination which can be included into the state system 29, 30.

A differential GPS is an enhancement to the standard GPS system. It operates by a stationary ground network or by fixed ground local stations. By knowing the exact position of the stationary receiver, it can calculate the errors from satellite signals and send out the differential corrections to the vehicle. A base station covers a small area and the differential correction is a local correction. There are several different techniques that are currently in use to obtain the differential.

INS is a completely independent system. The positioning is based on integration of the small changes in direction and velocity. This is detected by an Inertial Measurement Unit (IMU). Due to the minor offset in the change of the position, the new calculated position can quickly drift to a great error. This system is not suitable for use as a stand alone system due to the increasing error, but the technique can be used as a complement to increase the total accuracy of the combined systems correction signals.

The collision avoidance systems 31, 32, see figure 5, is arranged on the vehicles 27, 28 and connected to the state systems 29, 30 and the mobile nodes 19, 20. This avoidance system predicts the future positions of at least one vehicle 27, 28 on the basis of the vehicle state information. The future positions of a vehicle 27, 28 are predicted by the collision avoidance system on the basis of vehicle state information received from the state system 29, 30 and/or vehicle state information distributed from the server 26 via the mobile
node 19,20. This means that both vehicles (all vehicles) has vehicle state information from all other vehicles.

The collision avoidance systems 31,32 according to the present invention may use this information to compare the predicted future positions of at least two vehicles and determine a future probability of a collision between said vehicles. The collision avoidance system 31,32 may also assign a safety area around each vehicle on the basis of the predicted future positions.

The collision avoidance system, see figure 6, comprises a functionality for Self Future Trajectory Estimation. See figure 6. This functionality predicts the future position of the vehicle on which this system is located. It also comprises a functionality for Other Vehicle Future Trajectory Estimation to predict the future position for other vehicles. For both these predictions, the vehicle state information provided by the different state systems 29,30 is used. All vehicles has information about the vehicle state for all other vehicles communicating with the communication system.

The collision avoidance system also comprises a Potential Trajectory Conflict System combined with a Potential Collision Detector. See figure 6. The Detector indicates if there is a risk of a future collision between the vehicles. It also uses information from the Vision System to detect risk of collision, which will be described in the following. The Conflict system determines conflicts risks on the basis of the vehicle state information and informs the Detector. The Detector informs about the collision risk to an Avoidance Algorithm, which combined with the Avoidance Actuator makes sure that the vehicle does not collide. An automatic collision avoidance behaviour is for instance performed. As an additional functionality, a first vehicle may be alerted by a Warning Algorithm that a second vehicle is close to and/or is predicted to collide with the first vehicle.

As shown in figure 6, a vision system may also be used to assist positioning and collision avoidance. How this information is used for collision avoidance
will be described in the following. The vision system could for instance use a line following system, a camera system, radar sensors, laser scanners and/or lidar technique. The person skilled in the art realizes that any technique for visionizing may be used.

Even if every vehicle has a communication system, a positioning system, and has connection with everyone, an unpredictable object can occur on the test track. An animal can run across the roadway, a truck can lose its trailer, a vehicle can break down, etc. A vehicle with a human driver can react to this scenario and do an avoidance manoeuvre but an autonomous vehicle has to be extended with a vision system. For collision avoidance systems several different vision techniques are used. The demands of the vision system in this case is to achieve a satisfactory field of view (about 180°) and detect objects in front of the vehicle.

All vehicles are equipped with suitable tools (in this case communication devices and positioning systems). All vehicles are also able to communicate with each other (server based communication) and all vehicles will also have a vehicle state system, with a position system, to calculate the vehicles' positions. The server based communication supplies every user with information about all other vehicles states (such as position, heading, velocity, etc.). When this information is known the tracking and state estimation of the vehicles is unnecessary. All vehicles on the test track will have a communication device combined with a trajectory prediction to estimate all other vehicles positions. The vehicle may also comprise the vision system to take care of the unpredictable objects that could occur (e.g. animals and items that are blocking the roadway).

The prediction of the vehicle's position is intended to estimate the risk of a future collision. By using a model of the vehicle motion, the future position can be predicted. There are several vehicle models that can be used for prediction of the position with different degrees of complexity. All vehicle states are calculated by the vehicle itself and then transmitted to all other
vehicles, which leads to the errors in the states being less than when these states have to be estimated by the other vehicle. Another advantage is that the vehicle does not need vision contact with the other vehicles to track and estimate their future positions.

5 Since all vehicles receive the vehicle states from the other vehicles, the prediction will be the same, independent of which vehicle that does the prediction. When the states are known a prediction can be done. By comparing the prediction of a vehicle with surrounding vehicles, a future possibility of a collision can be detected. If the vehicle model and the measurement of the states are really good, an implementation of a collision avoidance system can be done by assigning a safety area around the vehicles. When this areas overlaps with any surrounding vehicle, the system will alert.

The vision system may be an ACC radar sensor which normally has a 15° field of view, but with this performance demand a fusion unit (several sensors) or a custom specified radar must be used. The LIDAR (Light Detection And Ranging) system has a greater field of view as well as the fusion unit.

A single lidar covers approximately 170° and a fusion unit (placed on each front corner) covers approximately 300°. The lidar is mounted on a truck's front left corner. The reflected image shows a detection of a car in front of the vehicle. The high resolution makes it possible to identify the object due to its significant structure. A fusion system also increases the redundancy of the complete system. The data that is collected from the same area makes it possible to verify the view of the front of the vehicle (the most relevant area in the collision avoidance system) with a second measurement.

The sensor fusion also features as a backup if malfunction in one sensor should occur. A general feature in automotive collision avoidance systems is the possibility of object tracking. The vision unit (e.g. radar or lidar) detects
the object and can observe a range to the object, a range rate measurement (e.g. by Doppler shift), and an azimuth angle to the object. By estimating the vehicle states, a prediction of the new position can easily be done. The predicted position can then be used to determine how an avoidance manoeuvre should be implemented. This is a feature that is relevant to use in regular traffic scenarios where every surrounding vehicle is unknown.

In the case of test track environment and surrounding conditions, the vehicle already has all the relevant vehicle states (from the communication) and all vehicles are known. When surrounding vehicles states are unknown, a tracking feature has to be implemented to observe the vehicles states. Due to the already known vehicle states, a more precise prediction can be done when the position and heading does not have to be estimated. Hence this tracking feature can improve the avoidance manoeuvre if an unknown object appears, e.g. an animal, a trailer, or a broken down vehicle.
CLAIMS
1. Method for sharing vehicle state information in a wireless cell-based communication network, wherein a mobile node (19,20) being arranged on a vehicle (27,28) is adapted for wireless communication with communication nodes (11,12,13,14) arranged in the network, the network further comprising a server (26) being connected to the communication nodes (11,12,13,14), the method comprises the steps of:

   the mobile node (19,20) comprising at least two communication interfaces (15,16) operates (701) in an interleaved fashion, so that when one first interface (15) is carrying an active communication with the present communication node (11), at least one second interface (16) at the same time is trying to establish a communication link with one of the available following communication nodes (12,13,14).

   the mobile node (19,20) uses (702) a directed graph that suggests which one or ones of the available following communication nodes (12,13,14) that the second communication interface (16) should primarily search for when trying to establish a communication link,

   characterized in the steps of:

   a state system (29,30) being arranged on the vehicle (27,28) determines (703) vehicle state information relating to the movement of the vehicle (27,28),

   the mobile node (19,20) receives (704) the vehicle state information from the state system (29,30) and distributes said information to the server (26).

2. Method according to claim 1 wherein a first mobile node (19) arranged on a first vehicle (27) receives vehicle state information distributed by the server (26), the information relating to the movement of a second vehicle (28), which information was determined by a second state system (30) arranged on the
second vehicle (28) and distributed to the server (26) by a second mobile node (20) also arranged on said second vehicle (28).

3. Method according to any of the preceding claims wherein the vehicle state information comprises information about time, position, speed, heading, yaw rate, velocity and/or longitudinal acceleration of the vehicle (27,28).

4. Method according to any of the preceding claims wherein a collision avoidance system (31,32) being arranged on the vehicle (27,28) and connected to the state system (29,30) and the mobile node (19,20) predicts the future positions of at least one vehicle (27,28) on the basis of the vehicle state information.

5. Method according to claim 4 wherein the future positions of a vehicle (27,28) are predicted by the collision avoidance system on the basis of vehicle state information received from the state system (29,30) and/or vehicle state information distributed from the server (26) via the mobile node (19,20).

6. Method according to any of the claims 4 - 5 wherein the collision avoidance system (31,32) compares the predicted future positions of at least two vehicles and determines a future probability of a collision between said vehicles.

7. Method according to claim 6 wherein the collision avoidance system (31,32) assigns a safety area around each vehicle on the basis of the predicted future positions.

8. Method according to any of the claims 4 - 7 wherein the vehicle state information also comprises information about an ID tag, track and/or information messages on which basis the collision avoidance system (31,32) obtains the vehicle status.
9. Method according to any of the preceding claims wherein the vehicle state information is gathered in a vehicle state message which is distributed to the server (26).

10. A state system (29,30) suitable for sharing vehicle state information in a wireless cell-based communication network, wherein a mobile node (19,20) being arranged on a vehicle (27,28) is adapted for wireless communication with communication nodes (11,12,13,14) arranged in the network, the network further comprising a server (26) being connected to the communication nodes (11,12,13,14), characterized in that

the state system (29,30) being arranged on the vehicle (27,28) is adapted to determine (703) vehicle state information relating to the movement of the vehicle (27,28),

the state system (29,30) further being adapted to distribute the state information to the mobile node (19,20) according to any of the claims 11 - 13 and/or the collision avoidance system (31,32) according to claim 14.

11. A mobile node (19,20) suitable for sharing vehicle state information in a wireless cell-based communication network, wherein the mobile node (19,20) being arranged on a vehicle (27,28) is adapted for wireless communication with communication nodes (11,12,13,14) arranged in the network, the network further comprising a server (26) being connected to the communication nodes (11,12,13,14),

the mobile node (19,20) comprising at least two communication interfaces (15,16) being adapted to operate (701) in an interleaved fashion, so that when one first interface (15) is carrying an active communication with the present communication node (11), at least one second interface (16) at the same time is trying to establish a communication link with one of the available following communication nodes (12,13,14).
the mobile node (19,20) being adapted to use (702) a directed graph that suggests which one or ones of the available following communication nodes (12,13,14) that the second communication interface (16) should primarily search for when trying to establish a communication link,

5 characterized in that

the mobile node (19,20) is adapted for receiving (704) the vehicle state information from a state system (29,30) according to claim 10 and distribute said information to the server (26).

12. A mobile node (19,20) according to claim 11 wherein a first mobile node (19) arranged on a first vehicle (27) is adapted to receive vehicle state information from the server (26) and distribute it to the collision avoidance system (31,32) according to claim 14, the information relating to the movement of a second vehicle (28).

13. A mobile node according to any of the claims 11 - 12 wherein the vehicle state information received by the first mobile node is determined by a second state system (30) according to claim 10, said system (30) being arranged on the second vehicle (30), said determined information being distributed to the server (26) by a second mobile node (20) also arranged on said second vehicle (30).

14. Collision avoidance system (31,32) suitable for sharing vehicle state information in a wireless cell-based communication network, wherein a mobile node (19,20) being arranged on a vehicle (27,28) is adapted for wireless communication with communication nodes (11,12,13,14) arranged in the network, the network further comprising a server (26) being connected to the communication nodes (11,12,13,14),

characterized in that

the collision avoidance system (31,32) being arranged on the vehicle (27,28) is adapted to predict the future positions of at least one vehicle
(27,28) on the basis of the vehicle state information received from the state system (29,30) according to claim 10 and/or vehicle state information received from the mobile node (19,20) according to any of the claims 11 - 13.

15. Vehicle control system comprising the state system (29,30) according to claim 10, the mobile node (19,20) according to any of the claims 11 - 13 and/or the collision avoidance system according to claim 14.

16. Vehicle comprising the vehicle control system according to claim 15.
Fig. 4
Fig. 5
Communication interfaces in mobile node searching for communication nodes in an interleaved fashion.

Mobile node using directed graph which suggests communication node to search for.

State system determining vehicle state information

Mobile node receiving said information and distributing to WLAN server

Fig. 7
INTERNATIONAL SEARCH REPORT

PCT/SE2009/000142

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W, G08G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search 5 June 2009

Date of mailing of the international search report 16-06-2009

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<td>A</td>
<td>US 20080064404 A1 (Y. ZHANG ET AL), 13 March 2008 (13.03.2008), figure 5, abstract, paragraphs (0001), (0005), (0047)</td>
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