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(54) **An apparatus and method operative for providing traffic information on a traffic area**

(57) An apparatus (100) operative for providing traffic information on a traffic area, comprising a locator (110) for determining a plurality of locations of a plurality of mobile devices in a cellular network (115) and a selector (120) for selecting a subgroup of the plurality of mobile devices based on the locations of the mobile devices, when the mobile devices are located in the traffic area and for not selecting mobile devices which are located outside the traffic area. The apparatus (100) further comprises a velocity calculator (130) for calculating a velocity of mobile devices of the subgroup and for generating data on a velocity of a traffic flow in the traffic area using the velocities of the mobile devices in the subgroup and wherein mobile devices not selected for the subgroup are not used for generating the data, wherein the velocity calculator (130) is adapted for calculating at least two velocities of each mobile device in the subgroup within a cell of the cellular network (115). The apparatus (100) further comprises an output interface (140) for outputting the traffic information, which is based on the data on the velocity of the traffic flow.

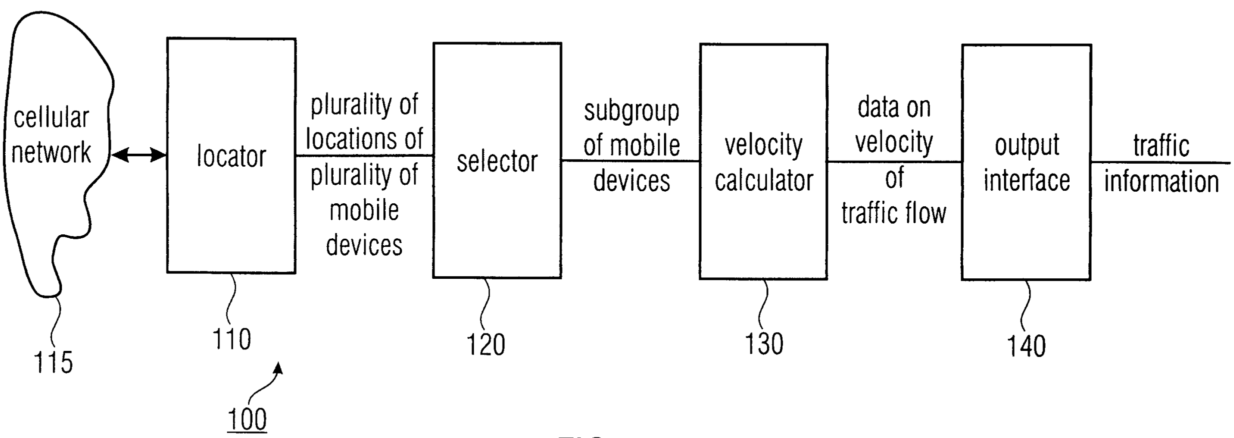

FIGURE 1

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Description

[0001] The present invention is in the field of traffic information acquisition, as for example, used for traffic management and routing purposes.

[0002] Nowadays, traffic becomes increasingly more dense as more and more vehicles are registered and used in public traffic. Moreover, vehicles and therewith mobility for people becomes increasingly more affordable, thus, traffic density is steadily increasing. To relieve overstressed roadways, intelligent transport systems have been proposed, which are able to evaluate the traffic situation and provide traffic information to road users. For example, radio broadcasting of traffic information messages has been part of regular broadcast radio programs for years. A problem of these broadcast messages is the delay involved. First, someone has to recognize a traffic situation before it can be reported to the respective radio station. At the radio station an according message has to be composed and fit into the radio program. Therewith, delays between the occurrence of the traffic situation and the actual reporting to the end user, can take a long time.

[0003] Other conventional solutions use embedded sensors in roadways, which are limited and cost-intensive in installation. Other techniques, without those installations, are less accurate.

[0004] As a result of increasing motorization, urbanization and population growth, road traffic congestions have increased worldwide. Forecasts imply that road traffic will grow faster than road capacity within the next years, leading to a worsening of the traffic situation, cf. Goodwin P, "The economic costs of road traffic congestion", discussion paper, The Rail Freight Group, London, UK, 2004. Requirements to ameliorate traffic congestions include efficient traffic management, using intelligent transport systems (ITS). They allow not only traffic management but also traffic reporting to advice road users.

[0005] The basis of ITS is the acquisition of traffic related data, which allows to judge how traffic is moving. The quality of the traffic estimation depends on the accuracy, reliability, up-to-dateness, and the statistical value and amount of the acquired data. To provide traffic information, several techniques from both private and government entities have been proposed and implemented, e.g. Monahan T, ""War Rooms" of the Street: Surveillance Practices in Transportation Control Centers", The Communication Review, vol. 10 (2007), pp. 367-389. On the one hand they include traffic warning systems such as SigAlert, evaluating traffic jam messages from police or individuals, and on the other hand sensor based approaches, using a limited installation of fixed sensors, such as radar-based traffic counters, loop sensors embedded in roadways, speed cameras or video cameras with image processing capability, infrared traffic counters, or ultrasonic traffic congestion detectors. The first approach, evaluating traffic jam messages, is not reliable and yields to high time delays between the occurrence of a traffic congestion and its reporting. It is nevertheless an important information source, but not applicable to provide high quality traffic information to road users in real-time.

[0006] Also the second approach, which uses certain traffic sensors, has a limited reliability and can be influenced by extreme weather conditions. Moreover, the used traffic sensors are expensive in installation and maintenance, and therefore not widespread. The level of tolerated congestion can be seen as a rational choice between the costs of improving the transportation system and the benefits of quicker travelling. Cost-intensive installations of additional sensors to cover worldwide all streets are therefore neither practical nor economically feasible.

[0007] To improve traffic transport management, complementary solutions have been introduced, where traffic data is collected from the vehicles moving with the traffic, cf. Gühnemann A, Schäfer RP, Thiessenhusen KU, Wagner P., "New Approaches to Traffic Monitoring and Management by Floating Car Data", Proceedings of the 10th World Conference on Transport Research, WCTR04, Istanbul 2004. In particular taxis, which are often equipped with both GPS (Global Positioning System) and a permanent wireless radio link, are capable to provide and update ongoing vehicle system data such as position and speed. This information can be collected in a database and evaluated by a service provider in order to estimate the current traffic situation. This Floating Car Data (FCD) method, where the traffic information is collected from the cars, has the advantage that no additional roadway infrastructure is required. On the other hand, the representativeness of a group of taxis, connected with the mentioned traffic data base, is limited and may not be reliable enough to enable proper traffic management.

[0008] Another FCD method utilizes traffic data collected from cellular networks. It can be assumed that nowadays nearly every driving car carries at least one mobile cell phone, which is registered into a cellular network. The locations of the cell phones can be retrieved from a location based service (LBS) server, or estimated by triangulation. After localization and continuous tracking of the cars, also their velocity can be estimated. The cellular based localization is less accurate than GPS based localization. But this disadvantage may be compensated by the higher statistics and potential coverage of the cellular approach, which can be applied to nearly every subscriber, at the price of increased signaling and messaging.

[0009] The estimation of traffic density and velocity, using cellular phone networks, has been discussed in several publications. However, most of the previous work deals with theoretical models and software simulations, as e.g. Ygnace JL, Drane C, Yim YB, Lacvivier R, "Travel Time Estimation on the San Francisco Bay Area Network Using Cellular Phones as Probes", UCB-ITS-PWP-2000-18, PATH Working Paper, University of California, Berkeley, 2000, White J, Quick J, Philippo J, "The use of mobile phone location data for traffic information", 12th IEE International Conference on Road Transport Information & Control - RTIC, London, 2004, Schneider W, Mrakotsky E, "Mobile phones as a basis for traffic state information", IEEE Conference on Intelligent Transportation Systems, pp. 782-784, September 2005, whereas the consideration of implementation aspects was mostly neglected. FCD implementations consider not only the non-line-of-sight (N-LOS) propagation in mobile networks, but also the limited availability of information, which can be retrieved out of the cellular network or out of the mobile equipment.

[0010] Information, which can be used for localization in cellular networks include the mobile system's protocol data, which is exchanged between the networks' infrastructure elements, or between base transceiver station (BTS) and mobile station (MS). Another data source may be additional satellite based positioning equipment, such as GPS, which may be attached to mobile phones. However, GPS enabled mobiles are still quite rare and additional signaling is necessary to have mobiles report their location, for example, by messages comprising their GPS coordinates.

[0011] Localization of mobiles is a desirable asset not only for traffic management, but also for emergency and rescue services such as the American E911 or the European E-Call. Cellular based positioning of users in mobile networks has therefore been discussed over the past about ten years, often focusing on GSM (Global System for Mobile Communications), cf. Drane C, Macnaughtan M, Scott C, "Positioning GSM telephones", IEEE Communications Magazine, vol. 36, no. 4, pp. 46-59, April 1998, and Kyammaka K, Jobmann K, "Location management in cellular networks: classification of the most important paradigms, realistic simulation framework, and relative performance analysis", IEEE Transactions on Vehicular Technology, vol. 54, pp. 687-708, 2005. It is particularly noteworthy that the techniques discussed in Kyammaka et al influenced the standardization in UMTS (Universal Mobile Telecommunications System) and GERAN (GSM/EDGE Radio Access Network, Enhanced Data rates for GSM Evolution). For instance, the specification 3GPP TS 25.305, Third Generation Partnership Project, Technical Specification Group Radio Access Network, "Stage 2 functional specification of User Equipment (UE) positioning in UTRAN", specifies the locating methods to be supported in UMTS.

[0012] Generally, it can be distinguished between mobile assisted GPS-free positioning, i.e. the mobile calculates its position using the signals received from base transceiver stations (BTSs), and mobile network based GPS-free positioning, i.e. the position of a mobile is determined by the network using transmissions from the mobile. Mobile network based GPS-free positioning is quite common, whereas mobile assisted GPS-free positioning has been treated in only few publications. Position estimation methods, evaluating the radio signal measurements inside mobile phone have been discussed in Waadt A, Hessamian-Alinejad A, Wang S, Statnikov K, Bruck GH, Jung P, "Mobile Assisted Positioning In GSM Networks", International Workshop on Signal Processing and its Applications, Sharjah, 2008. In Pattara-atikom W, Peachavanish R, Luckana R, "Estimating Road Traffic Congestion using Cell Dwell Time with Simple Threshold and Fuzzy Logic Techniques", Proceedings of the 2007 IEEE Intelligent Transportation Systems Conference, pp. 956-961, Seattle, USA, 2007, the authors estimate traffic situations by evaluating the Cell Dwell Time (CDT), i.e. the duration how long a mobile phone remains in a cell, which is associated with the cell-ID of the connected BTS.

[0013] In Juan C. Herrera, Alexandre M. Bayen, "Eulerian versus Lagrangian Sensing in Traffic State Estimation", University of California, Berkely, the authors disclose concepts for traffic state estimation. Traffic monitoring is critical for traffic state estimation. Current monitoring systems are based on loop detectors embedded in the pavement, which collect data used to estimate the state of the traffic. However, these sensors are expensive, need maintenance and their reliability varies. When traveling on-board vehicles, cell phones equipped with a Global Positioning System (GPS) are able to provide accurately position and velocity of the vehicle, and therefore can be used as probe traffic sensors. A few ways to use this data for speed or travel time estimation purposes can be found in the literature. Little attention has been devoted to the traffic state estimation problem using this type of data. Moreover, these estimates have not been compared with the ones that would have been obtained using loop detectors. The authors try to fill this gap. For this purpose, they first present two methods to incorporate mobile probe measurements into highway traffic state estimation.

[0014] Both techniques are used to reconstruct the state of traffic (density). The first method is an application of a method used in oceanography called Newtonian relaxation. The second method is based on Kalman filtering techniques. Finally, using loop detector data and GPS data collected from a field experiment performed in California, the state estimation is compared. The results are promising, showing that the proposed methods successfully incorporate the GPS data in the estimation of traffic. It is found that for a high loop detector density (more than two per mile) the estimates are comparable with those obtained when less than 5% of the vehicles are equipped with GPS and provide one observation every 3 minutes. This confirms that GPS-enabled cell phones are a real alternative for traffic monitoring and traffic state estimation.

[0015] In Schneider W, Mrakotsky E, "Mobile Phones as a Basis for Traffic State Information", Arsenal Research, IEEE Conference on Intelligent Transportation Systems, Vienna, Austria, September 13-16, 2005, the authors disclose a concept for generating traffic state information based on mobile phones as mobile sensors. The authors ran a series of experiments in the area of Vienna where smartphones were used to detect cell transitions. A server deduces traffic information from a series of geo-referenced cell transitions. The required travel times are opposed to the travel times during free traffic flow.

[0016] In Francesco Calabrese, Massimo Colonna, et al, "Real-Time Urban Monitoring Using Cellular Phones: a Case-Study in Rome", SENSEable Working Paper, 2007, the authors report on a real-time project carried out in Rome, Italy. The project used a location platform developed by Telecom Italia for the real-time evaluation of urban dynamics based on the anonymous monitoring of cell phones networks. In addition, data were supplemented based on the instantaneous locating of buses and taxis using GPS. All data were then processed and updated to provide information about urban mobility in real-time, from the condition of vehicular traffic to the movements of pedestrians and foreigners in the city. For the first time a large urban area, which covered most of the city of Rome, was monitored in real time using a variety of sensing systems and enabling to monitor public transportation, gatherings during regular days and on special events, which landmarks in Rome attract more people, etc.

[0017] A problem of these conventional concepts is that a reliable detection of, for example, traffic jams, is not possible. Especially the prediction of traffic conditions and the provision of traffic information to users in advance to enable effective routing considering said traffic conditions, is not provided.

[0018] Therewith, it is the object of the present invention to provide an improved concept for providing traffic information.

[0019] The object is achieved by an apparatus according to claim 1, a method according to claim 14 and a computer program according to claim 15.

[0020] It is a finding of the present invention, that based on location information from a cellular network, locations and velocities of mobile devices can be determined independently from the mobile devices almost anywhere and anytime. In other words, the velocities of mobile devices can be determined on top of their locations, therewith, mobile velocities can be matched to mobile locations as, for example, on a highway. From mobile device's locations it can be determined whether a mobile is located on a highway or not, and in case a mobile is located on said highway, its velocity can be used to determine the traffic situation on said highway at the mobile device's position.

[0021] It is a further finding of the present invention that the plurality of mobile devices in cellular networks, especially in frequented traffic areas, allows to derive a sufficient number of mobile device's locations and velocities in order to determine a highly accurate traffic information. In other words, the density of mobile devices in cellular networks is very high, as most of the passengers use and carry mobile devices nowadays. Therewith, hot spots, i.e. areas where occurrence of mobile devices is very dense, occur in highly frequented traffic areas. In these areas, a number of the mobile devices can be used to derive their locations and velocities, and evaluation thereof enables derivation of a sufficient statistic to reach accurate traffic information and enable reliable prediction, respectively.

[0022] It is a further finding of the present invention that said traffic information can be provided to users, subscribers, mobile phones, etc. in advance, i.e. before they approach a traffic area in a critical traffic condition. Consequently, this can enable advanced routing, i.e. such traffic information can be used to circumvent critical traffic situations, in some embodiments even taking into account user individual traffic habits.

[0023] It is a further finding of the present invention that usage of advanced localization algorithms in cellular networks may enable more accurate determination of a localization and a velocity of a mobile device. As opposed to conventional systems, which use, for example, cell transitions for localization, mobile device's locations and velocities can be determined, even if the velocity is very low or even zero. In other words, mobile devices stuck in a traffic jam can still be located and traffic jams can be detected.

[0024] Embodiments may provide the advantage that accurate and reliable low cost derivation of traffic information can be obtained using floating cellular data collected from cellular networks, mobile subscribers or mobile devices, respectively. This information can be utilized to estimate the locations and velocities of the subscriber's vehicles and in turn can be used as a basis for traffic congestion estimations. Therewith, embodiments may increase the accuracy of known cellular positioning techniques, and introduce a traffic congestion estimation service application exploiting the increased localization accuracy.

[0025] Embodiments may improve the localization accuracy and therefore the reliability of the estimated traffic situation. This may be achieved by evaluating collected statistics of additional information besides the cell-ID (identification). Embodiments may utilize mobile assisted positioning systems being applied to a framework of traffic congestion estimation services (TES).

[0026] Embodiments of the present invention will be detailed using the accompanying figures in which

Fig. 1 shows an embodiment of an apparatus operative for providing traffic information;

Fig. 2a illustrates an example of a construction of a Voronoi diagram in an embodiment;

Fig. 2b illustrates an example of a cell geometry;

Fig. 3a shows a view chart illustrating the localization accuracy in an embodiment;

Fig. 3b provides a table of the mapping between the RSSI and the received signal power in an embodiment;

Fig. 4 illustrates channel attenuation measurements from RSSI;

Fig. 5 illustrates the relation between timing advance (TA) and measured distance;

Fig. 6 illustrates mobile assisted localization accuracy in an embodiment;

Fig. 7 illustrates an example screen of an embodiment on a mobile client's screen;

Figs. 8a-8e illustrate the application of an embodiment on a user device.

[0027] In the following, the details of a number of embodiments will be described. It is to be understood that these details refer to the respective embodiments and are not to be interpreted as limiting the scope or spirit of the present invention.

[0028] Fig. 1 illustrates an embodiment of an apparatus 100 operative for providing traffic information on a traffic area. The apparatus 100 comprises a locator 110 for determining a plurality of locations of a plurality of mobile devices in a cellular network 115. Furthermore, the apparatus 100 comprises a selector 120 for selecting a subgroup of the plurality of mobile devices based on the locations of the mobile devices when the mobile devices are located in the traffic area and for not selecting mobile devices, which are located outside the traffic area. Moreover, the apparatus 100 comprises a velocity calculator 130 for calculating a velocity of mobile devices in the subgroup and for generating data on a velocity of a traffic flow in a traffic area using the velocities of the mobile devices in the subgroup, wherein mobile devices not selected for the subgroup are not used for generating the data. The velocity calculator is adapted for calculating at least two velocities of each mobile device in the subgroup within a cell of the cellular network 115. The embodiment of the apparatus 100 further comprises an output interface 140 for outputting the traffic information, which is based on the data on the velocity of the traffic flow.

[0029] In the following embodiments a mobile device may be any mobile device as e.g. a cell phone, a PDA (Personal Data Assistant), a PC (Personal Computer), a smartphone, etc. Such mobile device may be integrated in any kind of vehicle.

[0030] In embodiments, the locator 110 can be adapted for determining the plurality of locations based on radio link measurements provided by the cellular network 115. In other words, in embodiments the apparatus 100 can be adapted for exchanging information on mobile devices with the cellular network 115. Moreover, the locator 110 may determine the location of a mobile device based on an information on the cellular network's 115 infrastructure. Said information on the cellular network's 115 infrastructure may comprise a location of each base transceiver station or sector in the cellular network 115. Furthermore, it may comprise an identification of each base station transceiver. Moreover, for each base transceiver station a number and direction of all sectors may be comprised in the information on the network infrastructure. Moreover, the transmission levels in terms of a transmission power may be given per cell in the cellular network 115, i.e. per sector of the cellular network 115.

[0031] In embodiments, the radio link measurements may comprise an information on one of or a combination of the group of an RSSI (Receive Signal Strength Indicator) of a mobile device, a receive level (RXLEV) of a base station transceiver, a timing advance value of a radio connection between a mobile device and a base station transceiver, a measure on a radio link attenuation, a measure on a propagation delay, a base transceiver station identification from a mobile device. Moreover, in embodiments, the radio link measurements may be transmitted directly by a mobile device, for example using short message service (SMS) or general packet radio service (GPRS). Moreover, the apparatus 100 may comprise a GSM modem with a MSISDN (Mobile Subscriber ISDN Number, Integrated Services Digital Network) to which the mobile devices may directly report.

[0032] In the following, embodiments of the locator 110 will be detailed. Non-satellite based positioning in cellular networks can be enabled by exploiting mobile network 115 information, e.g. for GSM which will be considered subsequently by some embodiments. Generally embodiments may as well utilizes other cellular networks, as e.g. UMTS (Universal Mobile Communications System), LTE (Long Term Evolution), LTE-A (LTE-Advanced), etc. Determining the position of a mobile, commonly involves two main steps. First measurements are taken or information is collected, which is related to the mobile's location, and secondly, position estimates can be computed based on the measurements and/or information.

[0033] In case of GSM, the available information, which is related to the mobile's location, can be e.g. cell-ID, RSSI and TA (Timing Advance). The cell-ID is, in combination with the Location Area Code (LAC), the Mobile Network Code (MNC) and the Mobile Country Code (MCC), a unique identifier of a base transceiver station (BTS). The ID of the BTS, having a connection to a certain mobile station (MS), is known by both the mobile network and the mobile station, and can be used to estimate the position of the mobile subscriber.

[0034] The RSSI is a 6 bit value, indicating the strength of the base transceiver station's (BTS's) radio signal that is received by a mobile station (MS). For an increased accuracy, it can be used to estimate the distance between BTS and MS, before determining the MS's absolute position.

[0035] The TA is also a 6 bit value. It indicates the signal propagation delay from MS to BTS and can also be used to estimate the distance between MS and BTS. This allows a more accurate localization of the MS.

[0036] In the following cell-ID based localization of embodiments will be detailed. The locator may 110 may use a cell-ID as one option for determining a location of a mobile device. The unique ID of the BTS, which has a connection to a certain mobile station (MS) is known by both the mobile network and the mobile station. If the locations of the network's BTSs are known as well, they can be used to estimate the position of a mobile subscriber or mobile device. In the following, the expressions of mobile subscriber, user, mobile device, mobile station etc. will be used synonymously.

[0037] The simplest localization technique, evaluating the cell-ID, is to estimate the mobile station (MS) in the location of the connected base transceiver station (BTS). This is a rather rough and potentially inaccurate localization technique, since it does not take the cell's geometry into account. Due to the directional characteristic of common BTS antennas, they are in fact often located at the border of a cell or sector. If beside the cell-ID no additional information is known, then the estimation error can be minimized in embodiments by estimating the mobile station's location in the cell's center of gravity. The determination of the cell's center of gravity assumes the knowledge of the cell's geometry. In embodiments a more accurate determination of the cell's geometry may be achieved by measurements of the radio signal power from a reference BTS and neighboring BTS in an area around the reference BTS. The following section describes how to determine the cell's center of gravity in a simplified mathematical model of an embodiment, which does not require radio measurements.

[0038] In embodiments, the cell geometry can roughly be determined in a simplified model, which assumes free space propagation and an equivalent radiated power (ERP), which shall be assumed to be the same for all BTSs. In this case, the cell geometry becomes the Voronoi diagram of the BTSs.

[0039] Fig. 2a illustrates the construction of a Voronoi diagram in an embodiment. Fig. 2a shows in the center a reference base transceiver station (BTS) 200. The reference BTS 200 is surrounded by a number of neighborhood BTS 210-216. Fig. 2a illustrates the construction of a Voronoi diagram. The cell borders can be built by the middle bisectors of the connections from the reference BTS 200 to the respective neighborhood BTS 210-216. As can be seen from Fig. 2a, if there are several BTSs in the location of the reference BTS 200, having different directional characteristics, then the cell, resulting from the Voronoi diagram, is subdivided into sectors, which represent the cells of the different BTSs in the same location.

[0040] The outcome of the construction of the cell geometry shall be the set of the N cell's comers $\boldsymbol{c}_i = (x_i,y_i)^T$, i = 1...N + 1, with x_i,y_i being the coordinates of the i-th cell corner in two dimensions, and with $\mathbf{c}_{N+1} = \mathbf{c}_1$. The center s of gravity can then easily be calculated by

$$\boldsymbol{s} = \frac{1}{6 \cdot A} \cdot \begin{pmatrix} \sum_{i=1}^{N} (x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \\ \sum_{i=1}^{N} (y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \end{pmatrix}, \qquad (1)$$

with

$$A = \frac{1}{2} \cdot \sum_{i+1}^{N} (x_i y_{i+1} - x_{i+1} y_i) \qquad (2)$$

being the cell's area.

[0041] Fig. 2b illustrates an embodiment of a cell geometry of a GSM network in Duisburg/Germany. Fig. 2b shows an example of a computer constructed cell geometry of a cellular GSM network in an embodiment. The black marker 220 in the center of Fig. 2b represents the location of a reference BTS. The other gray markers 231, 232 and 233 in the centers of the three cell sectors represent the centers of gravity of the respective sectors, and the true locations of test mobiles to be located are indicated by the gray markers 241, 242 and 243.

[0042] The accuracy of the cell-ID based localization technique, using cells' centers of gravity, has been determined in measurement trips in the area of Duisburg. The estimation error d_{err} has been determined by the distance between the position, which was estimated with the cell-ID method, and the position of a GPS measurement, which served as a reference.

[0043] Fig. 3a provides a view chart illustrating the localization accuracy of an embodiment in the area of the Duisburg, based on the above-described cell-ID method, which may be carried out by embodiments of the locator 110. Fig. 3a shows the probability function of d_{err} on the ordinate and the respective distance d/m on the abscissa. As can be seen from Fig. 3a, in 50% of all cases, the error is less than 356m and in 90% of all cases below 881m.

[0044] Since the cell-ID is known by the mobile network, it can not only be used in mobile assisted positioning methods, but also in network centralized positioning methods. The mobile stations (MSs) know the cell-IDs from the broadcast control channels (BCCHs) of the base transceiver stations (BTSs). Every mobile station tracks the BCCHs of up to 7 base transceiver stations in its neighborhood. This is done to allow appropriate preparations for hand-over. Beside the increased number of cell-IDs, the tracking and measurement of the BCCHs provides also the RSSIs.

[0045] In the following, an embodiment of the locator 110 will be detailed, using RSSI based location. RSSI based location may be used on top or separately of the above described cell-ID based localization, i.e. accuracy can be further improved using the RSSI based concept detailed subsequently. Fig. 3b illustrates the mapping of RSSI values and the received signal power. The RSSI value is used in cellular networks for signaling the strength of a receive signal as experienced by a mobile device. The RSSI can be a 6 bit value (in GSM), indicating the strength of the broadcast control channels (BCCHs), received by the mobile station (MS). Since the MS tracks BCCHs from up to 7 base BTSs in its neighborhood, it determines up to 7 RSSIs.

[0046] The RSSI in GSM has a resolution of 1 dB. A RSSI value of $RSSI=63$, for instance, means that the BTS's radio signal is received with a power of -48dBm or more. A value of $RSSI=62$ indicates a signal strength between -48dBm and -49dBm. Fig. 3b shows the mapping between RSSI and received signal power, cf. 3rd Generation Partnership Project (3GPP), Technical Specification Group GSM/EDGE, "Radio Access Network; Radio subsystem link control (Release 1999)", 3GPP TS 05.08 V8.11.0, August 2001.

[0047] If the equivalent radiated power (ERP) of a certain BTS antenna is known, and the mobile station (MS) measures the RSSI of the radio signal, transmitted from the same BTS, then the MS can calculate the attenuation of the mobile channel from BTS to MS. The channel attenuation is a function of the distance and can therefore be used to calculate an estimation of the distance between BTS and MS.

[0048] Fig. 4 shows a view chart illustrating the channel attenuation as it can be determined from RSSI measurements dependent on the distance d/m. In the view chart in Fig. 4 the measured attenuations $a_{measured}$ are indicated by asterisk markers, the straight line in Fig. 4 shows the logarithmic approximation between distance and attenuation. There are several radio propagation models describing the relation between channel attenuation and distance between radio transmitter and receiver. Well known are e.g. the Okumura Hata, COST Hata, and COST Walfish Ikegami models. Since the channel attenuation in cities is essentially effected by obstacles like buildings, the RSSI becomes a random variable, with only view information about the true distance between MS and BTS. Fig. 4 shows the attenuation

$$a(d) = ERP - RSSI - 110\text{dB}, \qquad (3)$$

which was calculated after RSSI measurements in the area of Duisburg in the present embodiment.

[0049] The straight line in Fig. 4 shows the logarithmic approximation of the relation between distance and attenuation, which minimizes the absolute error. The mean error of this approximation is about 238m. Nevertheless, this estimation can be used to further improve the localization, when several RSSIs from different BTSs are known.

[0050] In the following, embodiments of the locator 110 will be detailed, which use timing advance (TA) based localization. In embodiments, timing advance based localization may be used on top of or separately from RSSI based and/or cell-ID based localization. In other words, in embodiments combinations of the above described cell-ID based and RSSI based localization and the timing advance based localization described subsequently can be used to further improve the accuracy. Other embodiments may utilize only one or two of these concepts for localization.

[0051] Again, an embodiment for GSM will be detailed. Since GSM uses TDMA (Time Division Multiple Access), the radio signals of the mobile stations (MSs) must reach the base transceiver station (BTS) in certain time slots. To allow accurate synchronization of the radio signals, which reach the BTS, the MSs must know the signal propagation delay of the mobile channel from MS to BTS. The Timing Advance (TA) is a 6 bit value, which indicates the signal propagation delay from MS to BTS and back. It is quantized in bit periods. In GSM, the bit period is $T_b \approx 3.69\mu s$, cf. 3rd Generation Partnership Project (3GPP), Technical Specification Group GSM/EDGE Radio Access Network, "Radio subsystem synchronization (Release 6)", 3GPP TS 45.010 V6.0.0, April 2003. When assuming free room propagation or line of sight (LOS) between MS and BTS, the distance d/m between MS and BTS can be estimated by

$$d(TA) = TA \cdot \frac{T_b \cdot c}{2} \approx 554 \cdot TA, \qquad (4)$$

where *c* is the speed of light. However, in most cases N-LOS (none line of sight) channels are considered, in particular in cities, where the radio signal often reaches the receiver after reflections or scattering. This leads to an increased signal propagation delay and *TA,* or an overestimated distance *d*. Along with cell-IDs, Timing Advances (TA) for a mobile phone in the area of Duisburg have been measured. The coordinates of the measurement points have been measured in addition by using a GPS device. The distance between the measurement points and the base transceiver stations (BTSs) have been calculated and served as reference distances to calculate the TA based distance estimation error. Fig. 5 illustrates the relation between measured TA and distance.

[0052] Fig. 5 shows a view chart displaying the timing advance versus the measured distance *d*/*m*. In Fig. 5, the discretization or quantization of the timing advance can be seen by the stepwise occurrence of the respective values. The straight line in Fig. 5 shows the linear approximation, which minimizes the absolute estimation error. The mean error is about 217 meters.

[0053] Fig. 6 illustrates the probability function of d_{err} for mobile assisted localization accuracy in the area of Duisburg. The TA can generally be used to increase the accuracy of localizations. But since the TA is measured only when a dedicated channel is allocated, the TA method is only conditionally applicable for the traffic estimation application. The cell-IDs and the RSSIs on the other hand can always be queried from the mobile, and allow localization with increased accuracy compared with network based methods without mobile assistance. The accuracy can be further improved by averaging consecutive measurement results. Fig. 6 shows the probability function of the localization error d_{err} for mobile assisted localization for the same measurements as in Fig. 3a. In 50 % of all cases, it kept below 117m, and in 90 % of all cases below 245m.

[0054] Embodiments can therewith provide the advantage, that the increased accuracy of the mobile assisted positioning can be used to enable a traffic congestion estimation service (TES), which can be established with higher reliability compared to conventional techniques. TES may, in embodiments, be realized comprising two key components, namely a server side and a client side. The server side may comprise an apparatus 100 as described above. In other words, an embodiment of the apparatus 100 may be implemented on a server side component, for detecting and estimating congestions, whereas on the client side, traffic information generated on the server side may be displayed to an end user. Moreover, the client side, for example a mobile device, may also acquire data for enabling the server side to determine the plurality of locations using an embodiment of the locator 110.

[0055] Fig. 7 illustrates a possible traffic scenario displayed on a mobile device's or client's screen. Fig. 7 shall illustrate an embodiment, in which traffic information is graphically depicted. In embodiments, the map of Fig. 7 may be displayed, for example on a mobile device as, for example, a mobile phone. In other embodiments said example may be displayed on any web application, possibly running on a personal computer, a laptop, etc. Fig. 7 shows an excerpt of a map of the area around Duisburg/Germany. As indicated in Fig. 7, the street map displays average speeds as traffic information. In other words, in Fig. 7 the average speeds of the vehicles on the main roads in the area around Duisburg, i.e. the average pace on the surrounding highways, are displayed to a user. The triangle 700 indicates the current position of a user or mobile device. As the average speed on the surrounding main roads is known, efficient routing our route planning can be carried out. For example, embodiments may also take into account user individual driving habits, i.e. if a user does not desire to travel at speeds higher that an individual maximum, then a certain traffic situation may be tolerable as opposed to a user who wants to travel as quick as possible. Moreover, knowledge of the traffic situations as part of the traffic information on the main roads, may allow to minimize a time to arrive a certain destination. In embodiments, different colors may be used to indicate different traffic situations, for example, different colors may be associated with different average velocities.

[0056] In embodiments the selector 120 can be adapted for selecting the subgroup of mobile devices from the plurality of mobile devices based on the street pattern within the traffic area. In other words, the traffic area may be defined by a street pattern or roadmap, etc. The traffic area may be an area of interest where a certain subscriber to the service is planning to travel, to transit through respectively. For example, a mobile device in terms of a navigation system may be implemented in a vehicle of a user. In order to determine the subgroup of the mobile devices the selector 120 may select mobiles, which are located on the streets, where the respective user is planning to travel. In other words, in order to enable efficient routing taking into account traffic information, the selector 120 may select mobile devices for evaluation, which are located on the route the respective user is planning to travel. The selector 120 can be adapted for selecting mobile devices, which are ahead of the desired user, in order to provide traffic information in advance. Any routes may be taken into account, in other words, the traffic area may comprise roads, highways, freeways, streets with predefined paces, country roads, toll roads, etc. The selector 120 can be further adapted for selecting mobile devices for the subgroup, which move at a certain velocity and are located on the desired route.

[0057] In embodiments the velocity calculator 130 can be adapted for generating the data such that the data comprises an average velocity based on at least half of the mobile devices in the subgroup. In other words, the velocity calculator 130 may be adapted for considering all or some of the mobile devices from the subgroup. For example, if a desired user is planning to travel a certain part of a highway, mobile devices being located at that part of the highway may be selected by selector 120. In embodiments, the selector 120 may be adapted for selecting only such mobile devices, which also have a certain velocity. In other embodiments the velocity calculator 130 can be adapted for generating the data on the traffic flow based on some mobile devices from the subgroup, which have a velocity within a certain range. For example, if a large number of mobile devices in said part of the highway have a high average velocity, but few of these mobile devices may have a very low velocity or even a zero velocity, because said mobiles are with parked cars, with pedestrians on a bridge across the highway, etc., only the fast moving mobile devices may be selected. Moreover, in embodiments the velocity calculator 130 may be adapted for taking a time average of velocities of mobile devices. In other words, in embodiments the selector 120 may select mobile devices for the subgroup, which establish a significant statistical sample for mobile devices traveling the respective route and the velocity calculator 130 can be adapted for generating the data on the traffic flow based on some mobile devices from the subgroup.

[0058] This may involve time averaging of velocities of individual mobile devices, as well as other statistical evaluations. Embodiments therewith provide the advantage that they consider the velocity dimension. In embodiments the velocity can be defined as a physical quantity composed of speed and direction components.

[0059] In embodiments the locator 110 can be adapted for determining a location of a mobile device based on a regular time basis. In other words, the locator 110 can be adapted for determining the location of a mobile device, for example every 500ms, 1s, 2s, etc. In embodiments, a certain sampling rate for locations of mobile devices may be established. Moreover, in embodiments the selector 120 and the velocity calculator 130 can be adapted for selecting the subgroup and calculating velocities of mobile devices from the subgroup on a regular time basis. Embodiments may enable the advantage of a determination of the velocities independently from time and locations of the respective mobile devices.

[0060] Moreover, the velocity calculator 130 can be adapted for determining the trajectories of a mobile device and its respective speeds. In embodiments the traffic information may comprise the traffic condition, for example, in terms of trajectories of moving mobile devices, their density and their speeds.

[0061] In embodiments, the output interface 140 can be adapted for generating an SMS for a user or a mobile device, the SMS may comprise the information on the traffic information. Furthermore, embodiments may further comprise a traffic jam detector being adapted for detecting a traffic jam based on a threshold detection on the velocity of the traffic flow and the output interface 140 may be adapted for outputting the traffic information comprising a traffic jam indication. In other words, once the velocity of the traffic flow is determined on a part of route of interest, a traffic jam may be detected by evaluating said velocity against a threshold. For example, in one embodiment if the velocity of the traffic flow on a highway falls below 10km/h, 20 km/h, 30 km/h, 50 km/h, etc., the traffic jam detector may detect a traffic jam, the corresponding traffic information may then comprise a traffic jam indication.

[0062] In embodiments the output interface 140 can be adapted for generating an alarm SMS for a user when the traffic jam is detected. Moreover, the output interface 140 may be adapted for outputting the traffic info to a web server. In embodiments the web server can be adapted for being accessed by mobile devices. In other words, the output interface 140 may comprise a web interface, a TCP/IP (Transmission Control Protocol, Internet Protocol) interface, or any other interface to a server. In embodiments the output interface 140 can be adapted for outputting the traffic information in terms of a graphical representation. The output interface 140 can be adapted for outputting as traffic information an information on one of or a combination of the group of the velocity of the traffic flow, the velocity or average velocity of the subgroup of mobile devices, an estimation on the future velocity of the traffic flow, a traffic jam or traffic jam expectation, an alternative route or an estimation of a time of arrival, a traffic jam indicator, a routing or trip delay, an approximated distance or duration of a traffic jam. In embodiments the output interface 140 can be adapted for regularly updating a mobile device, for example by SMS, GPRS data service, etc.

[0063] In the following two implementations of embodiments will be described in more detail. Two versions, a basic version and a premium version of implementations will be described. Firstly, the basic version shall be illuminated. The apparatus 100 may comprise a database in order to enable the locator 110 to determine the plurality of locations. In other embodiments the locator 110 may comprise an interface to the cellular network 115, through which the plurality of locations may be provided by the cellular network 115. In other embodiments, information in terms of radio link measurements may be provided by the cellular network 115 and stored in the above-mentioned database. The information in the database may comprise the location of each base transceiver station in the cellular network 115, the identity of the base station transceivers respectively. Moreover, the number and the directions of all sectors per base transceiver station and the respective transmit levels of each base transceiver station and their sectors may be comprised in the database. In embodiments, this database may be provided by the mobile network operator. It may be updated, as soon as changes in the infrastructure of the cellular network 115 occur, i.e. whenever base station transceivers and/or sectors thereof are added or removed. In embodiments this database may be uploaded to the apparatus 100, for example via an IP based VPN (Virtual Private Network) connection using a secure link. In embodiments, this connection may not fulfill real-time requirements, as updates to such a database can be rarely expected.

[0064] In embodiments, measurement reports associated with each mobile device participating the traffic congestion estimation application may be received by the locator 110. In embodiments these measurement reports may contain an identifier of a particular base transceiver station or a sector to which the particular mobile device may currently be connected, which is also called the connected base station transceiver. For example, the RXLEV (Receive Level) information associated with the connected base transceiver station and the timing advance information, which will be available in the case of an existing dedicated channel, i.e. when, for example a voice call is established, may be provided. The measurement reports can be provided by the mobile network directly. In other words, direct communication with any mobile device may not be carried out in embodiments. The measurement reports can be uploaded to the apparatus 100, the locator 110 respectively, for example, via an IP based VPN connection using a secure link. In embodiments this connection may fulfill real time requirements.

[0065] In embodiments traffic jam estimation results, i.e. traffic information, may be transmitted to mobile devices participating in the traffic congestion estimation application. In other words, the output interface 140 may be adapted for providing measurement reports for mobile devices as traffic information. The measurement reports may comprise indications whether traffic jams are to be expected in the vicinity of a particular mobile station, an expected trip delay caused by the traffic jam, an approximate distance, for example in meters, kilometers, minutes or hours, between a traffic jam and a particular mobile device, etc. The measurement reports may be transmitted regularly to the mobile stations or devices. In embodiments a new measurement report may be transmitted to a particular mobile station as soon as an update is available for this particular mobile station.

[0066] The output interface 140 may be adapted for outputting the traffic information in terms of using SMS, or, alternatively and depending on availability, by GPRS, for example exploiting the downlink in a mobile network, the cellular network 115 respectively. In other words, the cellular network 115 in which the plurality of locations of the mobile devices are determined by the locator 110, may not be the mobile network of a mobile device to which the traffic information is provided for output. In alternative embodiments, the outputting or the transmission of measurement reports can be done by a GSM modem connected to the apparatus 100, the output interface 140 respectively.

[0067] In embodiments, the output interface 140 may comprise a web connection, for example to Google Maps or a similar map provision. This connection may enable or enhance monitoring purposes of an operator of the apparatus 100. In embodiments the web connection may be a real-time connection.

[0068] In the following a premium version of an implementation will be described. With respect to the database, the same considerations as detailed above apply with respect to the locator 110. Again, the cellular network 115 may provide measurement reports associated with mobile devices participating in a traffic congestion estimation application. In the premium version, the mobile devices may be involved, in order to enable more accurate determination of the plurality of locations. In embodiments a mobile device may transmit a new measurement report as soon as it detects a change in the measurements. Again, said measurement reports can be transmitted using SMS or alternatively depending on availability, by GPRS. In other applications, any data connection may be used, as for example provided by UMTS, LTE, etc. Moreover, in such an embodiment, the apparatus 100 may comprise an interface to a GSM modem with a given MSISDN. In such embodiments transmission from mobile devices may address this particular MSISDN. Alternatively, information coming directly from the network operator of the cellular network 115 may be exploited in embodiments.

[0069] As already mentioned above, traffic jam estimation results may be output as part of the traffic information to mobile devices participating the traffic congestion estimation application. In a premium version, the measurement reports may be transmitted regularly to the mobile station or as soon as an update is available. Again SMS, GPRS, data connections, etc. may be used to provide the measurement reports to the mobile devices. Again, the output interface 140 may utilize a web connection to Google Maps or a similar map provision for outputting the traffic information.

[0070] Summarizing the apparatus 100 may in embodiments measure the radio network through the locator 110, for example by collecting measurement reports. The locator 110 can then be adapted for evaluating the locations of the mobile devices. Moreover, the velocity calculator 130 may be adapted for evaluating a mobile device's trajectories and mobile device's speeds, which can, for example, be done by exploitation of the measurement reports and the estimated locations. The selector 120, selects a subgroup of the plurality of mobile devices based on their locations as described above. The velocity calculator 130 can be adapted for estimating the presence of traffic jam, for example, by use of a traffic jam detector. In embodiments this may be carried out by exploiting the knowledge about the mobile devices' trajectories, the spatial density of the mobile devices and the mobile devices' speeds.

[0071] The output interface 140 can be adapted for presenting the estimation results graphically, for example by showing trajectories and value added information in Google Maps, for monitoring purposes. The output interface 140 can be adapted for transmitting measurement reports to participating mobile devices, for example using short message services (SMS). As mentioned above, it is noted that mobile devices to which such traffic information is provided, may not be registered in the cellular network 115, but in any other mobile communication network.

[0072] In embodiments, an expected accuracy of the evaluations can be anticipated to be as low as approximately

300m, i.e. the distance to the traffic jam and the length of the traffic jam may be provided in a resolution of about 300m in the case of the basic version. In the premium implementation of an embodiment resolution as low as 100m for the distance to a traffic jam and the length of a traffic jam may be obtained. In embodiments, the accuracy will depend on the speed of the mobile stations and on the spatial density of the base transceiver stations within the cellular network 115.

[0073] It is to be noted, that information provision by operators of the cellular network 115 may traditionally be value added services, and can provide improved location services. Pieces of information computed by the apparatus 100 can be further exploited in other location service applications in embodiments.

[0074] In the premium version of the above-described implementation of an embodiment, a client may be able to access traffic congestion estimation services using a client software on a mobile device. This installation may be done once after registering for the service in an embodiment. From then on, each time the user wants to access the information, the client software is started. The client software then automatically does all transmissions, receptions and information displays automatically, so no further action by the user may be necessary. In embodiments, the presentation can be done by, for example, accessing a graphical user interface through a web browser, which displays Google Maps. In other embodiments a simplified text message output is also possible, which is available to mobile stations without web browsers. Moreover, in embodiments the user may stop the execution of the client any time, for example at the point in time where no traffic jam information is desired any more.

[0075] Finally, Figs. 8a to 8e shall illustrate an implemented embodiment using a respective service. Fig. 8a shows a mobile device, exemplified as a Blackberry mobile device. A user may then start the service application as indicated in Fig. 8b. Figs. 8c to 8e illustrate the display of the mobile device in more detail. Figs. 8c to 8e show maps, in which a triangle 800 indicates a current position of the user. In Fig. 8c, the service indicates to the user that there is a congestion ahead, in a distance of 700 meters. This provision happens early enough, so the user may decide to change the route, in order to avoid the congestion. This is indicated in Fig. 8d, where the user indicated by triangle 800 left the highway to the eastern direction, in order to avoid the congestion indicated in Fig. 8c. In embodiments the suggestion of the alternative route may be automatically made by the mobile device. Finally, Fig. 8e shows that the user proceeds on the highway, however, on the part where the average velocity is higher. Figs. 8c to 8e indicate that the early provision of the traffic information may enable the user to take the shortcut through the side road, in order to avoid the congestion and therewith to save valuable time and optimize the route.

[0076] Embodiments can provide the advantage, that the enabled traffic estimation service allows drivers to safely avoid congested roads on-the-go. In addition, drivers can be enabled to better estimate the time needed to drive from one location to another. This may be carried out by embodiments through automatic calculation of the estimated velocities of other mobiles on the roads leading to the destination. Moreover, man hours can be saved, road risks can be reduced, help can be organized quicker, general organization and management may be more reliable and emergency help can be made available sooner.

[0077] Depending on certain implementation requirements of the inventive methods, the inventive methods can be implemented in hardware or in software. The implementation can be performed using a digital storage medium, in particular a disk, a DVD, a Blu-ray disk or a CD having electronically readable control signals stored thereon, which cooperate with a programmable computer system such that the inventive methods are performed. Generally, the present invention is, therefore, a computer program product with a program code stored on a machine readable carrier, the program code being operative for performing the inventive methods when the computer program product runs on a computer. In other words, the inventive methods are, therefore, a computer program having a program code for performing at least one of the inventive methods when the computer program runs on a computer.

[0078] While the foregoing has been particularly shown and described with reference to particular embodiments thereof, it will be understood by those skilled in the art that various other changes in the form and details may be made without departing from the spirit and scope thereof. It is to be understood that various changes may be made in adapting to different embodiments without departing from the broader concepts disclosed herein and comprehended by the claims that follow.

Claims

1. An apparatus (100) operative for providing traffic information on a traffic area, comprising:

a locator (110) for determining a plurality of locations of a plurality of mobile devices in a cellular network (115);
a selector (120) for selecting a subgroup of the plurality of mobile devices based on the locations of the mobile devices, when the mobile devices are located in the traffic area and for not selecting mobile devices which are located outside the traffic area;
a velocity calculator (130) for calculating a velocity of mobile devices in the subgroup and for generating data on a velocity of a traffic flow in the traffic area using the velocities of the mobile devices of the subgroup and

wherein mobile devices not selected for the subgroup are not used for generating the data, wherein the velocity calculator (130) is adapted for calculating at least two velocities of each mobile device in the subgroup within a cell of the cellular network (115);
an output interface (140) for outputting the traffic information, which is based on the data on the velocity of the traffic flow.

2. The apparatus (100) of claim 1, wherein the locator (110) is adapted for determining the plurality of locations based on radio link measurements provided by the cellular network (115).

3. The apparatus (100) of claim 2, wherein the radio link measurements comprise an information on one of or a combination of the group of a cell-ID (IDentification), an RSSI (Receive Signal Strength Indicator) of a mobile device, RXLEV (Receive Level) of a base transceiver station of the cellular network (115), a timing advance of a radio connection between a mobile device and a base transceiver station of the cellular network (115), a measure on a radio link attenuation, a measure on a propagation delay or an information on a location of a mobile device.

4. The apparatus (100) of one of the claims 1 to 3, wherein the selector (120) is adapted for selecting the subgroup based on street pattern within the traffic area.

5. The apparatus (100) of one of the claims 1 to 4, wherein the velocity calculator (130) is adapted for generating the data such that the data comprises an average velocity based on at least half of the mobile devices in the subgroup.

6. The apparatus (100) of one of the claims 1 to 5, wherein the locator (110) is adapted for determining a location of a mobile device based on a regular time basis.

7. The apparatus (100) of one of the claims 1 to 6, wherein the output interface (140) is adapted for generating an SMS for a user, the SMS comprising information on the traffic information.

8. The apparatus (100) of one of the claims 1 to 7, further comprising a traffic jam detector being adapted for detecting a traffic jam based on a threshold detection on the velocity of the traffic flow and wherein the output interface (140) is adapted for outputting the traffic information comprising a traffic jam indication.

9. The apparatus (100) of claim 8, wherein the output interface (140) is adapted for generating an alarm-SMS for a user when a traffic jam is detected.

10. The apparatus (100) of one of the claims 1 to 9, wherein the output interface (140) is adapted for outputting the traffic information to a web server.

11. The apparatus (100) of one of the claims 1 to 10, wherein the output interface (140) is adapted for outputting the traffic information in terms of a graphical representation.

12. The apparatus (100) of one of the claims 1 to 11, wherein the output interface (140) is adapted for outputting as traffic information an information on one of or a combination of the group of the velocity of the traffic flow, a velocity or an average velocity of the subgroup, an estimation on a future velocity of the traffic flow, a traffic jam or traffic jam expectation, an alternative route or an estimation for a time of arrival.

13. The apparatus (100) of one of the claims 1 to 12, wherein the output interface (140) is adapted for outputting the traffic information to a mobile device.

14. Method for providing a traffic information on a traffic area, comprising the steps of:

determining a plurality of locations of a plurality of mobile devices in a cellular network (115);
selecting a subgroup of the plurality of mobile devices based on the locations of the mobile devices when the mobile devices are located in the traffic area and for not selecting mobile devices, which are located outside the traffic area;
calculating a velocity of mobile devices in the subgroup;
generating data on a velocity of a traffic flow in a traffic area using the velocities of the mobile devices of the subgroup, wherein mobile devices not selected for the subgroup are not used for generating the data;
calculating at least two velocities of each mobile device in the subgroup within a cell of the cellular network

(115); and
outputting the traffic information based on the data on the velocity of the traffic flow.

15. Computer program having a program code for performing the method of claim 14, when the computer program code runs on a computer or processor.

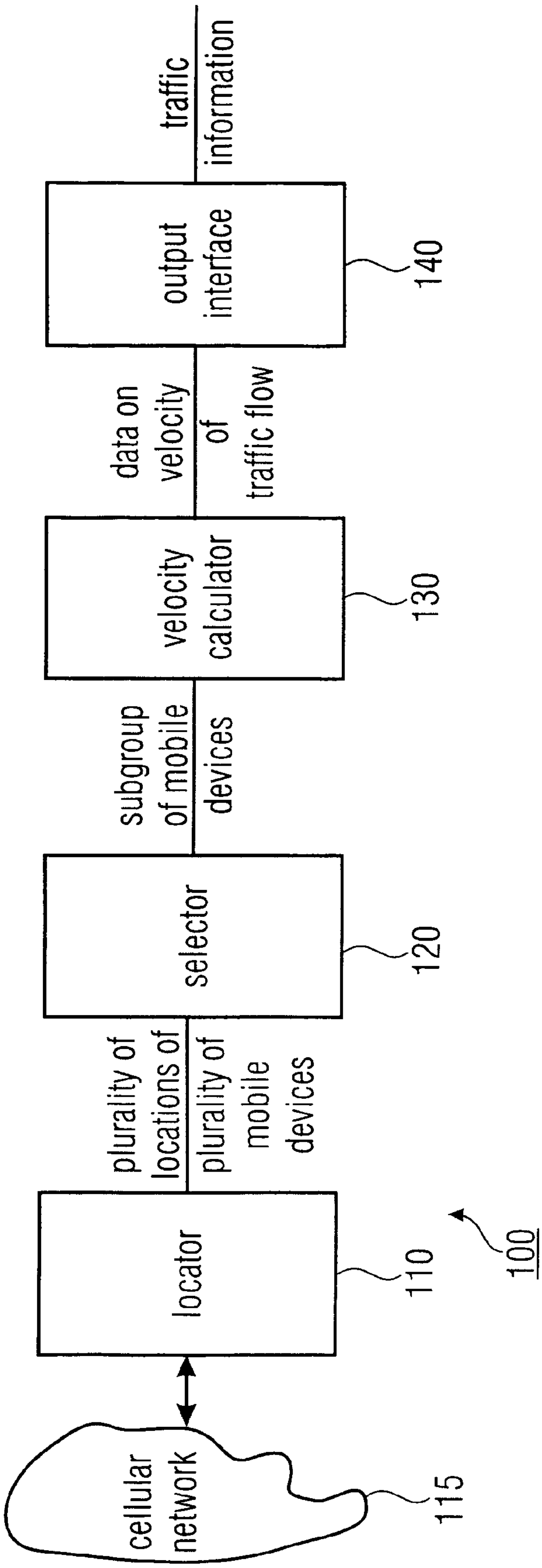
cellular network
115
locator
110
100
plurality of locations of plurality of mobile devices
selector
120
subgroup of mobile devices
velocity calculator
130
data on velocity of traffic flow
output interface
140
traffic information

FIGURE 1

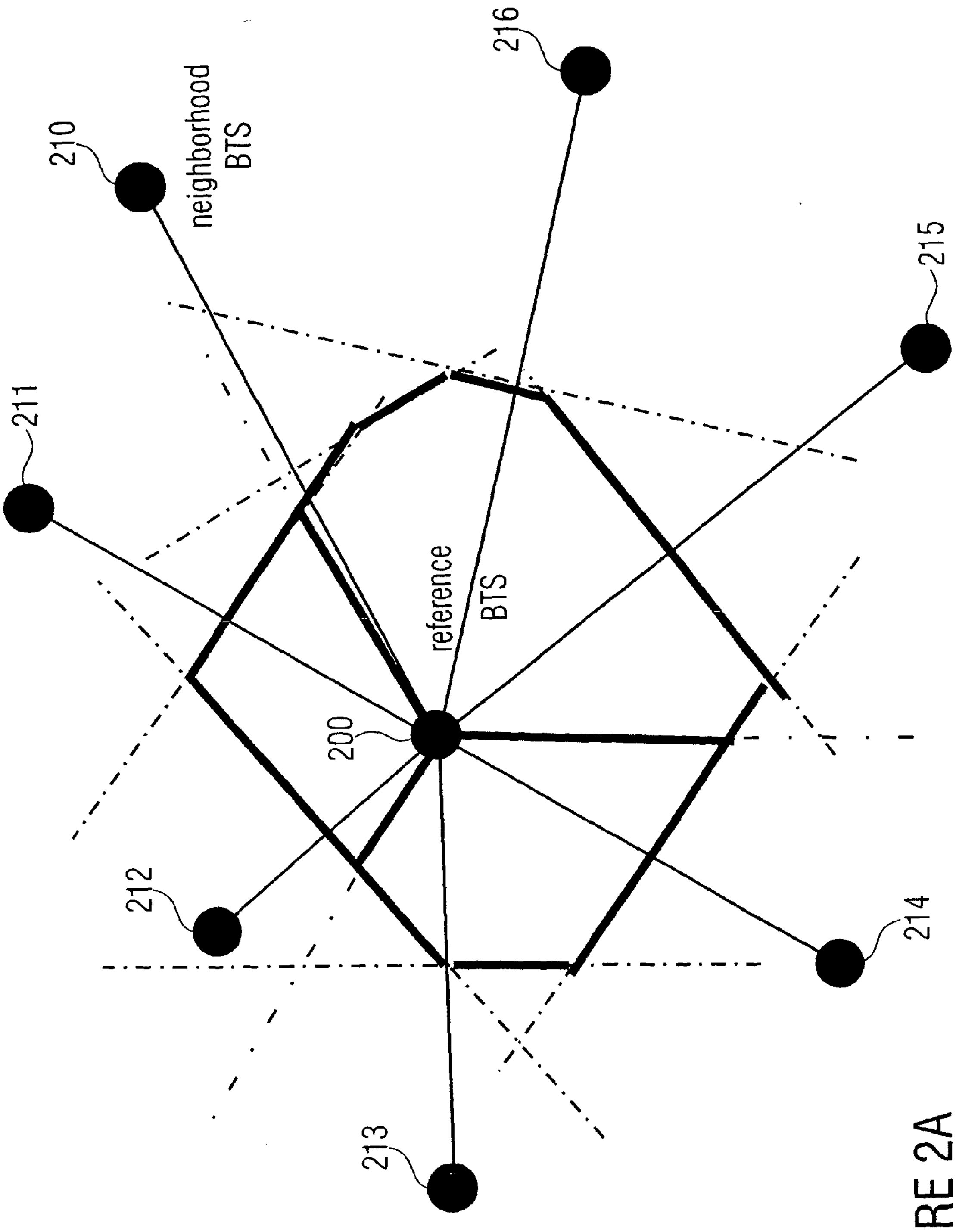
216
210
neighborhood BTS
215
211
reference BTS
200
212
214
213

FIGURE 2A

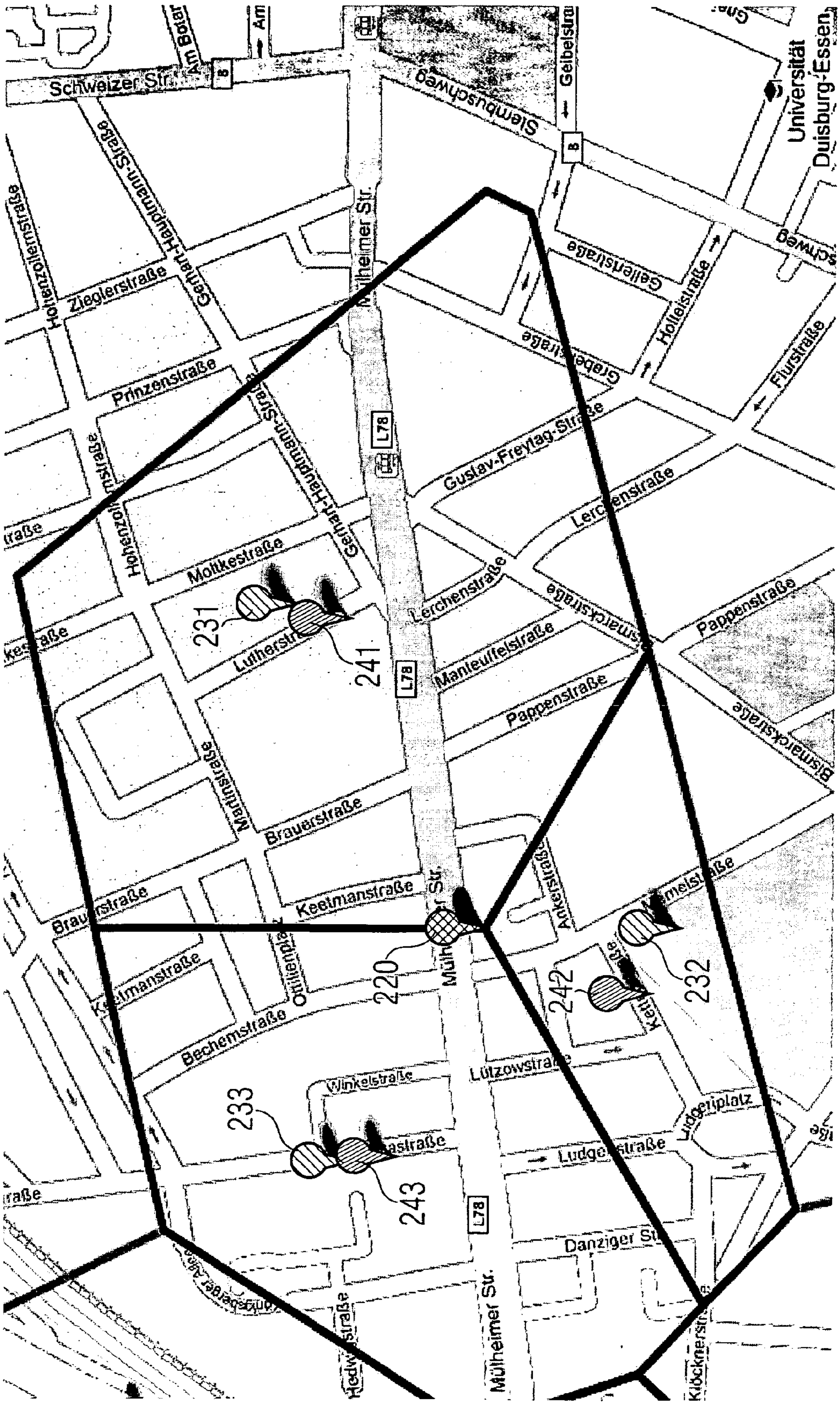
231
241
220
242
232
233
243
Schweizer Str.
Mülheimer Str.
Zieglerstraße
Prinzenstraße
Moltkestraße
Lutherstr
Martinstraße
Brauerstraße
Keetmanstraße
Bechemstraße
Winkelstraße
Lützowstraße
Ankerstraße
Pappenstraße
Manteuffelstraße
Lerchenstraße
Gustav-Freytag-Straße
Grabenstraße
Gellertstraße
Holteistraße
Flurstraße
Bismarckstraße
Danziger Str.
Klöcknerstraße
Geibelstraße
Sternbuschweg
Universität Duisburg-Essen
L78

FIGURE 2B

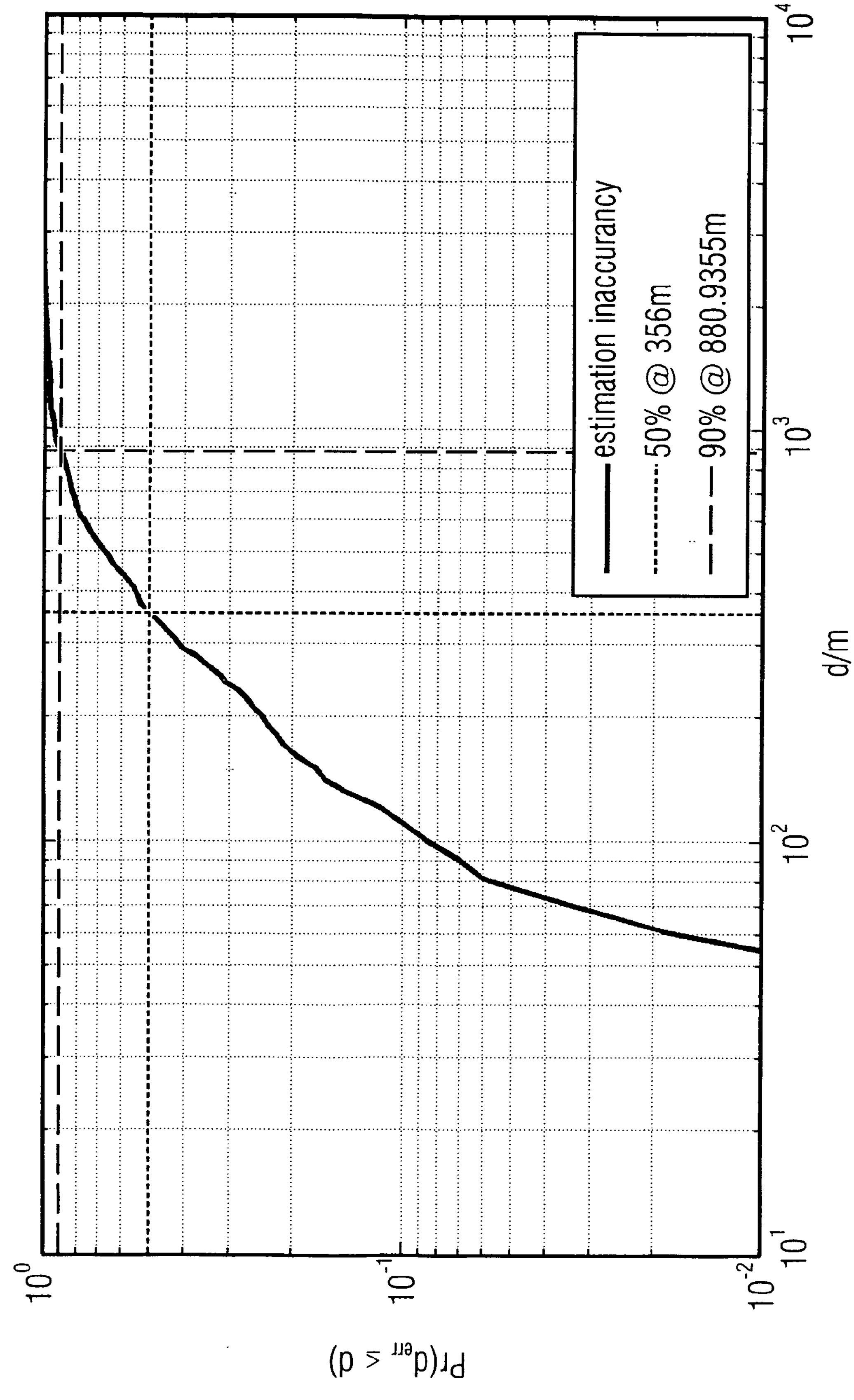
estimation inaccurancy
50% @ 356m
90% @ 880.9355m
d/m
Pr(d_err ≤ d)
10^0
10^-1
10^-2
10^1
10^2
10^3
10^4

FIGURE 3A

Table1. Range of *RSSI* parameter.

RSSI	received signal power *p*
0	$p < -110dBm$
1	$-110dBm \leq p < -109dBm$
⋮	⋮
62	$-49dBm \leq p < -48dBm$
63	$p \geq -48dBm$

FIGURE 3B

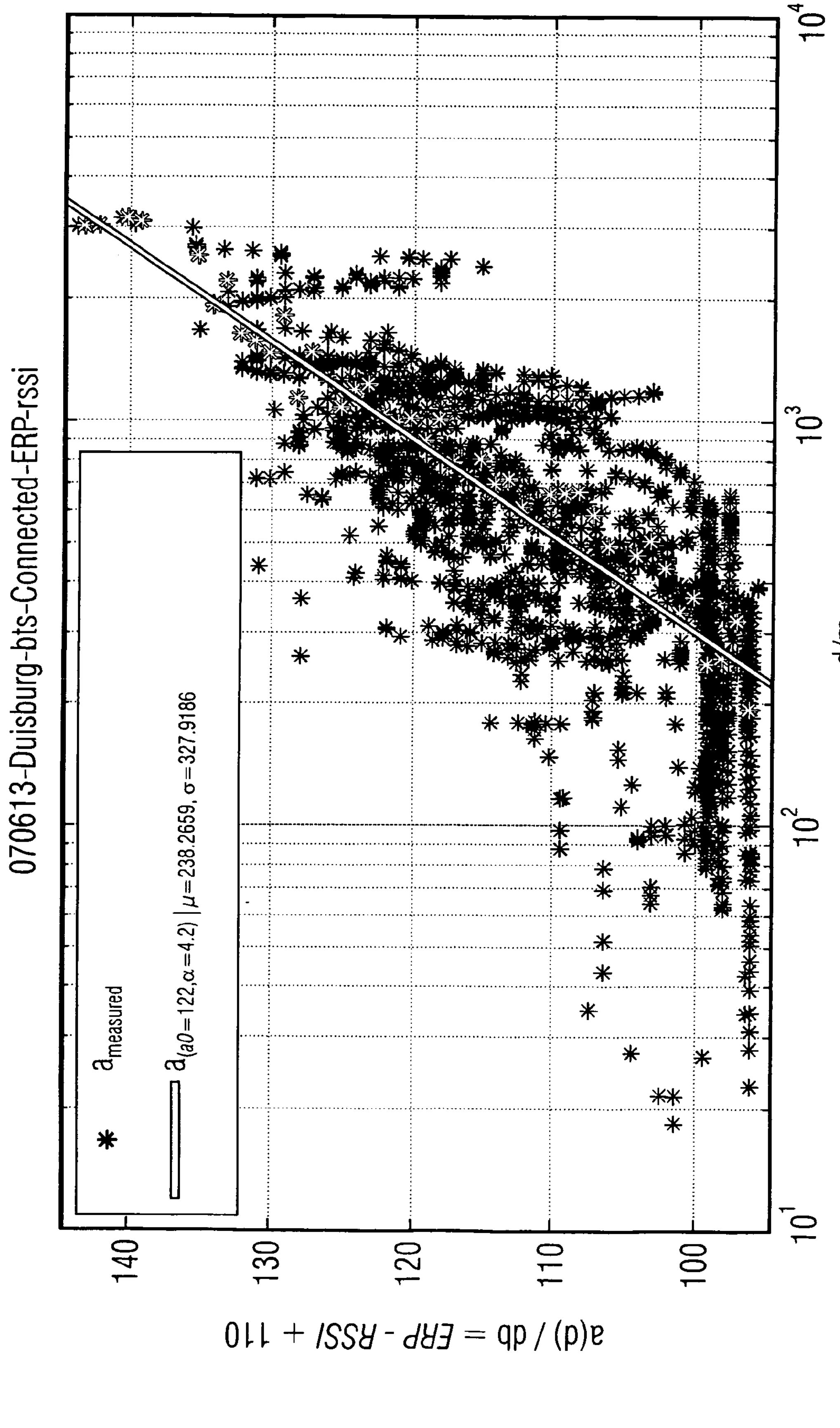
070613-Duisburg-bts-Connected-ERP-rssi
$a_{measured}$
$a_{(a0=122,\alpha=4.2)}$ | μ=238.2659, σ=327.9186
a(d) / db = ERP - RSSI + 110
140
130
120
110
100
10^1
10^2
10^3
10^4
d/m

FIGURE 4

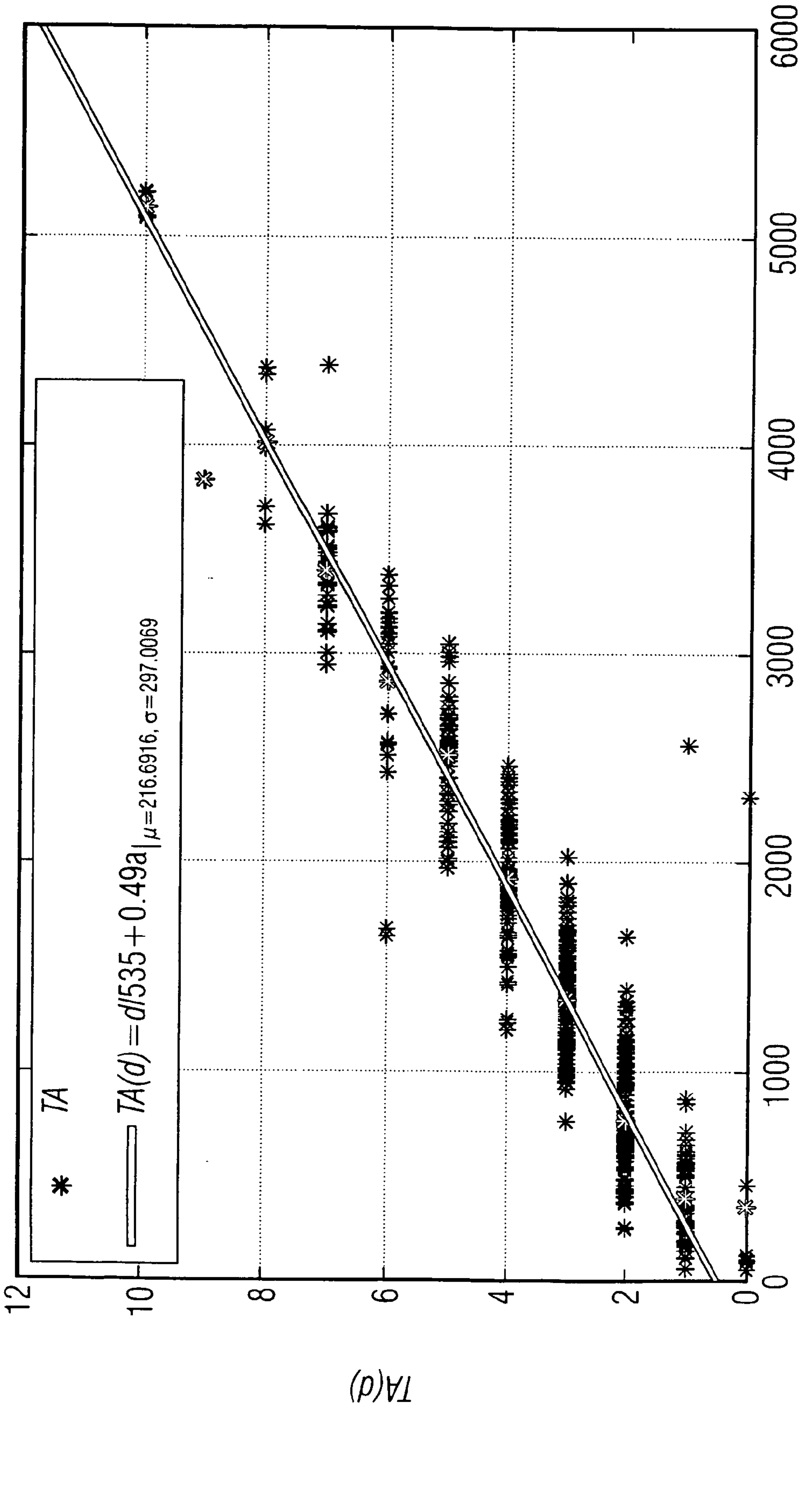
TA
TA(d) = d/535 + 0.49a |μ=216.6916, σ=297.0069
TA(d)
0
2
4
6
8
10
12
0
1000
2000
3000
4000
5000
6000
d/m

FIGURE 5

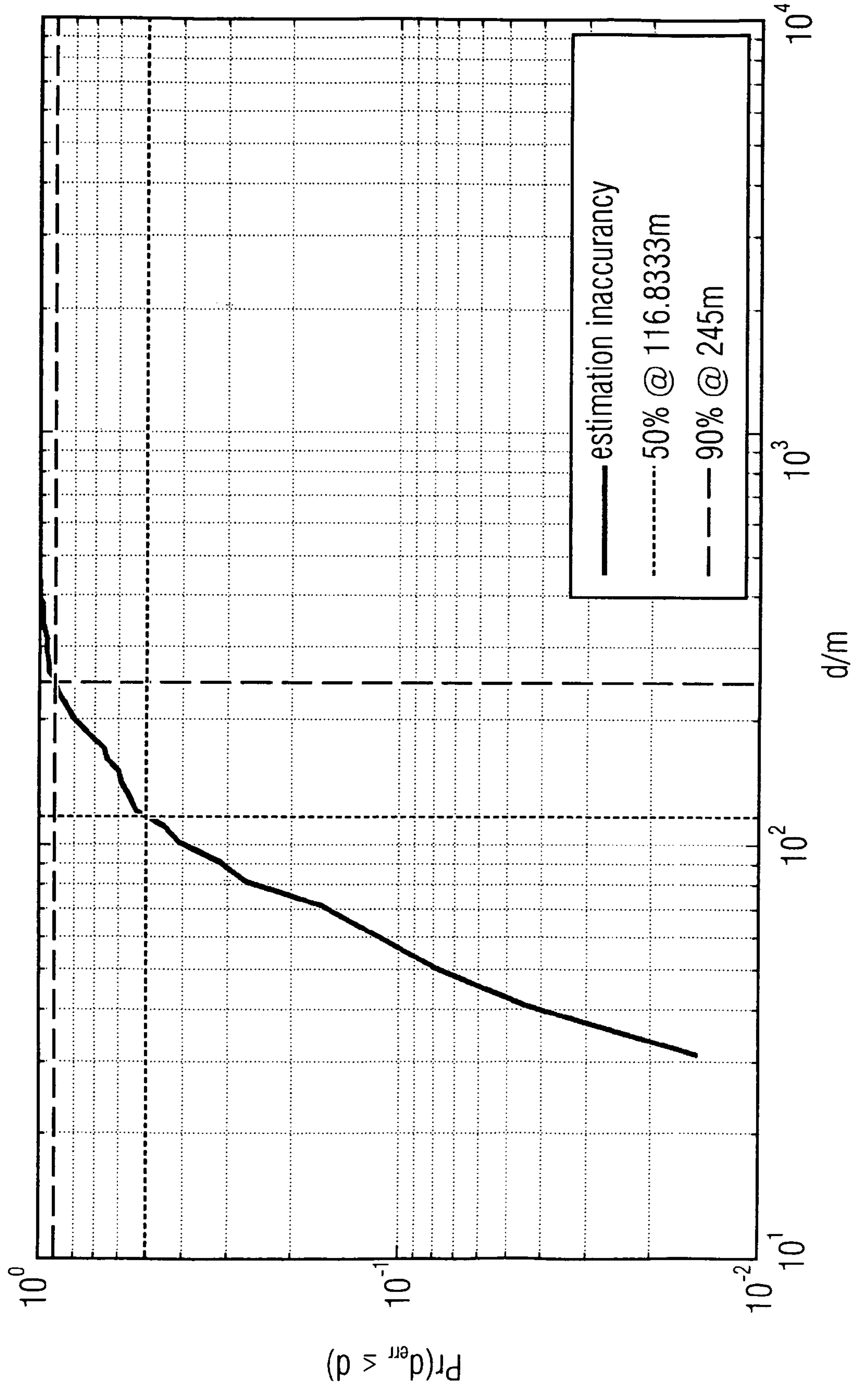
estimation inaccuracy
50% @ 116.8333m
90% @ 245m
d/m
Pr(d_err ≤ d)
10^0
10^-1
10^-2
10^1
10^2
10^3
10^4

FIGURE 6

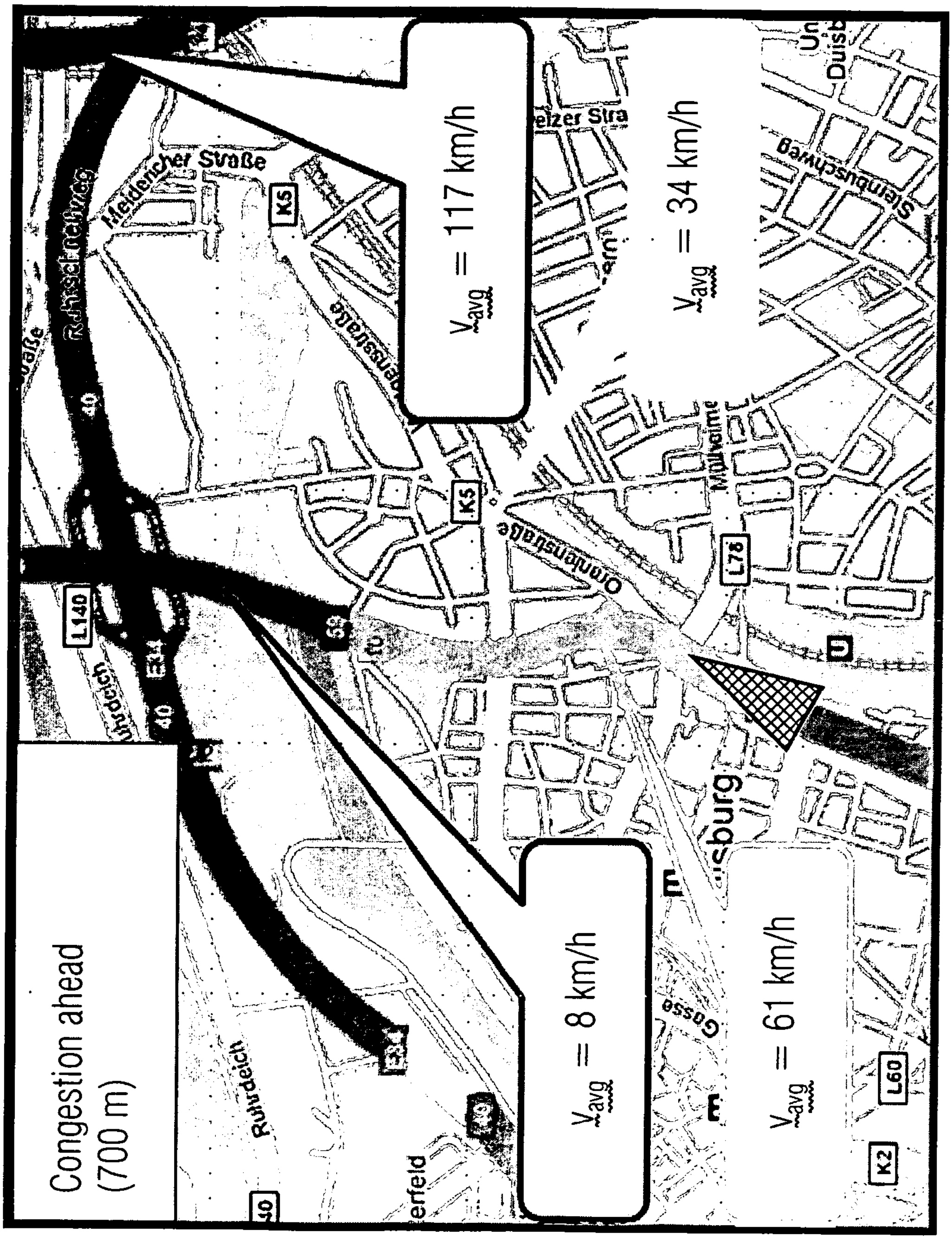
Congestion ahead
(700 m)
V_avg = 117 km/h
V_avg = 34 km/h
V_avg = 8 km/h
V_avg = 61 km/h
Meidericher Straße
Ruhrdeich
L140
E34
K5
L78
L60
K2
Oranienstraße
Steinbuschweg

FIGURE 7

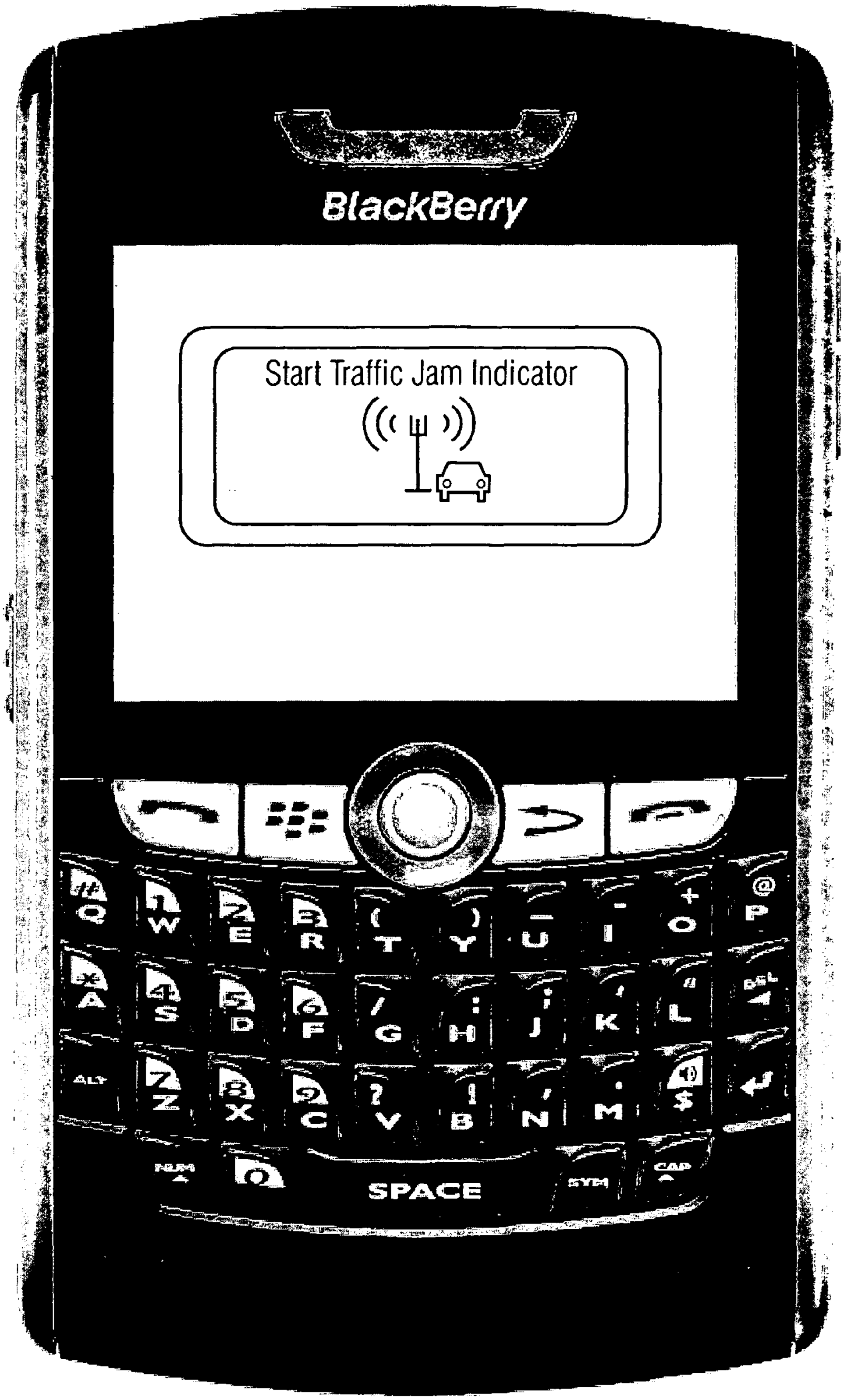

FIGURE 8A

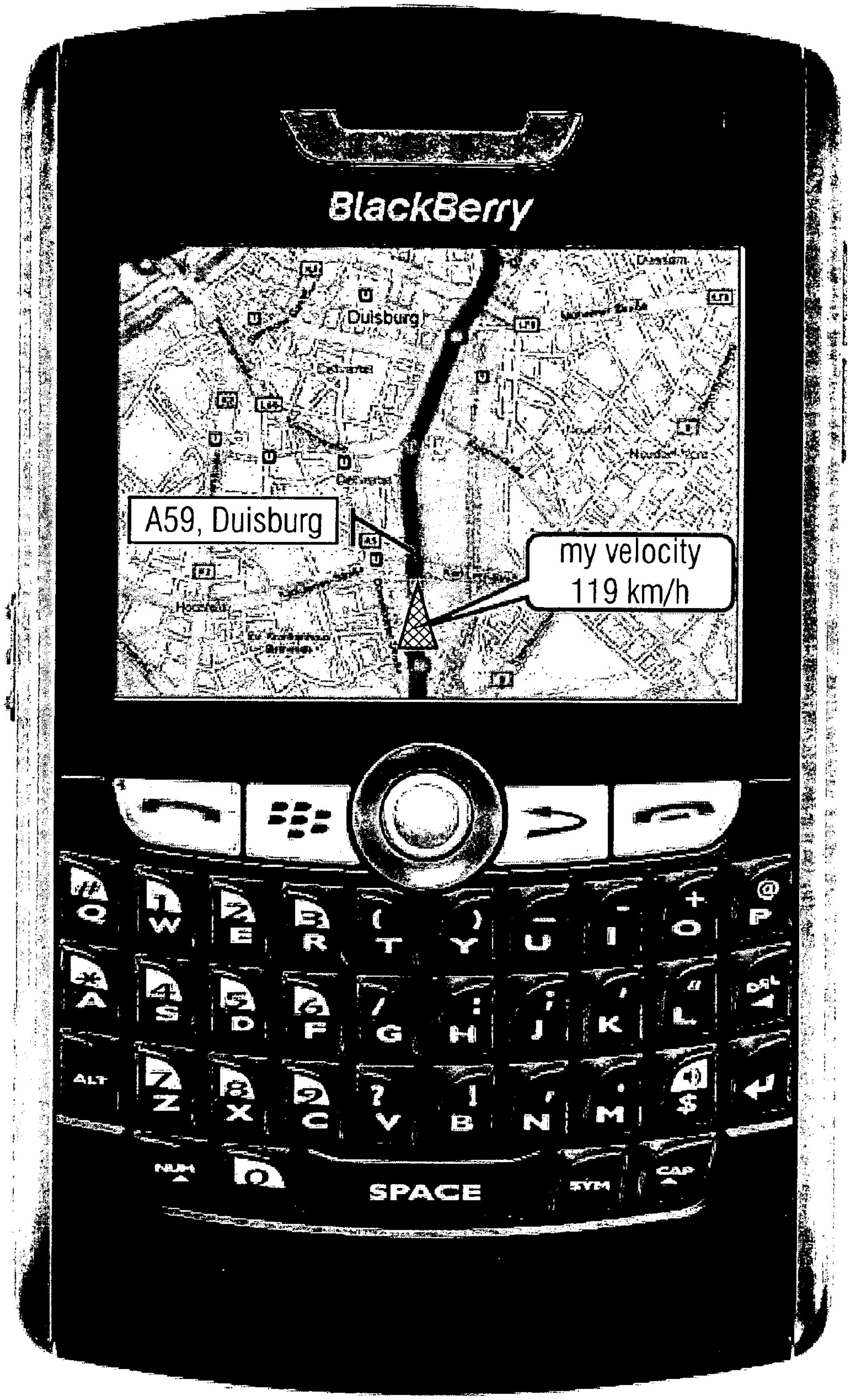
BlackBerry
Duisburg
A59, Duisburg
my velocity
119 km/h
SPACE

FIGURE 8B

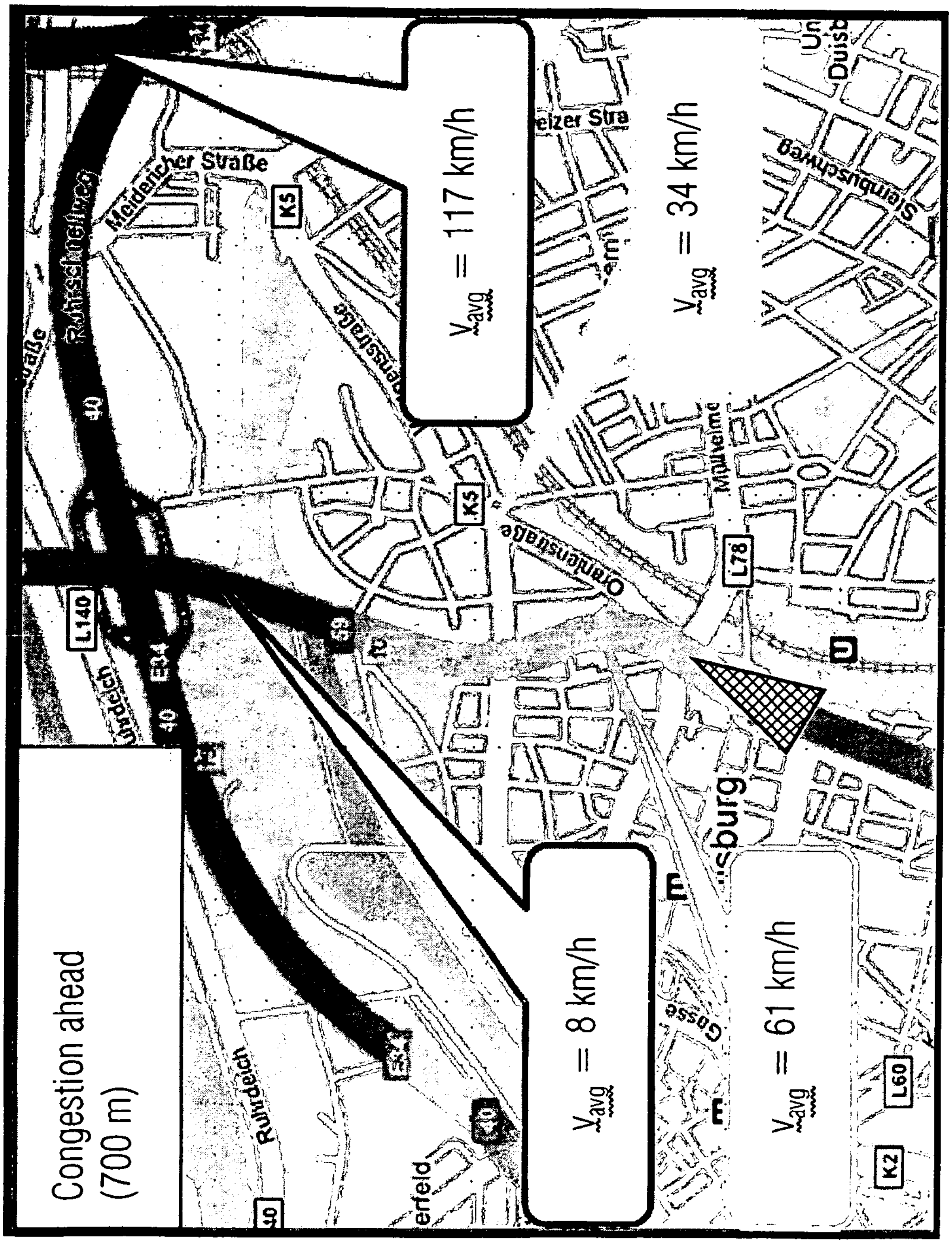
Congestion ahead
(700 m)
$\underset{\sim}{V_{avg}}$ = 117 km/h
$\underset{\sim}{V_{avg}}$ = 34 km/h
$\underset{\sim}{V_{avg}}$ = 8 km/h
$\underset{\sim}{V_{avg}}$ = 61 km/h
Meidericher Straße
Oranienstraße
Ruhrdeich
L140
K5
L78
L60
K2
E34
40

FIGURE 8C

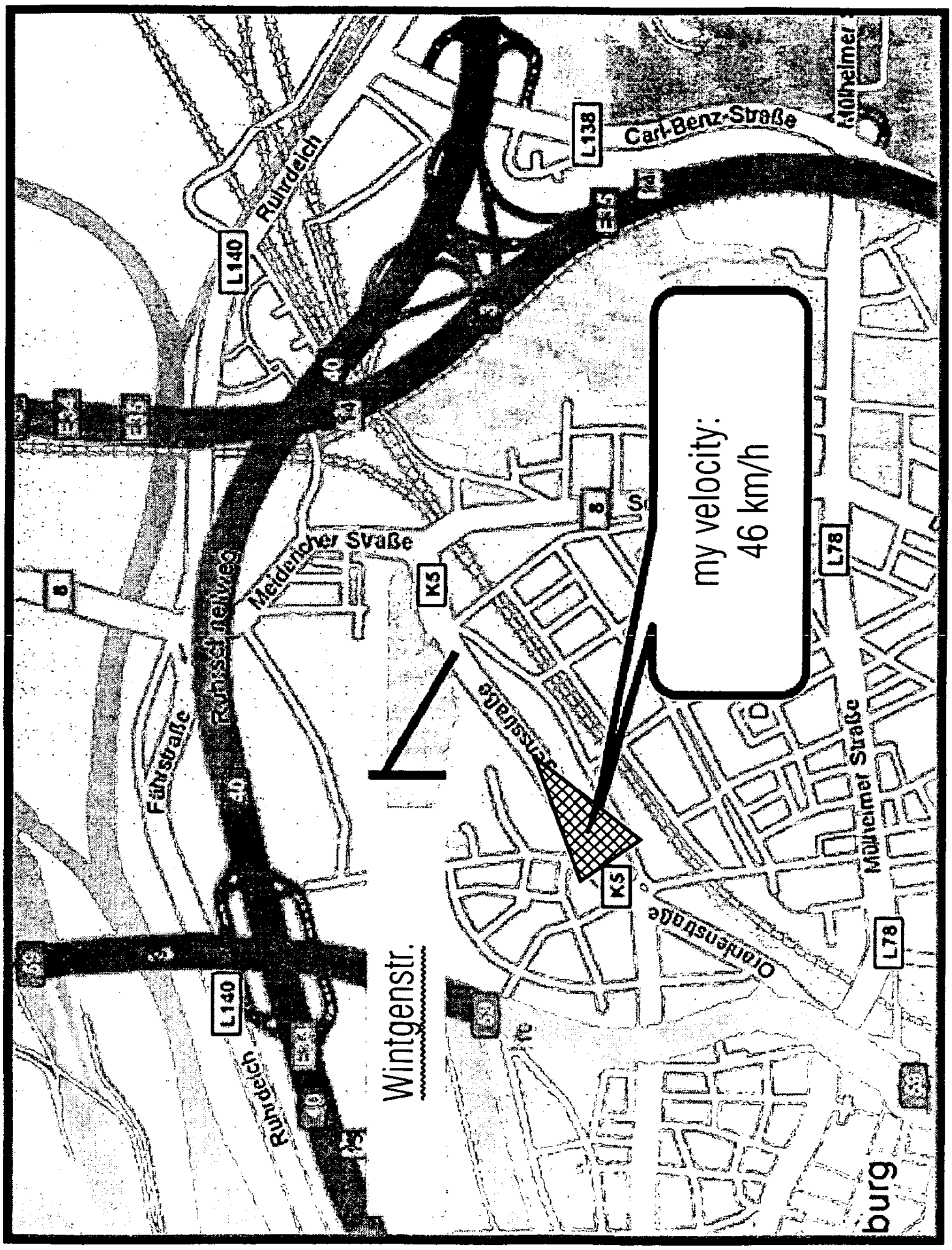
my velocity:
46 km/h
Wintgenstr.
Carl-Benz-Straße
Ruhrdeich
Meidericher Straße
Mülheimer Straße
L140
L138
L78
K5

FIGURE 8D

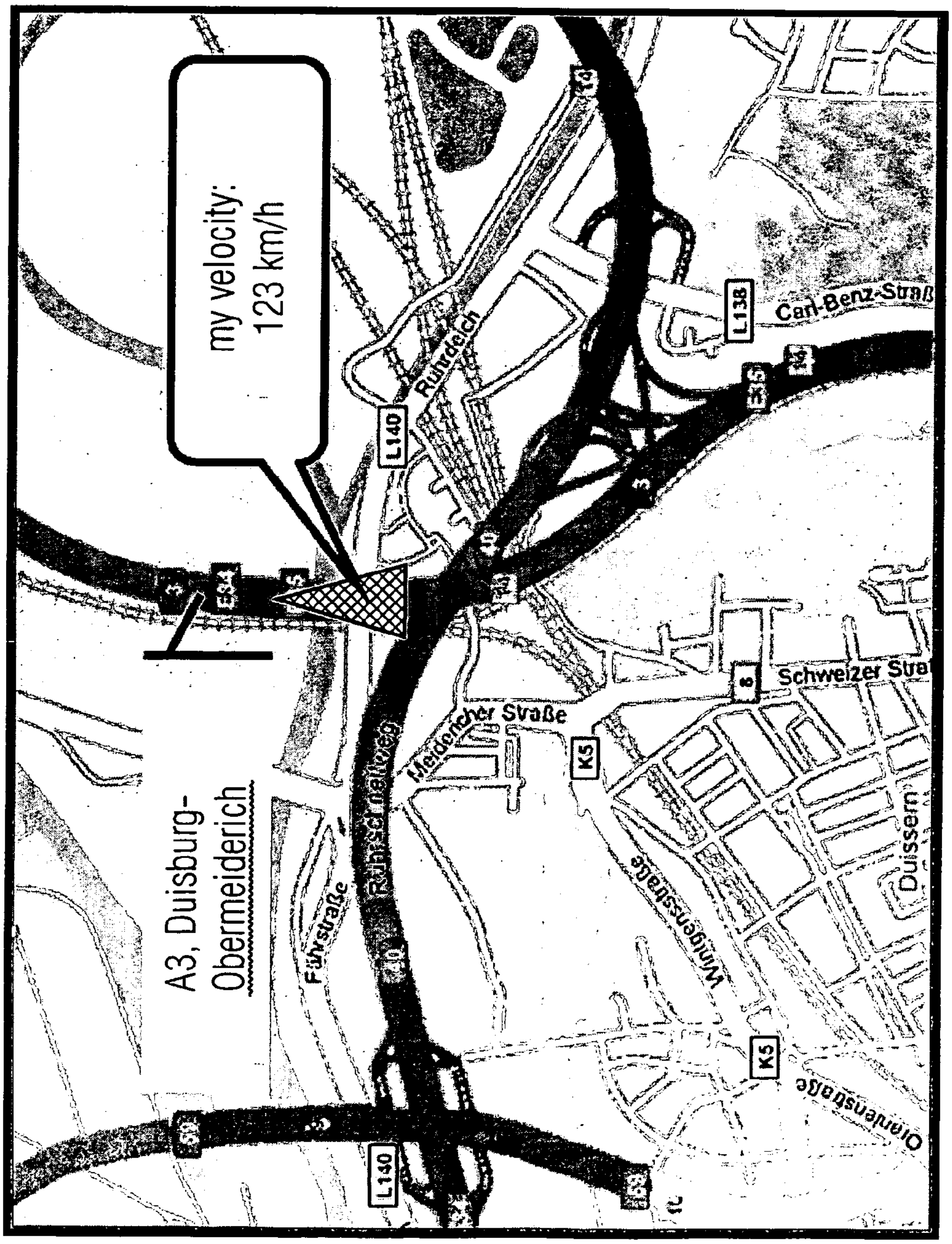
my velocity:
123 km/h
A3, Duisburg-
Obermeiderich
Ruhrdeich
L140
L138
Carl-Benz-Straß
Schweizer Stra
Meidericher Straße
K5
Duissern

FIGURE 8E

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EUROPEAN SEARCH REPORT

Application Number
EP 09 00 9831

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 January 2010	Flores-Jiménez, A

1

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X : particularly relevant if taken alone
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