According to an implementation of the device according to the first aspect, the DSRC module is further configured to: generate a dynamic map of areas surrounding the device based on the geographic data and the positioning information of the device and other devices.

Claims

1. (WO2017045139) APPARATUS AND METHOD FOR TRANSMITTING COMMUNICATION MESSAGES

Drawings

Description

Title of Invention : APPARATUS AND METHOD FOR TRANSMITTING COMMUNICATION MESSAGES

TECHNICAL FIELD

[0001] The present invention relates to the field of communication technologies, and in particular, to transmitting communication messages.

BACKGROUND

[0002] Automotive vehicle to everything (V2X) communication technology provides a vehicle with capabilities to communicate with other vehicles or roadside units. V2X technology improves safety on the roads by allowing information exchange between a moving vehicle and roadside equipment or other traffic objects (such as traffic lights, toll gates, vehicles, pedestrians, cyclists, etc.; referred to as "traffic objects" hereinafter), often via Dedicated Short Range Communication (DSRC) channels. DSRC channels are one-way or two-way short-range to medium-range wireless communication channels specifically designed for automotive use. DSRC works in 5.9 GHz band or other frequencies with an approximate range of 1000 meters. An exemplary DSRC communication system may contain two types of communicating nodes: vehicles (movable) and roadside stations (stationary). Vehicles and roadside stations provide each other with information, such as safety warnings and traffic information, through transmission of V2X messages. As a cooperative approach, DSRC communication systems can be more effective in avoiding accidents and traffic congestions than if each vehicle tries to solve these problems individually.

[0003] For most safety related applications, it is desired that V2X messages are received within 100 milliseconds (msec) of generation. However, it is found that effective dissemination of V2X messages among vehicles via the DSRC channels may be adversely affected by environmental characteristics such as buildings and tall automotives near the vehicles that obstruct line-of-sight (LOS) communications. An exemplary non-line-of-sight (NLOS) scenario is shown in Fig. 1, in which, effective dissemination of V2X messages between vehicles 180 and 182 via the DSRC system is obstructed by a building A, whereas dissemination of V2X messages between vehicles 180 and 184 via the DSRC system is obstructed by a building B, whereas dissemination of V2X messages between vehicles 180 and 184 is not obstructed. Without timely exchange of the V2X messages, moving vehicles may not accurately predict potential driving hazards. Therefore, it is needed to improve transmission reliability of the V2X messages.

[0004] SUMMARY

[0005] Accordingly, embodiments of the present application provide an apparatus, a system and a method for transmitting communication messages.

[0006] In a first aspect of the present application, a communication device is provided to enhance the communication capability in a relevant weak signal area. The device may be primarily used in a vehicle and may include: a receiver; a processor; a memory; circuitries forming a dedicated short range communication (DSRC) module; and circuitries forming a mobile network communication module. The receiver is configured to obtain positioning information indicative of a current location, a current moving speed and a current moving direction of the communication device, and receive positioning information from one or more other devices. The processor is configured to identify a weak signal area surrounding the device based on the geographic data and the positioning information of the device and other devices, and generate an area message indicating the weak signal area. The DSRC module is configured to generate a communication message; and the mobile network module is configured to transmit the communication message to one or more devices located within the weak signal area when the weak signal area is within a critical distance of the device.

[0007] By utilizing the communication device according to the embodiment of the present application, communication in weak signal areas, such as NLOS areas, is compensated via a mobile communication network. Therefore, the transmission quality of the communication messages is improved and a more reliable communication is achieved.

[0008] According to an implementation of the device according to the first aspect, the DSRC module is further configured to: generate a dynamic map of areas surrounding the device based on the geographic data and the positioning information of the device and other devices.
[0009] Optionally, in identifying a weak signal area surrounding the device, the processor is configured to identify the weak signal area on the dynamic map according to current environmental condition of the communication device.

[0010] Optionally, the memory is further configured to store a plurality of path loss models, each of which corresponds to an environmental condition, and wherein in identifying the weak signal area on the dynamic map, the processor is configured to: on the dynamic map, divide an area surrounding the device into a plurality of units areas; select one path loss model from the plurality of path loss models for each unit area according to the current environmental condition of the unit area; calculate a received signal strength (RSS) value for a unit area on the dynamic map based on the selected RSS model; and group the unit areas whose RSS values being less than a threshold into the weak signal area.

[0011] Optionally, in identifying the weak signal area on the dynamic map, the processor is configured to: on the dynamic map, divide an area surrounding the device into a plurality of units areas; select one or more path loss models from the stored one or more path loss models according to a current environment of the device; respectively calculates multiple RSS values of multiple divided unit areas on a dynamic map based on the selected one or more RSS models; and group the weak signal unit areas that correspond to RSS values being less than a threshold.

[0012] Optionally, the dynamic map is updated based on a predetermined frequency.

[0013] Optionally, the DSRC module is further configured to broadcast the communication message in a communication range via a DSRC network.

[0014] Therefore, by calculating multiple RSS values of multiple divided unit areas on the dynamic map, the processor may generate a propagation map. Since a RSS value of each unit area may be calculated based on the propagation map, the weak signal area may be determined according to a comparison of the RSS value/RSS values and a threshold. An accurate weak signal area is thus identified, which further ensures the communication reliability within the weak signal area.

[0015] In a second aspect, a communication method performed by a communication device is provided. The method includes the steps of: receiving positioning information indicative of a current location, a current moving speed and a current moving direction of the communication device; receiving positioning information of the other communication devices; identifying a weak signal area surrounding the communication device based on stored geographic data and the positioning information of the communication device and other communication devices; generating a communication message and an area message indicating the weak signal area; transmitting the area message indicating the weak signal area to a mobile network node and instructing the mobile network node to transmit the communication message to one or more communication devices located within the weak signal area when the weak signal area is within a critical distance of the device.

[0016] According to a first implementation of the communication method according to the second aspect, the communication method includes: generating, a dynamic map of the area surrounding the device based on the geographic data and the positioning information of the device and other devices.

[0017] Optionally, the communication method includes: identifying the weak signal area on the dynamic map according to current environmental condition of the communication device.

[0018] Optionally, the communication method includes: on the dynamic map, dividing an area surrounding the device into a plurality of units areas; selecting one path loss model from a plurality of path loss models for each unit area according to the current environmental condition of the unit area, wherein each of the path loss models corresponds to an environmental condition; calculating a received signal strength (RSS) value for a unit area on the dynamic map based on the selected RSS model; and grouping the unit areas whose RSS values being less than a threshold into the weak signal area.

[0019] Optionally, the dynamic map is updated based on a predetermined frequency.

[0020] Optionally, the method further includes the step of broadcasting the communication message in a communication range via a DSRC network.

[0021] In a third aspect of the present application, a communication system is provided to guarantee the delivery of the transmission messages. The communication system include: a communication device, configured to receive positioning information indicative of a current location, a current moving speed and a current moving direction of the device and receive positioning information from one or more other devices, identify a weak signal area surrounding the device based on the positioning information, transmit an area message indicating the weak signal area, and transmit a communication message via a mobile network when the weak signal area is within a critical distance; and a mobile network server configured to receive the area message and forward the communication messages to one or more devices located within the weak signal area.

[0022] According to a first implementation of the communication method according to the third aspect, the communication system includes an application server coupled to the communication device and mobile network server, and wherein the application server comprises: a processor, configured to select a transmission mode to transmit the communication messages; and a transmitter, configured to transmit one or more cell identifications (IDs) to the mobile network server when a multicasting transmission mode is selected, and to transmit one or more road object IDs to the mobile network server when a broadcasting transmission mode is selected.

[0023] Optionally, the application server further comprises: a receiver configured to receive an area message indicating the weak signal area; and a memory coupled to the processor and configured to store a cell layout; wherein the processor is further configured to determine the cell IDs by identifying one or more cells covered by an overlapping area of the weak signal area and the cell layout.

[0024] Optionally, in forwarding the communication messages, the mobile network server is configured to receive the cell IDs of the identified cells from the application server, and to broadcast the communication message to the traffic objects in the cells corresponding to the cell IDs, also, the transmitter is further configured to transmit a request message indicating the weak signal area when the multicast mode is selected.

[0025] Optionally, the communication system further comprises: a location server coupled to the communication device and wherein the location server comprises: a location server receiver, configured to receive the request message; a location server processor, configured to store and retrieve the positioning information of the traffic objects; and a location server processor, coupled to the location server receiver and the location memory, and configured to identify the traffic objects within the weak signal area based on the stored positioning information and provide the traffic object IDs.

[0026] Optionally, the application server further comprises: a memory configured to store information of the traffic objects, wherein the processor is further configured to identify the traffic objects within the weak signal area based on the stored information and provide the traffic object IDs.

[0027] Optionally, in forwarding the communication messages, the mobile network server is further configured to receive the traffic object IDs and multicast the communication messages to the traffic objects corresponding to the traffic object IDs.

[0028] In general, by utilizing the communication system, a promising transmission is realized and communication quality in the weak signal areas is improved via the LTE network. In a fourth aspect, a communication device is provided. The communication device includes a processor; and a non-transitory computer readable storage medium having computer-executable instructions requiring static data stored thereon, and the computer-executable instructions, when executed by the processor, causes the processor to: obtain positioning information indicative of a current location, a current moving speed and a current moving direction of the communication device, and receive positioning information from one or more other devices; identify a weak signal area surrounding the device based on geographic data and the positioning information of the device and other...
According to a first implementation of the communication device according to the fourth aspect, the computer-executable instructions, when executed by the processor, further causes the processor to generate a dynamic map of areas surrounding the device based on the geographic data and the positioning information of the device and other devices.

By utilizing the communication device according to the embodiment of the present application, communication in weak signal areas, such as NLOS areas, is compensated via a mobile communication network. Therefore, the transmission quality of the communication messages is improved and a more reliable communication is achieved.

Other systems, methods, features, and advantages of the present invention will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present invention, and be protected by the accompanying claims.

**DETAILED DESCRIPTION**

Objectives, technical solutions and advantages of the present application are described in the following with reference to the accompanying drawings and embodiments. Apparently, the described embodiments are merely a part rather than all of the embodiments of the present application.

Furthermore, in the following detailed description of the embodiments, numerous specific details are set forth in order to provide a thorough understanding of the present application. However, it will be recognized by one of ordinary skills in the art that the present application may be practiced without these specific details. On the other hand, well known methods, procedures and components may not been described in detail as not to unnecessarily obscure aspects of the present application.

Embodiments of the present application provide a communication device. The device may be based on prior art vehicular communication devices using DSRC technology, and is additionally equipped with appropriate hardware circuits that enable the device to communicate with other communication devices via a wireless cellular communication network (referred to as a mobile network hereinafter), thus to realize a more reliable communication. The mobile network is distributed over land areas called cells, and each of the cells is served by at least one fixed-location transceiver, known as a cell site or a base station. The transceiver is connected to various nodes of the mobile network, which include network controllers and network servers. Examples of the mobile network include a long term evolution (LTE) network, LTE advance (LTE-A) network, global system for mobile communication (GSM) network, code division multiple access (CDMA) network, wideband code division multiple access (WCDMA) network, general packet radio service (GPRS) network, etc. Using the communication device, vehicular communication messages, e.g., V2X messages, are disseminated via the mobile network in non-line-of-sight (NLOS) directions, and the communication reliability may be improved in the NLOS directions. In the following description, the LTE network is used for illustration purposes, and the use of LTE network for the illustration purposes should not be construed as limiting the present application to such a particular network.

The receiver 152 is configured to receive positioning information of the communication device 150 (or the vehicle). The positioning information enables the communication device 150 to determine its current location, current moving speed and current moving direction. Such positioning information enables the communication device 150 to determine its current location, which is used by the system for transmitting communication messages.
The receiver 152 and is also configured to receive V2X communication messages from other DSRC communication devices or traffic objects. Positioning information of each of these devices, such as current location, current moving speed and current moving direction of the device, can be determined from the positioning information contained in the V2X messages received from the device.

The DSRC module 154 is configured to generate a dynamic map of the area surrounding the device 150 based on the received positioning information of the device 150, received positioning information of traffic objects surrounding the device, and stored geographic data. The DSRC module 154 may further configured to generate one or more V2X messages, and may also configured to broadcast the V2X messages in a communication range via a DSRC network. As mentioned above, V2X messages may be used to indicate a current traveling status of the vehicle, and may include regular information indicating the vehicle’s position, speed and direction, and emergency information generated during an event such as an accident or an emergency, as well as other communication information. The regular information can be included in cooperative awareness messages (CAM) or basic V2X messages (BSM) and is usually designed to be generated periodically under the control of the DSRC module 154. The emergency information can be transmitted via decentralized environment notification messages (DENM). These messages are collectively called V2X messages. In one embodiment, the V2X messages are generated in a certain frequency range, such as from 1Hz (1 per second) to 10Hz (1 per 0.1 second).

These functions of the DSRC module 154 may be performed by appropriate components such as a processor and a transmitter. Specific structure of the DSRC module 154 will be further described in embodiments below.

The processor 158 is configured to identify one or more weak signal areas surrounding the device 150 based on the dynamic map, and is further configured to generate an area message indicating a weak signal area. A dynamic map is a combined map with dynamic positioning information on a static digital map. For example, the static digital map may be obtained according to geographic data stored, for example, in the memory 160. The geographic data may include longitude, latitude, and elevation information. Furthermore, the geographic data may further include information of environmental objects such as traffic attributes and communication node features. However, unless it is displayed on a display unit of the device, the static digital map and/or dynamic map does not need to take the form of a digital image. It can be a data packet with all information needed to generate the digital image. For example, the dynamic map may be generated by a local dynamic map (LDM) facility (also software program) in the DSRC module 154 based on the received positioning information, received V2X message from other traffic objects and geographic data. For example, the dynamic map may be generated by extending a static digital map with traffic attributes, static roadside unit and communication node features, intersecting features and landmarks for referencing and positioning, and containing temporary regional information such as dynamic positioning information of traffic objects near the device. In an embodiment, the dynamic map is updated in a certain frequency. For example, the updating frequency may equal to the dissemination frequency of the V2X messages, since the dynamic map may be updated based on the V2X messages received from other traffic objects. The LDM facility is specified by an ETSI standard ETSI EN 302 895 and will not be further illustrated here.

Meanwhile, the LTE communication module 156 is configured to transmit the area message indicating the weak signal area to a mobile network node and to instruct the mobile network node to transmit the V2X messages generated by the DSRC module 154 to one or more traffic objects located within the weak signal area. In NLOS directions when the weak signal area is within a critical distance of the device 150.

Therefore, to traffic objects located within the weak signal area or in NLOS directions, the V2X messages may be transmitted via both the DSRC channels and the mobile network, the transmission reliability is thus improved.

The communication device 150 may be realized with different structures and compositions, such as the communication devices illustrated in Fig. 3 and Fig. 5.

Fig. 3 is a block diagram of a communication device 100 in accordance with one embodiment of the present application. The communication device 100 includes various circuitries and hardware modules, which include a main processor 102, a DSRC module 104, a LTE communication module 106, and a memory 108, and may optionally include a user interface 110.

The DSRC module 104 may include a processor 120, a transmitter 124, a receiver 126 and a memory 128. In an embodiment, the receiver 126 is configured to perform similar functions as the receiver 152 in Fig. 2. i.e., to receive positioning information. Such positioning information enables the communication device 100 to determine its current location, current moving speed and current moving direction. Further, the receiver 126 is configured to receive V2X messages from other traffic objects. Form the received V2X messages, current locations, current moving speeds and current moving directions of the other traffic objects can be determined.

Alternatively, like the communication device 150, the communication device 100 may use a dedicated receiver (not shown in Fig. 3) to receive the positioning information. It is to be understood that regardless of whether the receiver is included or not located outside of the DSRC module 104, it may realize the same function of receiving the positioning information and V2X messages.

The dynamic map may be generated by the processor 120 by executing instructions in the local dynamic map (LDM) facility (also software program). Upon generating the dynamic map, the DSRC module 104 shares the dynamic map (or a data package corresponding to the dynamic map) with the main processor 102.

As mentioned above, the communication device 100 may include the user interface 110. The user interface 110 may include any element or component that conveys information to a user of the communication device 100 and/or receives input from the user, such as a keypad, a microphone, a speaker, and/or a display unit. For example, the V2X messages may be automatically generated or created by a user of the communication device 100 through the user interface 110. In an embodiment, the dynamic map is displayed on the display unit of the user interface 110.

The functions of the DSRC module 104 are specified in European Telecommunications Standards Institute (ETSI) standard ETSI EN 302 637-2 and will not be discussed in details here.

Based on the dynamic map, the main processor 102 identifies one or more weak signal areas surrounding the device or the vehicle. In an embodiment, a weak signal area is an area or zone where a radio transmission from the device across a path to another vehicle or traffic object is wholly or partially obstructed, usually by a physical object. The transmission of the signals across the path via the DSRC channels may become ineffective, because of the NLOS condition between the transmitting end and the receiving end. Conditions that commonly cause the NLOS conditions include static obstacles like buildings, trees, hills, mountains, and, in some cases, moving obstacles such as large or tall vehicles. As will be discussed below, the obstacles may cause various degrees of path loss, and a path loss value of a point on the dynamic map relative to the vehicle may be calculated using different path loss models.

Generally, a path loss is a loss of signal intensity experienced by a signal transmitted from a transmitting end to a receiving end due to environmental conditions between the transmitting end and the receiving end. As described above, examples of the environmental conditions that may cause significant path loss include buildings, trees, vehicles, intersections and distance, etc. between the transmitting end and the receiving end. In an embodiment, a current environmental condition is indicative of objects surrounding the communication device 100. The composition of environmental and traffic objects on the dynamic map can be categorized as different types of environmental conditions. Each type of environmental conditions can be represented by a path loss model for calculating a pass loss value of a signal. Groups of program codes, each corresponding to a path loss model,
may be stored in the memory 108 for calculating the path loss values by the main processor 102. For example, a path loss model A may represent an urban environment and includes the effects of buildings; a path loss model B may represent a highway environment and includes the effects of tall or large vehicles on the highway; and a path loss module C may represent an intersection environment and includes the effects of buildings and bridges, etc.; and there may be other path loss models representing other environmental conditions or combinations thereof.

In one embodiment, the main processor 102 selects, from several path loss models stored in the memory 108, one or more path loss models based on the environmental conditions as indicated on the dynamic map. For instance, the main processor 102 analyzes the environment of a surrounding area of the vehicle based on the dynamic map. In an embodiment, the surrounding area may be defined as a circular area with a unit radius or a square area with a unit size. For each of these unit areas, the main processor 102 calculates a RSS value based on the distance from the center of the unit area and the communication device 100 or the vehicle, utilizing the chosen one or more path loss models for that area. In an embodiment, the main processor 102 is further configured to generate a propagation map by calculating the RSS value for each divided unit area on the dynamic map based on the selected path loss model or several path loss models for that area.

Upon selecting one of the one or more path loss models, the main processor 102 calculates path loss values of signals from the current position of the vehicle to one or more points on the dynamic map. Specifically, each path loss value is calculated based on the positions of two points, i.e. the signal transmitting point and the signal receiving point, a parameter that represents the selected path loss model, and a transmitted signal strength (TSS). The path loss value is a value of the losses that the transmitted signal will have at the signal receiving point. Therefore, by inputting the current position of the communication device 100 or the vehicle, a position of a certain point on the dynamic map and the TSS, the value of the losses at the point may be calculated. Meanwhile, based on a path loss value, a value of received signal strength (RSS) at a signal receiving point may be calculated according to the following equation (1):

$$RSS = TSS - path\ loss\ (1)$$

where TSS is the transmitted signal strength. Therefore, RSS value of each point on the dynamic map from the current position of the vehicle may be calculated.

In another embodiment, the main processor 102 divides the dynamic map into one or more unit areas whose size depends on the computational capabilities of the main processor 102. For example, a unit area may be a one meter by one meter (1x1 meter$^2$) square area or an area with a different size or shape. For each of these unit areas, the main processor 102 calculates a RSS value based on the distance from the center of the unit area and the communication device 100 or the vehicle, utilizing the chosen one or more path loss models for that area. In an embodiment, the main processor 102 updates the propagation map is the same as the surrounding area based on which the main processor 102 analyses the RSS values to update the entire propagation map, the main processor 102 may only update the propagation map within the immediate surrounding area and calculates the RSS values of corresponding unit areas in the immediate surrounding area. One example of the immediate surrounding area may be a unit circle having a radius. The radius may be adjustable according to the computational capability of the main processor 102, e.g., a higher computational capability corresponds to a greater radius. In an embodiment, the immediate surrounding area within which the main processor 102 updates the propagation map is the same as the surrounding area based on which the main processor 102 analyses the environment as described above.

In one embodiment, to further optimize the performance of the main processor 102, the main processor 102 only calculates the RSS value of unit areas overlapping roads on the dynamic map to generate the propagation map, which means that the calculation of the unit areas overlapping the buildings may be omitted.

The main processor 102 may further determine the relevant NLOS area based on a traveling situation of the vehicle. The traveling situation may include a front-end collision warning (FCW) application and a rear-end collision warning (RCW) application. The main processor 102 then defines the relevant NLOS area based on the traveling situation. For example, in the FCW applications, the main processor 102 defines those unit areas that are in front of the vehicle as the relevant NLOS areas; in the RCW applications, on the other hand, the main processor 102 defines those unit areas that are behind the vehicle as the relevant NLOS areas. The traveling applications may relate to the environments that the main processor 102 utilizes for calculating the RSS value. One simple example is that the processor 102 defines the traveling application as the FCW application when the vehicle is in the urban environment where the front-end collision is more likely, or as the RCW application when the vehicle is in the highway environment where the rear-end collision is more likely.

The transmitter 124 in the DSRC module 104 broadcasts the V2X message in a communication range via a DSR channel. As described above, the V2X message may include the regular messages such as the CAMs and the emergency messages such as DENMs. In one embodiment, both the regular messages and the emergency message can be broadcast via a DSR channel by the transmitter 124. In DSR message broadcast, the IEEE 802.11p WAVE or ETSI ITS G5 protocols can be used, for example. The communication range may be varied depending on the type of the V2X message. For example, the CAM messages may be transmitted by the originating ITS station (ITS-S) to all ITS-Ss within the direct communication range as defined in ETSI TS 102 637-2. On the other hand, DENM messages may be disseminated to as many ITS-Ss as possible located within the relevance area as defined in ETSI TS 102 637-3. Moreover, the receiver 126 in the DSRC module 104 may be configured to receive V2X messages transmitted by other traffic objects.

The LTE module 106 of the communication device 100 is capable of communicating with a LTE network base station (such as an eNodeB) in a manner similar to a mobile terminal. For example, the LTE module 106 of the communication device 100 is in communication with various network nodes of the LTE network via the base station. Under the control of the main processor 102, the LTE module 106 is configured to transmit an area/NLOS message indicating a weak signal area or a relevant NLOS area to the LTE network nodes upon the identification of the weak signal area or the relevant NLOS area, and to instruct the LTE network nodes to transmit the V2X messages to one or more relevant traffic objects via the LTE network when the weak signal area or the relevant NLOS area is within a critical distance from the vehicle. As shown in Fig. 3, the LTE module 106 includes a processor 130, a transmitter 134, a receiver 136 and a memory 132. The relevant traffic objects to which the V2X messages are to be sent via the LTE network are determined based on the NLOS area, and identifying the relevant traffic objects will be further described in conjunction with Fig. 6.
To be specific, the main processor 102 estimates the critical distance based on the current speed of the vehicle. As shown in Fig. 4, a critical distance may be defined as a moving object travels in a certain time period from its current position to a possible point where the moving object may collide with another object. A hypothetical collision point of a vehicle 282 and a vehicle 292 is shown at the center of the circles. In Fig. 4, by way of example, the radius of a circle 294 (42 meters) stands for a distance from a vehicle's position, a random point of the circle 294, to the collision point, i.e. center of the circle. Assuming that the vehicle's traveling speed is 30 km/hr, it will reach the collision point in 3 seconds, and the driver's awareness time is estimated to be 3 seconds. Therefore, 25 meters is a critical distance for a vehicle traveling at 30km/hr. Alternatively, the radius of a circle 296 (42 meters) represents the critical distance for a vehicle traveling at 50 km/hr assuming the awareness time is still 3 seconds.

Given that the awareness time of human being is relatively constant, the critical distance may be roughly estimated based on the current speed of the vehicle. In one embodiment, a table representing the critical distances based on the speed of the vehicle may be stored in the memory 108. In another embodiment, an algorithm for calculating the critical distance as a function of the speed of the vehicle is stored in the memory 108. The main processor 102 may look up the table to estimate the critical distance according to the current speed of the vehicle or calculate the critical distance using the algorithm and the speed of the vehicle. Moreover, the critical distance may be further related to a required awareness time and other scenarios. An example can be found in X. Yan et al., "The Influence of In-Vehicle Speech Warning Timing on Drivers' Collision Avoidance Performance at Signalized Intersections", Transportation Research Part C: Emerging Technologies, Volume 51, February 2015, Pages 231-242.

The transmitter 134 in the LTE module 106 then utilizes a mobile network node, e.g., an application server and/or a LTE multimedia broadcast multicasting services (MBMS) server of the LTE network to disseminate the V2X messages. Specifically, the LTE module 106 transmits a weak signal area/NLOS area message indicating the weak signal/NLOS area to the MBMS server, and instructs the MBMS server to transmit the V2X messages to one or more traffic objects located within the weak signal/NLOS area via a mobile network when the weak signal/NLOS area is within a critical distance of the communication device 100 or the vehicle.

In an embodiment, two alternative transmitting modes are designed for forwarding the V2X message to relevant traffic objects: either broadcasting to all the traffic objects in relevant cells corresponding to the weak signal/NLOS area, or multicasting only to traffic objects to which the V2X message is identified as relevant. Specifically, the LTE network module 106 transmits the weak signal/NLOS area message to an application server in the LTE network. The weak signal/NLOS area message includes positioning information of the relevant traffic object within the weak signal/NLOS area. The application server then obtains relevant cell identifications (IDs) or provides relevant traffic object IDs based on the weak signal/NLOS area message. In one instance, the application server utilizes a location server to generate the IDs of the relevant traffic objects. The MBMS server of the LTE network may broadcast the V2X message in the relevant cells or multicast the V2X message to the relevant traffic objects. The MBMS server, the application server and the location server will be described further below in conjunction with Fig. 6. In an embodiment, the receiver 136 is configured to receive the V2X message sent by other traffic objects over the LTE network.

Furthermore, other compute-executable programs or instructions that cause the main processor 102 to perform different functions as described herein may also be stored in the memory 108.

In an embodiment, the memory 108 may be a computer-readable storage medium that stores application data and computer programs, and facilitates transfer of data and computer programs from one place to another. By way of example, and not limitation, such computer-readable storage medium may be RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store program data means that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

In general, by utilizing the communication device 100 according to the embodiment of the present application, vehicular communication in weak signal or NLOS areas is compensated via a wireless communication network. Therefore, the transmission quality of the V2X messages is improved and a more reliable communication is achieved.

It should be known that, although three processors are shown in the communication device 100, it may not be necessary to have three physically separated processors to realize the corresponding functions of the main processor 102, the processor 120 and the processor 130. In other words, the number of the processors in the communication device 100 should not be limited. For example, a common processor may be shared by the communication device 100, the DSRC module 104 and the LTE module 106. Similarly, a common memory may be utilized to store the path loss models, vehicle positioning information, geographic data, dynamic maps and other computer program instructions or codes in accordance with the embodiments of the present application.

By way of example, Fig. 5 shows a simplified block diagram of a communication device 200, in accordance with another embodiment of the present application. The communication device 200 may include a processor 202, a DSRC transceiver 204, a LTE transceiver 206, a memory 208 and a user interface 210. Differing from the DSRC module 104 and the LTE module 106, each of which includes its own processor and memory, the DSRC transceiver 204 and the LTE transceiver 206 each only includes a transceiver (224 and 234) and a receiver (226 and 236). The processor 202 may perform the relevant functions of the DSRC module 104 and the LTE module 106. The memory 208 may be configured to store data and program codes used by the DSRC module 104 and the LTE module 106. It is to be understood that by combining the DSRC transceiver 204 with the processor 202, a virtual DSRC module that may perform the functions of the DSRC module 104 may be realized, while by combining the LTE transceiver 206 with the processor 202, a virtual LTE module that may perform the functions of the LTE module 106 may be realized. The communication device 200 has similar functions as the communication device 100 in Fig. 3, thus will not be described in detail.

In another embodiment, the communication device 150, 100 or 200 may be implemented by a LTE terminal device that is equipped with corresponding hardware ports or plug-in components to realize the DSRC communication functions. In one instance, the DSRC communication functions may be achieved on the LTE terminal device by connecting with a DSRC hardware module and/or using downloaded corresponding software. For instance, the DSRC hardware port may either be standard RS 232 or Ethernet compatible. Meanwhile, the downloaded software may provide additional functionalities to the LTE terminal device to convert the LTE terminal device to a communication device like the aforesaid mentioned communication device 150, 100 or 200.

In further another embodiment, the communication device 150, 100 or 200 may be implemented by a DSRC device that is equipped with corresponding hardware ports or plug-in components to realize the LTE communication functions.

Those having skills in the art will recognize that the state of the art has progressed to the point where there is little distinction left between hardware and software implementations of aspects of systems, and the use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software can become significant) a design choice representing cost vs. efficiency tradeoffs. Those having skills in the art will appreciate that there are various vehicles by which processes and/or systems and/or other technologies described herein can be effected (e.g., hardware, software, and/or firmware), that the preferred vehicle will vary with the context in which the processes and/or systems and/or other technologies are deployed.

Fig. 6 is a block diagram of a communication system 300, in accordance with one embodiment of the present application. The communication system 300 includes a communication device 310, which may be carried in or mounted on a moving vehicle and thus is a wireless device, an application server 302, a mobile network server, such as a LTE multimedia broadcast multicasting service (MBMS) server 304, a location server 306. Multiple other communication devices/traffic objects 308-1, 308-2, ..., 308-N may establish connections with the system 300. In an embodiment, the application server
The communication device 310 is configured to identify a weak signal area such as a relevant NLOS area for the vehicle based on a dynamic map generated on the basis of the vehicle's positioning information and transmit a vehicular communication message via the LTE network when the weak signal area is within a critical distance. The vehicular communication message includes a current traveling status of the vehicle, for example, the vehicular communication message is a V2X message generated by a DSRC module of the communication device 310. The communication device 310 in Fig. 6 has the same function as the communication device 150 illustrated in Fig. 2, communication device 100 illustrated in Fig. 3 or as the communication device 200 illustrated in Fig. 5, and thus will not be described in detail.

After identifying the existence of the relevant NLOS area where V2X messages are partly or totally obstructed, the communication device 310 decides to transmit the V2X messages via the LTE network besides the DSRC network, thus initiating the process of session creation with the LTE MBMS server 304 and delivers the V2X messages to the LTE MBMS server 304.

Moreover, upon identification of the relevant NLOS area, the communication device 310 transmits the NLOS message to the server 306 via the LTE network. As shown in Fig. 7, the application server 302 includes a receiver 402, a memory 404, a processor 406 and a transmitter 408.

In an embodiment, the transmitter mode may include a broadcast mode and a multicast mode.

In an embodiment, the transmission mode is selected based on the number of the traffic objects that may receive the V2X messages. In the broadcast mode, all traffic objects within the cell or cells overlapped the NLOS area will receive the V2X messages. However, the V2X messages may not be relevant to the traffic objects, especially when large cells are involved. In multicast mode, only the traffic objects that need to receive the V2X message, do receive the V2X message. Therefore, the multicast mode may reduce the amount of unwanted/un-related received messages which reduces the processing onboard.

Specifically, the processor 406 is configured to transmit one or more cell IDs to the LTE MBMS server 304 when the broadcast mode is selected, and to transmit the traffic object IDs to the LTE MBMS server 304 when the multicast mode is selected.

In the broadcast mode, the processor 406 identifies a relevant cell or several relevant cells corresponding to an overlapping area of the NLOS area and a cell layout stored in the memory 404. Specifically, the processor 406 extracts the NLOS area from the NLOS message and overlays the NLOS area on the cell layout to obtain the overlapping area. The cell or cells within the overlapping area are therefore identified to be relevant. In one embodiment, different mobile network providers utilize different cell layouts. The processor 406 of the application server 302 is also configured to select a mobile network provider of the LTE network. In this case, the processor 406 of the application server 302 chooses one of the cell layouts to identify the relevant cell or cells according to the selected mobile network provider information. In an embodiment, given that the application server 302 may correspond to multiple LTE network providers, it may be located separately from any one of EPCs that belongs to a specific LTE network provider.

Moreover, the application server 302 transmits the cell IDs of the identified cell or several cells to the LTE MBMS server 304. After receiving the cell IDs, the LTE MBMS server 304 broadcasts the V2X messages in relevant cells. All the traffic objects in the relevant cell or cells are expected to receive the V2X messages.

In an embodiment, the application server 302 utilizes the location server 306 to obtain relevant traffic object IDs. As shown in Fig. 8, the location server 306 includes a receiver 502, a memory 504, a processor 506 and a transmitter 508. The memory 504 is configured to provide the traffic objects' traveling information, for example, the exact location and direction information of each traffic object may be provided. In an embodiment, the memory 504 may be configured to only provide the traveling information of certain numbers of designated traffic objects. The designated traffic objects may be decided based on their type, for example. After the receiver 502 received the NLOS message, the processor 506 identifies traffic objects within the NLOS area based on the traffic objects' traveling information. In particular, the processor 406 analyses each traffic object's position based on the stored traffic object's traveling information and identifies the traffic objects within the NLOS area. The transmitter 508 then transmits the traffic object IDs corresponding to the identified traffic objects to the application server 302, which will forward the traffic object IDs to the LTE MBMS server 304. In one embodiment, the traffic object's traveling information stored in the memory 504 is updated based on a certain frequency. In the LTE multicast scenario, the traffic object IDs may be represented as IP addresses of the traffic objects.

In an embodiment, the request message includes the NLOS area to the location server 306, and the location server 306 responds with a reply message to indicate the relevant traffic object IDs. An exemplary request message format and an exemplary reply message format are shown in Fig. 9 and Fig. 10, respectively. As shown in Fig. 9, the request message includes a “type” field that indicates current message is a request type. The request message may further include an “originator” field and a NLOS field. The “originator” field represents the IP address of the sender, i.e., the application server 302 and the NLOS field may include information indicating the NLOS area. To respond the request, the reply message is sent by the location server 306. As shown in Fig. 10, the reply message also includes a “type” field and an “originator” field that represents the IP address of the transmitter, i.e., the location server 306. The reply message further includes an IP field in which the list of IP addresses of the relevant traffic objects are represented.

In an embodiment, the memory 504 of the application server 302 stores a database that may provide the traffic objects' traveling information. Therefore, instead of visiting the location server 306, the application server 302 queries its own memory 504 to obtain the traffic object IDs.

In general, by utilizing the communication system 300 according to one embodiment of the present application, communication quality in NLOS areas is improved via the LTE network. Meanwhile, multiple LTE transmission modes may be selected to deliver the V2X messages to certain relevant traffic objects. Therefore, the transmission efficiency is improved and the transmission forms are more flexible.

Referring to Fig. 11, a communication method 800 performed by the communication devices in accordance with an embodiment of the present application is illustrated. Fig. 11 is described in combination with Fig. 2 to Fig. 5. The communication device may be the communication device 150 in Fig. 2, communication device 100 in Fig. 3 or the communication device 200 in Fig. 5.

At 810, a receiver, which may be the receiver 126 in the dedicated short range communication (DSRC) module (DSRC module 104 or the DSRC module 204) or the dedicated receiver 152 in the communication device 150, receives positioning information indicating a current location, a current moving speed and a current moving direction of the communication device and other devices.

At 820, a processor, which may be the processor 158 in the Fig. 2, the main processor 102 in the Fig. 3 or the processor 202 in the Fig. 5, identifies a weak area surrounding the device based on the positioning information. In an embodiment, the weak signal area may be a relevant NLOS area of the vehicle where the communication device 150, 100 or 200 located or mounted. For instance, the relevant NLOS area may be an area or zone...
where a radio transmission over the DSRC network across a path to another traffic object is wholly or partially obstructed, usually by a physical object.

In an embodiment, the step 820 may include following steps to identify the weak signal area surrounding the device, as shown in Fig. 12.

At 820-1, the dedicated short range communication (DSRC) module, which may be the DSRC module 104 in Fig. 3 or the virtual DSRC module in Fig. 5, generates a dynamic map of the area surrounding the device based on the positioning information and geographic data stored in a DSRC database. For example, a LDM facility in the DSRC module 104 may generate a dynamic map based on the received information. Alternatively, the processor 202 may realize the function of the LDM facility to generate the dynamic map when executing the corresponding instructions stored on the memory 208 in Fig. 5. In an embodiment, the DSRC memory may be the memory 122 in Fig. 3, or be the memory 208 in Fig. 5. At 820-2, the processor identifies the weak signal area on the dynamic map according to current environmental condition of the communication device. The step 820-2 may include following steps to identify the weak signal area surrounding the device, as shown in Fig. 13.

At 820-2-2, the processor divides an area surrounding the device into a plurality of units areas on the dynamic map. At 820-2-2, the processor selects one or more path loss model from multiple path loss models according to an environment of the device. For example, the main processor 102 or the processor 202 determines the current environment based on the current position of the vehicle and the dynamic map, and then selects the one or more path loss models according to the current environment accordingly. The path loss models are stored in a memory and each one of the path loss models corresponds to an environment. In an embodiment, the memory, which may be the memory 108 in Fig. 3 or the memory 208 in Fig. 5, stores multiple groups of program codes, and each group corresponds to a path loss model. Based on one or more of the path loss models, a received signal strength (RSS) value of each point on a dynamic map may be calculated. The dynamic map may be generated by the local dynamic map (LDM) facility in the DSRC module 104 based on the received information as illustrated in Fig. 3, or be generated by the processor 202 based on the received information, when executing the instructions stored on the memory 208. Generally, the path loss refers to the losses experienced by a signal transmitted by a vehicle due to an environment between the vehicle and a receiving end. As described above, examples of the environmental conditions that may cause significant path loss include buildings, trees, vehicles, intersections and distance, etc. Therefore, a typical environmental condition can be represented by a path loss model for calculating pass loss of a signal. In an embodiment, groups of program codes, each corresponding to a path loss model, may be stored in the memory 108 or memory 208.

At 820-2-3, the processor respectively calculates several RSS values of several divided unit areas on the dynamic map based on the selected at least one RSS model. Specifically, each path loss model gets input as the position of two points, i.e. the signal transmitting point and the signal receiving point, and the transmission signal strength, and the output is a value of the losses that the transmitted signal will have at the signal receiving point. Therefore, by utilizing the equation (1) illustrated above, the RSS value of each point on the dynamic map from the current position of the device may be calculated. Furthermore, in an embodiment, the processor divides the dynamic map into unit areas. For each of these unit areas, the processor calculates its RSS value based on the distance from the centre of the unit area and the communication device/the vehicle on which the communication device 100 mounted, utilizing the chosen one or more path loss models.

At 820-2-4, the processor groups the weak signal unit areas that correspond to RSS values being less than a threshold. In an embodiment, the weak signal unit areas may be grouped as the relevant NLOS area.

At 820-2-5, the processor further selects the weak signal area based on a traveling situation of the communication device, wherein the traveling situation is determined according to the environment, as illustrated in relevant of Fig. 3.

Referring back to Fig. 11, at 830, the processor generates an area message indicating the weak signal area.

At 840, the DSRC module generates one or more vehicular communication messages. In an embodiment, the vehicular communication message may be V2X messages, which has been illustrated in Fig. 3 and will not be described in detail herein.

At 850, a mobile network module, transmits vehicular communication messages to a mobile network node. For instance, the mobile network module may be the LTE module 106 in Fig. 3 or the virtual LTE module in Fig. 5, and the mobile network node may be the application server and/or the LTE MBMS server described in Fig. 6 to Fig. 8.

At 860, the mobile network module, instructs the mobile network node, to transmit the vehicular communication messages to one or more traffic objects located within the weak signal area via a mobile network when the weak signal area is within a critical distance of the device. In an embodiment, the processor estimates the critical distance based on the current speed of the vehicle, the critical distance is described in Fig. 3 and will not be illustrated in detail herein.

In an embodiment, at 870, the DSRC module broadcasts the vehicular communication message in a communication range via a DSRC network. In an embodiment, the communication range may be varied depending on the type of the V2X messages as described in associated with Fig. 3.

Therefore, within the weak signal area, the communication device may deliver the vehicular communication message via both the DSRC network and the mobile network. The transmission reliability is thus improved.

Referring to Fig. 14, a communication method 1000 in accordance with an embodiment of the present application is illustrated. Fig. 14 is described in combination with Fig. 2 to Fig. 9.

At 1010, a communication device receives positioning information indicating a current location, a current moving speed and a current moving direction of the device. The communication device may be the communication device 100 in Fig. 3 or the communication device 200 in Fig. 5.

At 1020, the communication device identifies a weak signal area surrounding the device based on the positioning information. Since the identifying the weak signal area procedure is illustrated in Fig. 2, and Fig. 9, it will not be further described herein.

At 1030, the communication device transmits vehicular communication messages via a mobile network when the weak signal area is within a critical distance, wherein the vehicular communication message indicates a current traveling status of the device. The critical distance is described in detail in Fig. 3, and will not be further described herein.

At 1040, a mobile network server forwards the vehicular communication message to one or more traffic objects located within the weak signal area. The mobile network server may be the LTE MBMS server 304 in Fig. 6.

In an embodiment, the step 1040 may be realized by performing following steps, which is shown as in Fig. 15. At 1040-1, a processor of an application server, which may be the main processor 400 in Fig. 7, selects a transmission mode to transmit the vehicular communication message upon receiving the vehicular communication message.

At 1040-2, the transmitter, which may be the transmitter 408 of the application server 302, transmits one or more cell IDs to the mobile network server when a broadcasting transmission mode is selected. In one embodiment, the cell IDs may be obtained by performing following steps: at 1040-2-1, the receiver 402 of the application server receives the area message sent by the communication device; at 1040-2-2, the processor 406 of the
At 1040-3, the mobile network server receives the cell IDs of the identified one or more cells from the application server.

At 1040-4, the mobile network server broadcasts the vehicular communication message to the traffic objects in the cells. In other word, if the broadcasting transmission mode is selected, the mobile network server broadcasts the V2X messages to the traffic objects.

At 1040-5, the transmitter 408 of the application server transmits at least one traffic object IDs to the mobile network server when a multicasting transmission mode is selected.

In an embodiment, the application server may involve a location server to generate the traffic object IDs, which may include following steps: at 1040-5-1, the transmitter of the application server transmits a request message indicating the weak signal area; at 1040-5-2, the receiver of the location server receives the request message; the processor 506 of the location server identifies one or more traffic objects within the weak signal area based on a stored traveling information, the traveling information may be stored in a memory, such as the memory 504; at 1040-5-3, the processor of the location server provides the traffic object IDs. The location server may be the location server 306 in Fig. 8 or the location server 500 in Fig. 8.

In an embodiment, the application server generates the traffic object IDs without involving a location server. In this case, the application server includes a memory that may store the traveling information of the traffic objects. In an embodiment, the traveling information is updated in certain frequency. The traffic object IDs generating process may include following steps: at 1040-5-4, the processor 406 of the application server identifies the traffic objects within the weak signal area based on the stored traveling information. For example, the traveling information may be stored in the memory 404 of the application server in Fig. 6; at 1040-5-5, the processor provides the traffic object IDs.

At 1040-6, the mobile network server receives the traffic object IDs. In an embodiment, in the LTE multicast scenario, the traffic object IDs may be represented as IP addresses of the traffic objects.

At 1040-7, the mobile network server multicasts the vehicular communication message to the traffic objects according to the received traffic object IDs.

In an embodiment, at 1050, the communication device broadcasts the vehicular communication messages in a communication range via a dedicated short range communication (DSRC) network. As illustrated in Fig. 3, the communication range may be varied depending on the type of the V2X message.

In summary, the communication device identifies a NLOS area surrounding the communication device and sends out an area message indicating the NLOS area. Meanwhile, the communication device utilizing the mobile network server to forward the V2X messages to one or more relevant traffic objects through a mobile network when the NLOS area is within a critical distance. An application server is utilized to identify the relevant traffic objects and select a transmission mode for the mobile network server. When the broadcasting transmission mode is selected, the application server provides one or more cell IDs to the mobile network server. The mobile network server thus may broadcast the V2X messages to all the users using the mobile network in the one or more cells. When the multicasting transmission mode is selected, the application server provides one or more traffic object IDs to the mobile network server. The mobile network server thus may multicast the V2X to the corresponding traffic objects. Therefore, the reliability and efficiency of the V2X messages transmission may be realized.

It is to be understood that features described in Fig. 11 to Fig. 15 are not limited to serial execution, but rather, any number of threads, processes, services, servers, and/or the like that may execute asynchronously, concurrently, in parallel, simultaneously, or otherwise, and/or the like are contemplated by the disclosure. As such, some of these features may be mutually contradictory, in that they cannot be simultaneously present in a single embodiment. Similarly, some features are applicable to one aspect of the invention, and inapplicable to others.

What has been described above includes examples of one or more embodiments. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the aforementioned embodiments, but one of ordinary skill in the art may recognize that many further combinations and permutations of various embodiments are possible. Accordingly, the described embodiments are intended to embrace all such alterations, modifications and variations that fall before the end of the spirit and scope of the appended claims. Furthermore, to the extent that the term “includes” is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term “comprising” as “comprising” is interpreted when employed as a transitional word in a claim.

Claims

[Claim 1] A communication device, comprising a receiver; a processor; a memory; circuits forming a dedicated short range communication (DSRC) module; and circuits forming a mobile network communication module; wherein the receiver is configured to obtain positioning information indicative of a current location, a current moving speed and a current moving direction of the communication device, and receive positioning information of one or more other devices; the processor is configured to identify a weak signal area surrounding the device based on geographic data stored in the memory and the positioning information of the device and other devices, and generate an area message indicating the weak signal area to the mobile network server.

[Claim 2] The communication device of claim 1, wherein the DSRC module is further configured to broadcast the communication message in a communication range via a DSRC network.

[Claim 3] The communication device of claim 2, wherein the DSRC module is further configured to broadcast the communication message to the traffic objects in the cells.

[Claim 4] The communication device of claim 3, wherein the memory is further configured to store a plurality of path loss models, each of which corresponds to an environmental condition, and wherein in identifying the weak signal area on the dynamic map, the processor is configured to use the path loss model associated with the current environmental condition.

[Claim 5] The communication device of claim 4, wherein the DSRC module is further configured to broadcast the communication message in a communication range via a DSRC network.

[Claim 6] The communication device of claim 5, wherein the DSRC module is further configured to broadcast the communication message in a communication range via a DSRC network.
[Claim 7] A method for a communication device to communicate with other communication devices, comprising: receiving positioning information indicative of a current location, a current moving speed and a current moving direction of the communication device; receiving positioning information of one or more other devices; identifying a weak signal area surrounding the communication device based on stored geographic data and the positioning information of the communication device and other communication devices; generating a communication message and an area message indicating the weak signal area; transmitting the area message indicating the weak signal area to a mobile network node and instructing the mobile network node to transmit the communication message to one or more communication devices located within the weak signal area when the weak signal area is within a critical distance of the device.

[Claim 8] The method of claim 7, further comprising: generating, a dynamic map of areas surrounding the device based on the geographic data and the positioning information of the device and other devices.

[Claim 9] The method of claim 8, wherein in identifying a weak signal area surrounding the device, the method comprises: identifying the weak signal area on the dynamic map according to a current environmental condition of the communication device, wherein the current environmental condition is indicative of objects surrounding the communication device.

[Claim 10] The method of claim 9, wherein in identifying the weak signal area on the dynamic map, the method comprises: on the dynamic map, dividing an area surrounding the device into a plurality of unit areas; selecting one path loss model from a plurality of stored path loss models for each unit area according to the current environmental condition of the unit area, wherein each of the path loss models corresponds to an environmental condition; calculating a received signal strength (RSS) value for a unit area on the dynamic map based on the selected RSS model; and grouping the unit areas whose RSS values being less than a threshold into the weak signal area.

[Claim 11] The method of claim 8, wherein the dynamic map is updated based on a predetermined frequency.

[Claim 12] The method of claim 7, further comprising: broadcasting the communication message in a communication range via a DSRC network.

[Claim 13] A communication system, comprising: a communication device, configured to receive positioning information indicative of a current location, a current moving speed and a current moving direction of the device and receive positioning information from one or more other devices, identify a weak signal area surrounding the device based on the positioning information, transmit an area message indicating the weak signal area, and transmit a communication message via a mobile network when the weak signal area is within a critical distance; and a mobile network server configured to forward the communication message to one or more devices located within the weak signal area.

[Claim 14] The communication system of claim 13, further comprising: an application server coupled to the communication device and mobile network server, and wherein the application server comprises: a processor, configured to select a transmission mode to transmit the communication message; a transmitter, configured to transmit one or more cell identifications (IDs) to the mobile network server when a broadcasting transmission mode is selected, and to transmit one or more device IDs to the mobile network server when a multicasting transmission mode is selected.

[Claim 15] The communication system of claim 14, wherein the application server further comprises: a memory configured to store traveling information of the other devices, wherein the processor is further configured to identify the devices within the weak signal area based on the stored traveling information and the area message, and provide the device IDs.

[Claim 16] The communication system of claim 15, wherein in forwarding the communication message, the mobile network server is configured to multicast the communication message to the devices corresponding to the device IDs.

[Claim 17] The communication system of claim 14, wherein in forwarding the communication message, the mobile network server is configured to broadcast the communication message to the devices in one or more cells corresponding to one or more cell IDs, wherein the cell IDs are generated based on the area message.

[Claim 18] A communication device comprising: a processor; a non-transitory computer readable storage medium having computer-executable instructions and geographic data stored thereon; and the computer-executable instructions, when executed by the processor, causes the processor to: obtain positioning information indicative of a current location, a current moving speed and a current moving direction of the communication device, and receive positioning information from one or more other devices; identify a weak signal area surrounding the device based on geographic data and the positioning information of the device and other devices; generate an area message indicating the weak signal area and a communication message; and transmit the area message indicating the weak signal area to a mobile network node and to instruct the mobile network node to transmit the communication message to one or more devices located within the weak signal area when the weak signal area is within a critical distance of the device.

[Claim 19] The communication device of claim 18, wherein the computer-executable instructions, when executed by the processor, further causes the processor to: generate a dynamic map of areas surrounding the device based on the geographic data and the positioning information of the device and other devices.

[Claim 20] The communication device of claim 19, wherein the computer-executable instructions, when executed by the processor, further causes the processor to: identify the weak signal area on the dynamic map according to a current environmental condition of the communication device, wherein the current environmental condition is indicative of objects surrounding the communication device.

Drawings

[Fig. 0001]
[Fig. 0006]

[Fig. 0007]

[Fig. 0008]

[Fig. 0009]

[Fig. 0010]

[Fig. 0011]

RECEIVING POSITIONING INFORMATION OF THE COMMUNICATION DEVICE AND OTHER DEVICES

IDENTIFYING A WEAK SIGNAL AREA BASED ON THE RECEIVED INFORMATION

GENERATING AN AREA MESSAGE INDICATING THE WEAK SIGNAL AREA

GENERATING ONE OR MORE VEHICULAR COMMUNICATION MESSAGES

TRANSMITTING THE AREA MESSAGE TO A MOBILE NETWORK NODE

INSTRUCTING THE MOBILE NETWORK NODE TO TRANSMIT THE VEHICULAR COMMUNICATION MESSAGES TO ONE OR MORE TRAFFIC OBJECTS LOCATED WITHIN THE WEAK SIGNAL AREA VIA A MOBILE NETWORK

BROADCASTING THE VEHICULAR COMMUNICATION MESSAGES VIA A DSRC NETWORK

TYPE ORIGINATOR NLOS AREA

TYPE ORIGINATOR RELEVANT ROAD USERS
**Fig. 0012**

- GENERATE A DYNAMIC MAP OF AREAS SURROUNDING THE DEVICE
- IDENTIFYING THE WEAK SIGNAL AREA ON THE DYNAMIC MAP

**Fig. 0013**

- DIVIDING AN AREA SURROUNDING THE DEVICE INTO UNIT AREAS
- SELECTING ONE PATH LOSS MODEL
- CALCULATING A RSS VALUE FOR A UNIT AREA ON THE DYNAMIC MAP
- GROUPING THE UNIT AREAS

**Fig. 0014**

- RECEIVING POSITIONING INFORMATION THAT INDICATES LOCATION, SPEED AND DIRECTION OF A COMMUNICATION DEVICE
- IDENTIFYING A WEAK SIGNAL AREA BASED ON THE POSITIONING INFORMATION
- TRANSMITTING VEHICULAR COMMUNICATION MESSAGES VIA A MOBILE NETWORK

**Fig. 0015**

- FORWARDING THE VEHICULAR COMMUNICATION MESSAGE TO AT LEAST ONE RELEVANT TRAFFIC RELATED OBJECT
- BROADCASTING THE VEHICULAR COMMUNICATION MESSAGE VIA A DSRC NETWORK
- SELECTING A TRANSMISSION MODE TO TRANSMIT THE VEHICULAR COMMUNICATION MESSAGES
- TRANSMITTING ONE OR MORE CELL IDS WHEN A BROADCASTING TRANSMISSION MODE IS SELECTED
- RECEIVING THE ONE OR MORE CELL IDS
- BROADCASTING THE VEHICULAR COMMUNICATION MESSAGES IN THE CELLS
- MULTICASTING THE VEHICULAR COMMUNICATION MESSAGES TO THE CORRESPONDING TRAFFIC OBJECTS