(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 241 366 B1

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
31.10.2018 Bulletin 2018/44

(21) Application number: **14830964.4**

(22) Date of filing: **30.12.2014**

(51) Int Cl.:
H04W 4/021 *(2018.01)* ***H04W 4/029*** *(2018.01)*

(86) International application number:
PCT/EP2014/079431

(87) International publication number:
WO 2016/107644 (07.07.2016 Gazette 2016/27)

(54) **METHOD AND SYSTEM FOR ESTIMATING A NUMBER OF PERSONS IN A CROWD**

VERFAHREN UND SYSTEM ZUR SCHÄTZUNG DER ANZAHL VON PERSONEN IN EINER MENGE

PROCÉDÉ ET SYSTÈME PERMETTANT D'ESTIMER LE NOMBRE DE PERSONNES FORMANT UNE FOULE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(43) Date of publication of application:
08.11.2017 Bulletin 2017/45

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Description

Background of the Invention

Field of the Invention

[0001] The present invention relates to crowd counting, i.e. to techniques for counting or estimating the number of persons in a crowd. In the present description and for the purposes of the present invention, by "crowd" it is meant a gathering of a certain number of people, gathered in a certain location for, e.g., attending at public events or happenings, of the most disparate nature, like for example (and non-exhaustively) live television shows, artistic/entertaining performances, cultural exhibitions, theatrical plays, sports contests, concerts, movies, demonstrations and so forth.

[0002] Particularly, the present invention relates to crowd counting techniques exploiting information provided by wireless or mobile telecommunication networks.

Overview of the Related Art

[0003] In the tasks of urban planning, management of activities (e.g., transport systems management and emergencies management), and tourism and local marketing, it is useful to have a knowledge of amounts of people who gathered at certain locations or Areas of Interest (AoI for short, e.g., a building, such as for example a stadium or a theatre or a cinema, the surroundings thereof, a square or a street(s) of a city or town or village, a district *etc.*), e.g. because they attended at public happenings like shows (e.g., related to culture, entertaining, politics or sports) that took place within the Area of Interest. In facts, this knowledge allows for example a more effective planning of subsequent public happenings of the same type. Particularly, this knowledge allows a more effective planning and managing of resources and activities (such as infrastructures, transport system and security) directly or indirectly related to similar public happenings that may take place in the future (such as for example sports matches that regularly take place at a stadium). Moreover, from a commercial viewpoint, this knowledge allows a better management of marketing activities intended to promote similar events that may take place in the future.

[0004] Nowadays, mobile communication devices (referred to as mobile phones or UE in the following, including cellular phones, smartphones, tablets and the like) have reached a thorough diffusion among the population of many countries, and mobile phone owners almost always carry their mobile phones with them. Since mobile phones communicate with a plurality of base stations of the mobile phone networks, and each base station covers (i.e., serves) one or more predetermined serving areas, or cells, which are known to the mobile communication services provider (e.g. mobile phone network owner or virtual mobile phone services provider), mobile phones result to be optimal candidates as tracking devices for collecting data useful for identifying the amount of people who attended to one or more public happenings.

[0005] In the art, many systems and methods have been proposed in order to collect information about time and locations at, and in which, a User Equipment (UE, e.g. a mobile phone, a smartphone, a tablet, *etc.)* of an individual connects to the mobile phone network (e.g., for performing a voice call or sending a text message), and use such collected information in order to derive information related to how many attendees a certain public happening had.

[0006] For example, Francesco Calabrese, Carlo Ratti, "Real Time Rome", Networks and Communications Studies 20(3-4), pages 247-258, 2006, discloses the Real Time Rome project, presented at the 10th International Architecture Exhibition in Venice, Italy. The Real Time Rome project is the first example of a urban-wide real-time monitoring system that collects and processes data provided by telecommunications networks and transportation systems in order to understand patterns of daily life in Rome. Observing the real-time daily life in a town becomes a means to understanding the present and anticipating the future urban environment.

[0007] F. Manfredini, P. Pucci, P. Secchi, P. Tagliolato, S. Vantini, V. Vitelli, "Treelet decomposition of mobile phone data for deriving city usage and mobility pattern in the Milan urban region", MOX-Report No. 25/2012, MOX, Department of Mathematics "F. Brioschi", Politecnico di Milano, available at http://mox.polimi.it, discloses a geo-statistical unsupervised learning technique aimed at identifying useful information on hidden patterns of mobile phone use. These hidden patterns regard different usages of the city in time and in space which are related to individual mobility, outlining the potential of this technology for the urban planning community. The methodology allows obtaining a reference basis that reports the specific effect of some activities on the Erlang data recorded and a set of maps showing the contribution of each activity to the local Erlang signal. Results being significant for explaining specific mobility and city usages patterns (commuting, nightly activities, distribution of residences, non systematic mobility) have been selected and their significance and their interpretation from a urban analysis and planning perspective at the Milan urban region scale has been tested.

[0008] Ramon Caceres, James Rowland, Christopher Small, and Simon Urbanek, "Exploring the Use of Urban Greenspace through Cellular Network Activity", 2nd Workshop on Pervasive Urban Applications (PURBA), June 2012, discloses the use of anonymous records of cellular network activity to study the spatiotemporal patterns of human density in an urban area. This paper presents the vision and some early results of this effort. Firstly, a dataset of six months of activity in the New York metropolitan area is described. Secondly, a technique for estimating network coverage areas is presented. Thirdly, the used approach in analyzing changes in activity volumes within those areas is described. Finally, preliminary results regarding changes in human density around Central Park are presented.

[0009] F. Girardin, A. Gerber, A. Vaccari, A. Biderman, C. Ratti, "Towards estimating the presence of visitors from the aggregate mobile phone network activity they generate", International Conference on Computers in Urban Planning and Urban Management, 2009, examines the use of locally and non-locally registered mobile phones in the vicinity of the "Waterfalls" public exhibit in New York City in 2008. Aggregated statistics (i.e. number of calls) related to the network sectors covering the exhibit and its proximity are studied. With the future contribution of traditional survey techniques, such as field counts, to calibrate these mobile phone network measurements, there is an aim at developing techniques to estimate the aggregate movements and location of visitors through time and space, while assuring their privacy.

[0010] F. Calabrese, F. C. Pereira, G. Di Lorenzo, L. Liu, C. Ratti, "The Geography of Taste: Analyzing Cell-Phone Mobility in Social Events," Pervasive Computing, LNCS 6030, Springer, 2010, pp. 22-37, discloses the analysis of crowd mobility during special events. Nearly 1 million cell-phone traces have been analyzed and associated with their destinations with social events. It has been observed that the origins of people attending an event are strongly correlated to the type of event, with implications in city management, since the knowledge of additive flows can be a critical information on which to take decisions about events management and congestion mitigation.

[0011] Traag, V. A.; Browet, A.; Calabrese, F.; Morlot, F., "Social Event Detection in Massive Mobile Phone Data Using Probabilistic Location Inference", 2011 IEEE Third International Conference on Privacy, Security, Risk and Trust (Passat), and 2011 IEEE Third International Conference on Social Computing (Socialcom), pp.625,628, 9-11 Oct. 2011, focuses on unusually large gatherings of people, i.e. unusual social events. The methodology of detecting such social events in massive mobile phone data is introduced, based on a Bayesian location inference framework. More specifically, a framework for deciding who is attending an event is also developed. The method on a few examples is demonstrated. Finally, some possible future approaches for event detection, and some possible analyses of the detected social events are discussed.

[0012] The paper by Ferrari Laura et al. "Discovering events in the city via mobile network analysis", presents a methodology to discover events from human mobility patterns as recorded by mobile network usage. Experiments conducted over an extensive dataset from the main Italian telecom operator show that the proposed approach is effective and can be applied to a number of different scenarios. These results can have a strong impact on a wide range of pervasive applications ranging from location-based services to urban planning.

Summary of the Invention

[0013] The Applicant has observed that, generally, method and systems known in the art provide unsatisfactory results, as they are not able to determine (or have a limited ability in determining) whether a UE owner has been in an Area of Interest (AoI) where one or more public happenings have been held, for attending thereat or for other reasons (for example, because the UE owner resides or has a business in proximity of, or within, the area of interest). In addition, the results provided by the known solutions are strongly influenced by the size of the area of interest selected for the analysis of the amount of attendees at the one or more public happenings. In other words, if the area of interest has a large size, a certain number of UE owners that are not actually part of the crowd will be taken into account in the evaluation of the number of attendees of the public happening. Conversely, if the area of interest has small size, a certain number of UE owners actually part of the crowd will be excluded from the evaluation of the number of persons in the crowd.

[0014] Therefore, subsequent planning and managing of resources and activities (of the type mentioned above) based on results obtained by the methods and systems known in the art will achieve a limited efficiency due to the limited accuracy thereof.

[0015] The Applicant has thus coped with the problem of devising a system and method adapted to overcome the problems affecting the prior art solutions.

[0016] The Applicant has found that it is possible to determine the size of an optimal area of interest on the basis of operational information related to UE during the course of the one or more public happenings and in a certain number of days preceding the one or more public happenings.

[0017] Particularly, one aspect of the present invention proposes a method of estimating a number of persons that gathered at an Area of Interest for attending a public happening Sn during a time interval $[Tsn; Ten]$ on a day gn. Said Area of Interest is defined by an Area of Interest center C and an Area of Interest radius Ra and is covered by a mobile telecommunication network having a plurality of communication stations each of which is adapted to manage communications of user equipment in one or more served areas in which the mobile telecommunication network is subdivided. The method comprises the following steps: a) defining a plurality of calculated radius values Rk of the Area of Interest radius Ra, and, for each calculated radius value Rk: b) identifying a first number of user equipment Unk associated with at least one event record er_i of a corresponding event e_i of interaction occurred between the user equipment and the mobile communication network during the time interval *[Tsn; Ten]* on the day *gn* within the Area of Interest; c) identifying a second number *Upnk* of user equipment associated with at least one event record $er_{i'}$ of a corresponding event $e_{i'}$ of interaction occurred between the user equipment and the mobile communication network during the time interval [*Tsn*; *Ten*] for each day *gpn* of a predetermined number *P* of previous days *gpn* preceding the day *gn* within the Area of Interest; d) combining the first number *Unk* of user equipment and the second numbers *Upnk* of user equipment for obtaining a statistical quantity *Znk*; e) detecting the occurrence of the public happening *Sn* if the statistical quantity *Znk* reaches a certain threshold *Zth*; f) computing an optimum radius value *Ro* of the Area of Interest radius *Ra* as the average of the calculated radius values *Rk* within which the public happening *Sn* is detected; g) counting a number *An* of persons that gathered for attending at the public happening *Sn* within an Area of Interest having the Area of Interest radius *Ra* equal to the optimum radius values *Ro*.

[0018] Preferred features of the present invention are set forth in the dependent claims.

[0019] In one embodiment of the present invention, the public happening *Sn* comprises a plurality of public happenings, the method further comprising the step of: iterating steps b) to e) for each one of the public happenings *Sn* of the plurality of public happenings, and wherein the step f) of computing an optimum radius value *Ro* of the Area of Interest radius *Ra* as the average of the computed radius values *Rk* within which the public happening is detected, comprises: computing an optimum radius value *Ro* of the Area of Interest radius *Ra* as the average of the computed radius values *Rk* weighted by a number *DSk* of detected public happenings *Sn* within the Area of Interest having the Area of Interest radius *Ra* equal to the same computed radius values *Rk*, said number of detected public happenings *DSk* being the sum of the public happenings *Sn* determined by iterating step e).

[0020] In one embodiment of the present invention, the method further comprises for each calculated radius value: i) identifying a number of relevant served areas among the served areas of the mobile communication network, wherein said relevant served areas are served areas at least partially superimposed on the Area of Interest.

[0021] In one embodiment of the present invention, a served area is identified as a relevant served area if it verifies the following condition:

$$Dist(C, B) \leq |Rc + Rk|,$$

where *C* is the center of the Area of Interest, *B* is the center of the served area, *Dist(C, B)* is the geographical distance between the center of the Area of Interest *C* and the center of the served area *B, Rc* is the radius of the served area, and *Rk* is the calculated radius value.

[0022] In one embodiment of the present invention, the step b) identifying a first number *Unk* of user equipment comprises: identifying a user equipment of the first number *Unk* of user equipment, within at least one of the relevant served areas, and the step c) of identifying a second number *Upnk* of user equipment comprises: identifying a user equipment of the second number *Upnk* within at least one of the relevant served areas.

[0023] In one embodiment of the present invention, the step d) of combining the first number *Unk* of user equipment and the second numbers *Upnk* of user equipment for obtaining a statistical quantity *Znk* comprises: combining the second UE numbers *Upnk* of each one of the previous days *gpn* in order to determine an average UE number μnk and a UE number standard deviation σnk.

[0024] In one embodiment of the present invention, the step d) of combining the first number *Unk* of user equipment and the second numbers *Upnk* of user equipment for obtaining a statistical quantity *Znk* further comprises computing the statistical quantity *Znk* as:

$$Znk = (Unk - \mu nk)/\sigma nk,$$

wherein *Unk* is the first number, μnk is the average UE number and σnk is the UE number standard deviation.

[0025] In one embodiment of the present invention, the plurality of calculated radius values *Rk* ranges from a minimum radius value *Rmin* to a maximum radius value i, each calculated radius value *Rk* being separated from a next calculated radius value by an iteration width Δ.

[0026] In one embodiment of the present invention, the step g) of counting a number of persons that gathered for attending at the public happening *Sn* within the area of interest having the Area of Interest radius *Ra* equal to the optimum radius value *Ro* comprises: j) identifying a number of relevant served areas among the served areas comprised in the mobile communication network, wherein said relevant served areas are served areas at least partially superimposed on the Area of Interest having the Area of Interest radius *Ra* equal to the optimum radius value *Ro*.

[0027] In one embodiment of the present invention, a served area is identified as a relevant served area if it verifies the following inequality:

$$Dist(C, B) \leq |Rc + Ro|,$$

where *C* is the center of the Area of Interest, *B* is the center of the served area, *Dist(C, B)* is the geographical distance between the center of the Area of Interest *C* and the center of the served area *B, Rc* is the radius of the served area, and *Ro* is the optimum radius value.

[0028] In one embodiment of the present invention, the step g) of counting a number of persons that gathered for attending at the public happening *Sn* within the area of interest having the Area of Interest radius *Ra* equal to the optimum radius *Ro* value further comprises: k) building a UE list *uLn* comprising an identifier of each user equipment *UEj* associated with at least one event record er_i among the event records er_i occurred in the time interval *[Tsn; Ten]* on the day *gn* within the AoI.

[0029] In one embodiment of the present invention, the step g) of counting a number of persons that gathered for attending at the public happening within the area of interest having the AoI radius *Ra* equal to the optimum radius value *Ro* further comprises for each user equipment *UEj* of the UE list *uLn:* 1) computing an average intermediate arrival time *iat* between consecutive event records er_i, $er_{i'}$ associated with the user equipment *UEj.*

[0030] In one embodiment of the present invention, the average intermediate arrival time *iat* is computed on the basis of event records er_i, $er_{i'}$ occurred on both the day *gn* and on the previous days *gpn.*

[0031] In one embodiment of the present invention, the step g) of counting a number of persons that gathered for attending at the public happening *Sn* within the area of interest having the Area of Interest radius *Ra* equal to the optimum radius value *Ro* further comprises for each user equipment *UEj* of the UE list *uLn:* m) identifying a first time data tdn_f and last time data tdn_l referred to a first event record er_f and a last event record er_l, respectively, occurred in the time interval *[Tsn; Ten]* on the day *gn* within the AoI, and n) combining the first time data tdn_f, the last time data tdn_l and the average intermediate arrival time *iat* in order to determine a first time fraction *f1*, indicating a time period that the user equipment *UEj* has spent within the AoI on the day *gn* during the time interval *[Tsn; Ten].*

[0032] In one embodiment of the present invention, the first time fraction *f1* is determined as:

$$f1 = \frac{|tdn_f - tdn_1 + iat|}{Ten - Tsn},$$

where tdn_1 is the first time data, tdn_f is the last time data, *iat* is the average intermediate arrival time, *Tsn* is the start time of the public happening and *Ten* is the end time of the public happening.

[0033] In one embodiment of the present invention, the step g) of counting a number of persons that gathered for attending at the public happening *Sn* within the area of interest having the Area of Interest radius *Ra* equal to the optimum radius value *Ro* further comprises for each user equipment *UEj* of the UE list *uLn:* o) identifying a first previous time data and last previous time data referred to a first event record and a last event record, respectively, occurred in the time interval on the previous days within the Area of Interest, and p) combining the first previous time data tdn_f, the last previous time data tdn_l and the average intermediate arrival time *iat* in order to determine a second time fraction *f2*, indicating a time period that the user equipment *UEj* has spent within the Area of Interest during the previous days *gpn.*

[0034] In one embodiment of the present invention, the second time fraction *f2* is determined as:

$$f2 = \frac{|tdpn_1 - tdpn_1 + iat|}{Tgpn},$$

where $tdpn_1$ is the first previous time data, $tdpn_f$ is the last previous time data, *iat* is the average intermediate arrival time, and *Tgpn* is total duration of the previous days.

[0035] In one embodiment of the present invention, the step g) of counting a number of persons that gathered for attending at the public happening *Sn* within the area of interest having the Area of Interest radius *Ra* equal to the optimum radius value *Ro* further comprises for each user equipment *UEj* of the UE list *uLn:* q) combining the first time fraction *f1* and the second time fraction *f2* in order to determine a probability that the owner of the user equipment *UEj* attended at the public happening *Sn.*

[0036] In one embodiment of the present invention, the probability *pj* that the owner of the user equipment attended at the public happening is computed as:

$$pj = f1 * (1 - f2),$$

wherein *f1* is the first time fraction and *f2* is the second time fraction.

[0037] In one embodiment of the present invention, the step g) of counting a number of persons that gathered for attending at the public happening *Sn* within the area of interest having the Area of Interest radius *Ra* equal to the optimum radius value *Ro* further comprises: r) computing a persons number *An* that gathered for attending at the public happening *Sn* as the sum of probabilities *pj* determined for each user equipment *UEj* of the UE list *uLn.*

[0038] In one embodiment of the present invention, the method further comprises the step of: s) iterating steps j) to r) for each one of the public happenings *Sn.*

[0039] Another aspect of the present invention proposes a system coupled with a wireless telecommunication network for estimating a number of persons that gathered at an Area of Interest. The system comprises a computation engine adapted to process data retrieved from a mobile telephony network, a repository adapted to store data regarding interactions between the user equipment and the mobile telephony network, computation results generated by the computation engine and, possibly, any processing data generated by and/or provided to the system, and an administrator interface operable for modifying parameters and/or algorithms used by the computation engine and/or accessing data stored in the repository. The system according to the present invention further comprises a memory element storing a software program product configured for implementing the method of above through the system.

[0040] In one embodiment of the present invention, the system further comprises at least one user interface adapted to receive inputs from, and to provide output to a user of the system, the user comprising one or more human beings and/or one or more external computing systems subscriber of the services provided by the system.

[0041] One of the advantages of the solution according to the present invention is that it is computationally simple, involving just operations of counting and algebraic operations.

Brief Description of the Drawings

[0042] These and others features and advantages of the solution according to the present invention will be better understood by reading the following detailed description of an embodiment thereof, provided merely by way of non-limitative examples, to be read in conjunction with the attached drawings, wherein:

- **Figure 1** is a schematic representation of a crowd estimation system according to an embodiment of the present invention;
- **Figures 2A** - **2E** are exemplary shapes in which the cells of the mobile communication network may be modeled according to an embodiment of the present invention;
- **Figures 3A** - **3E** are exemplary shapes that the AoI to be determined may take according to an embodiment of the present invention;
- **Figures 4A** - **4D** are relevant cells among the cells of the mobile communication network 105 with respect to the AoI according to an embodiment of the invention, and
- **Figures 5A** - **5C** are a schematic flowchart of a public happenings evaluation algorithm according to an embodiment of the present invention.

Detailed Description of the Invention

[0043] With reference to the drawings, **Figure 1** is a schematic representation of a crowd estimation system, simply denoted as system **100** hereinafter, according to an exemplary embodiment of the present invention.

[0044] The crowd estimation system allows performing an estimation of a number of persons in a crowd gathered for attending at one or more public happenings, of the most disparate nature, like for example (and non-exhaustively) live television shows, artistic/entertaining performances, cultural exhibitions, theatrical plays, sports contests, concerts, movies, demonstrations and so forth.

[0045] The system **100** is coupled to a mobile communication network **105,** such as a (2G, 3G, 4G or higher generation) mobile telephony network, and is configured for receiving from the mobile communication network **105** positioning data of each User Equipment, UE in the following (*e.g.* a mobile phone, a smartphone, a tablet with 2G-3G-4G connectivity, *etc.),* of individuals located in a geographic Area of Interest, AoI in brief, schematized in **Figure 1** as the area within the dash-and-dot line **107** *(e.g.,* a building, such as for example a stadium or a theatre or a cinema, the surroundings thereof, a square or a street(s) of a city or town or village, a district *etc.).*

[0046] The AoI **107** (further described in the following) may generally comprise a core place (e.g., a stadium, a theater, a city square and so on) where one or more public happenings have taken place and, possibly, surroundings (e.g., nearby parking lots, nearby streets, nearby transport stations and so forth) of the core place.

[0047] The mobile communication network **105** comprises a plurality of (two or more) communication stations **105a** (e.g., radio base stations of the mobile telephony network) geographically distributed through the AoI **107**. Each communication station **105a** is adapted to manage communications of UE (not shown, such as for example mobile phones) in one or more served areas or cells **105b** (in the example at issue, three cells are served by each communication station **105a)** as will be discussed in greater detail below.

[0048] Even more generally, each communication station **105a** of the mobile communication network **105** is adapted to interact with any UE located within one of the cells **105b** served by such communication station **105a** (*e.g.*, interactions at power on/off, at location area update, at incoming/outgoing calls, at sending/receiving SMS and/or MMS, at Internet access *etc.).* Such interactions between UE and mobile communication network **105** will be generally denoted as events e_i (i = 1,..., I; where I is an integer) in the following.

[0049] The system **100** comprises a computation engine **110** configured to be adapted to process data retrieved from the mobile communication network **105,** and a repository **115** (such as a database, a file system, *etc.)* configured to be adapted to store data regarding interactions between the UE and the mobile communication network **105,** computation results generated by the computation engine **110** and, possibly, any processing data generated by and/or provided to the system **100** (generally in a binary format). The system **100** is provided with an administrator interface **120** *(e.g.,* a computer) configured and operable for modifying parameters and/or algorithms used by the computation engine **110** and/or accessing data stored in the repository **115.**

[0050] Preferably, the system **100** comprises one or more user interfaces **125** *(e.g.,* a user terminal, a software running on a remote terminal connected to the system **100)** adapted to receive inputs from, and to provide output to a user of the system **100.** The term "user of the system" as used in the present disclosure may refer to one or more human beings and/or to external computing systems (such as a computer network, not shown) of a third party being subscriber of the services provided by the system **100** and enabled to access the system **100** - e.g., under subscription of a contract with a service provider owner of the system **100,** and typically with reduced right of access to the system **100** compared to the right of access held by an administrator of the system **100** operating through the administrator interface **120.**

[0051] It should be appreciated that the system **100** may be implemented in any known manner; for example, the system **100** may comprise a single computer, or a network of distributed computers, either of physical type *(e.g.,* with one or more main machines implementing the computation engine **110** and the repository **115,** connected to other machines implementing administrator and user interfaces **120** and **125)** or of virtual type *(e.g.,* by implementing one or more virtual machines in a computer network).

[0052] The system **100** is adapted to retrieve (and/or receive) an event record er_i for each event e_i occurred between a UE and the mobile communication network **105** (through one of its communication stations **105a**) within the AoI **107**. Preferably, each event record er_i retrieved by the system **100** from the mobile communication network **105** comprises - in a non-limitative manner - an identifier of the UE that is involved in the corresponding event e_i (*e.g.*, the UE identifier may be selected as one or more among the International Mobile Equipment Identity - IMEI, the International Mobile Subscriber Identity - IMSI and the Mobile Subscriber ISDN Number - MSISDN code), time data (also denoted as timestamp) indicating the time at which the corresponding event e_i has occurred, and UE geographical position data, *e.g.* spatial indications based on the cell **105b** in which the UE is located at the time of occurrence of the corresponding event e_i.

[0053] In one embodiment of the present invention, the UE identifier of the UE involved in the event record er_i may be provided as encrypted information in order to ensure the privacy of the UE owner. Anyway, if the need arises, the encrypted information (*i.e.,* the identity of the owner of the UE corresponding to the UE identifier) may be decrypted by implementing a suitable decryption algorithm, such as for example the algorithm SHA256 described in "Secure Hash Standard (SHS)", National Institute of Standards and Technology FIPS - 180-4, March 06, 2012.

[0054] The system **100** may retrieve (and/or receive) the event records er_i related to a generic UE from the mobile communication network **105** by acquiring records of data generated and used in the mobile communication network **105.** For example, in case the mobile communication network **105** is a GSM network, Charging Data Records (CDR), also known as call data records, and/or Visitor Location Records (VLR) may be retrieved from the mobile communication network **105** and re-used as event records er_i. The CDR is a data record (usually used for billing purposes by a mobile telephony service provider operating through the mobile communication network **105**) that contains attributes specific to a single instance of a phone call or other communication transaction performed between a UE and the mobile communication network **105.** The VLR are databases listing UE that have roamed into the jurisdiction of a Mobile Switching Center (MSC, not shown) of the mobile communication network **105,** which is a management element of the mobile communication network **105** managing events over a plurality of communication stations **105a.** Each communication station **105a** in the mobile communication network **105** is usually associated with a respective VLR.

[0055] Conversely, if the mobile communication network **105** is a LTE network, records of data associated with the event records er_i of a generic UE are generated by a Mobility Management Entity, or MME, comprised in the mobile communication network **105,** which is responsible for a UE tracking and paging procedure in LTE networks (where no VLR is implemented).

[0056] It should be noted that the method described in the present disclosure may be implemented by using any source of data (*e.g.*, provided by one or more WiFi networks) from which it is possible to obtain event records er_i comprising a univocal identifier of individuals (such as the UE identifier mentioned above), a position indication of such individuals, and a time indication of an instant during which such event has occurred.

[0057] In operation, event records er_i may be continuously retrieved by the system **100** from the mobile communication network **105**. Alternatively, event records er_i may be collected by the system **100** periodically, *e.g.* for a predetermined time period *(e.g.,* every certain number of hours, on a daily or weekly basis). For example, event records er_i may be transferred from the mobile communication network **105** to the system **100** as they are generated, in a sort of "push" modality, or event records er_i may be collected daily in the mobile communication network **105** and then packed and transferred to the system **100** periodically or upon request by the system **100.**

[0058] The event records er_i retrieved from the mobile communication network **105** are stored in the repository **115,** where they are made available to the computation engine **110** for processing. Preferably, event records er_i generated by a same UE are grouped together in the repository **115,** *i.e.* event records er_i are grouped together if they comprise a common UE identifier and are denoted to as event records group erg_l (*e.g.*, l = 0,..., L, L ≥ 0) hereinafter.

[0059] Preferably, the computation engine **110** processes a crowd estimation algorithm (described in the following) implemented by a software program product stored in a memory element **110a** of the system **110,** comprised in the computation engine **110** in the example of **Figure 1,** even though the software program product could be stored in the repository **115** as well (or in any other memory element provided in the system **100).**

[0060] Even more preferably, the event records er_v are processed according to the event records er_i (as discussed in detail below) according to instructions provided by the system administrator (through the administrator interface **120**), for example stored in the repository **115,** and, possibly, according to instructions provided by a user (through the user interface **125**). Finally, the computation engine **110** provides the results of the processing performed on the event records er_i to the user through the user interface **125,** and optionally stores such processing results in the repository **115.**

[0061] Turning now to **Figures 2A - 2E,** they are exemplary shapes in which the cells **105b** of the mobile communication network **105** may be modeled according to an embodiment of the present invention.

[0062] For the purposes of the present invention, each cell **105b** of the mobile communication network **105** may be modeled as an area (as shown in **Figure 2A**) having a respective cell center *B* (not necessarily corresponding to a geographic position of the communication station **105a**) and a respective cell radius *Rc*, that encloses an effectively served area (not shown) served by the corresponding communication station **105a** (e.g., an area in which each point is reached by radio-signals transmitted by the communication station **105a**). Alternatively, the cell radius *Rc* may correspond to the radius of a circumference that encloses a substantial part of the effectively served area, such as the 85% or more of the effectively served area, such as for example the 90%, of the effectively served area.

[0063] It should be noted that the cells **105b** are not limited to a disc-like shape, in facts, the cells **105b** may have the shape of a, preferably regular, polygon. In this case, the cell center *B* corresponds to a center of mass (or centroid) of the polygon, while the cell radius *Rc* corresponds to a segment adjoining the center of mass of the polygon, i.e. the cell center *B*, with a vertex of the polygon (as shown in **Figures 2B** and **2D**) or with a midpoint of a side of the polygon (as shown in **Figures 2C** and **2E**).

[0064] The effectively served area, and therefore the cell radius *Rc*, may be defined by means of well-known network planning software tools used by a provider of the mobile communication network **105**, or may be computed on the basis of (omnidirectional or directional, such as with 120° radiation angles) antennas radiation diagrams and simple radiation models such as for example the ones described in Theodore S. Rappaport, "Wireless Communications", Prentice Hall, 1996.

[0065] Alternatively, the mobile communication network **105** may be modeled by means of a Voronoi tessellation diagram, in which each Voronoi cell corresponds to a **cell 105b** of the mobile communication network **105** (since Voronoi tessellation diagrams are well known in the art, they are not discussed further herein).

[0066] Preferably, the modeling, the list and the number of cells **105b** of the mobile communication network **105** are inputted to the system **100** by the administrator through the administrator interface **120.**

[0067] In the solution according to an embodiment of the present invention, the system **100** is adapted to identify whether individuals attended to one or more public happenings occurred within the AoI **107** based on events e_i generated by an interaction between the UE and the mobile communication network **105** serving such UE within the AoI **107.**

[0068] Turning now to **Figures 3A** - **3E,** they are exemplary shapes that the AoI **107** to be determined may take according to an embodiment of the present invention.

[0069] Generally, the AoI **107** for one or more public happenings may be modeled as an area having an AoI center *C* and an AoI radius *Ra*. For example, the AoI **107** may be delimited by a circumference centered in the AoI center *C* and having the AoI radius *Ra* as circumference radius (as shown in **Figure 3A**).

[0070] It should be noted that the AoI **107** may have shapes different from the circumference. For example, the AoI **107** may have the shape of a, preferably regular, polygon. In this case, the AoI center *C* corresponds to a center of mass (or centroid) of the polygon, while the AoI radius *Ra* corresponds to a segment adjoining the center of mass of the polygon with a vertex of the polygon (as shown in **Figures 3B** and **3D)** or with a midpoint of a side of the polygon (as shown in **Figures 3C** and **3E**) in a similar way as for the cells **105b** modeling discussed above.

[0071] The AoI center *C* may be set (e.g., by a user through the user interface **125** or by a system administrator through the administrator interface **120**) as a (geographical) central point of the AoI **107** (e.g., a geographical central point of the core place), as an address of the core place of the one or more public happenings, as a point provided by a mapping software, such as web mapping services (e.g., Google maps™, OpenStreetMap™, *etc*.).

[0072] As will be described in more detail in the following, the AoI radius *Ra* may take zero or negative values along with positive values. In case the AoI radius *Ra* takes zero or negative values, the AoI **107** is limited to the AoI center *C* (i.e., the core place of the one or more public happenings). The meaning of zero or negative values for the AoI radius *Ra* will be further clarified by reference to such zero or negative values in the embodiments described below.

[0073] The algorithm described in the following is configured to determine an optimum radius value *Ro* for the AoI radius *Ra* of the AoI **107**. In one embodiment of the invention, the optimum radius value *Ro* is determined by means of iterative steps starting from a minimum radius value *Rmin* to a maximum radius value *Rmax* (as described hereinbelow). Preferably, the minimum radius value *Rmin* and the maximum radius value *Rmax* are set by the administrator of the system **100** through the administrator interface **120.**

[0074] In an embodiment of the present invention, on the basis of statistical analysis of empirical data regarding a plurality of past public happenings the minimum radius value *Rmin* is set equal to -1500m (*Rmin* = -1500m), while the maximum radius value *Rmax* is set equal to 1500m (*Rmax* = 1500m).

[0075] Having defined the shape of the cell **105b** of the mobile communication network **105** and the shape of the AoI **107**, the concept of relevant cell, i.e., a cell **105b** of the mobile communication network **105** that is considered at least partially belonging to the AoI **107** according to an embodiment of the invention will be now be introduced.

[0076] **Figures 4A** - **4D** are relevant served areas or cells **405a-d** among the cells **105b** of the mobile communication network **105** with respect to the AoI **107** according to an embodiment of the invention.

[0077] In one embodiment of the invention, given the AoI **107** having the AoI center *C* and the generic **cell 105b** having the cell center *B* and the cell radius *Rc*, the generic cell **105b** may be considered a relevant cell **405a-d** for the AoI **107** if the following inequality is verified:

$$Dist(C, B) \leq |Rc + Ra|, \qquad (1)$$

where *Dist(C, B)* is the geographical distance between the AoI center *C* and the cell center *B*.

[0078] According to the value of the AoI radius *Ra* of the AoI **107**, inequality (1) may take three different meanings.

[0079] Namely, if the AoI radius *Ra* of the AoI **107** is greater than zero (i.e., R*a* > 0), inequality (1) reduces to:

$$Dist(C, B) \leq (Rc + Ra) \qquad (2)$$

and the generic cell **105b** is considered a relevant cell (such as the case of relevant cell **405a** in **Figure 4A)** for the AoI **107** having an AoI radius *Ra* greater than zero if the area of the AoI **107** and the generic cell **105b** are at least partially superimposed (even if the AoI center *C* fall outside the generic cell **105b).**

[0080] If the AoI radius *Ra* of the AoI **107** is equal to zero (i.e., *Ra* = 0) the inequality (1) reduces to:

$$Dist(C, B) \leq Rc \qquad (3)$$

and the generic **cell 105b** is considered a relevant cell (such as the case of relevant cells **405b** and **405c** in **Figures 4B** and **4C**) for the AoI **107** having an AoI radius *Ra* equal to zero if the AoI center *C* of the AoI **107** is comprised in the generic cell **105b.**

[0081] Finally, if the AoI radius *Ra* of the AoI **107** is smaller than zero (i.e., *Ra* < 0) the generic cell **105b** is considered a relevant cell (such as the case of relevant cell **405d** in **Figure 4D**) for the AoI **107** having an AoI radius *Ra* smaller than zero if the AoI center *C* of the AoI **107** is comprised within the generic cell **105b** at a distance from the cell center *B* equal to or smaller than *Rc* - |*Ra*|.

[0082] A generic public happening *S*, apart from being held at a specific location (i.e., the AoI **107**), has a start time *Ts* and an end time *Te.* Consequently, for the purposes of the present invention the generic public happening *S* has a relevant duration equal to an observation time interval [*Ts, Te*] (i.e., a time interval that starts at the a start time *Ts* and ends at the end time *Te,* lasting for *Te* - *Ts* time units, e.g. seconds, minutes or hours).

[0083] Both the start time *Ts* and the end time *Te* may be defined so as to correspond to the official (officially announced) start and end times scheduled for that generic public happening *S*. Nevertheless, the Applicant has observed that by anticipating the start time *Ts* with respect to the official start time of the generic public happening *S* it is possible to take into account the fact that people (i.e., UE owners that attend at the generic public happening *S*) arrive at the AoI **107** before the official start time of the generic public happening *S*, which may be useful for collecting data about a trend in time of a flow of attendees arriving at the generic public happening *S*. For example, on the basis of empirical data of previous public happenings, the Applicant has found that the start time *Ts* may be usefully anticipated to 60 minutes before the official start time of the generic public happening *S* in order to take into account the trend of attendees arriving at the generic public happening *S*.

[0084] Similarly, the Applicant has observed that the end time *Te* may be delayed with respect to the official end time of the generic public happening *S* in order to take into account the fact that people leave the AoI **107** after the official end time of the generic public happening *S*, which may be useful for collecting data about a trend in time of a flow of attendees leaving the generic public happening *S*. For example, on the basis of empirical data of previous public happenings, the Applicant has found that the end time *Ts* may be usefully delayed by 30 minutes after the official end time of the generic public happening *S* in order to take into accounts the trend of attendees leaving the generic public happening *S*.

[0085] Anyway, the administrator through the administrator interface **120**, and/or the user through the user interface **125**, may set any custom start time *Ts* and end time *Te* for the generic public happening *S*. For example, the start time *Ts* and the end time *Te* may be set in order to define the observation time interval [*Ts, Te*] shorter than the effective duration of the generic public happening *S* (i.e., shorter than the duration of the whole public happening) in order to analyze a number or a variation of persons in the crowd attending at the generic public happening *S* only during a sub-portion of the whole time duration of the generic public happening *S*.

[0086] Having described the system **100**, and the time (i.e., the start time *Ts* and the end time *Te*) and spatial (i.e., the AoI center *C* and AoI radius *Ra* of the AoI **107**) characteristics of a generic public happening *S,* a crowd estimation algorithm (or crowd counting algorithm) of persons attending at one or more public happenings according to an embodiment of the present invention will be now described, by making reference to **Figures 5A** - **5C,** which are a schematic block diagram thereof.

[0087] Let N (where N is an integer number, that may be defined by the administrator through the administrator interface **120** and/or by the user through the user interface **125**) be a number of public happenings *Sn,* where *n* is a happening variable indicating which of the N public happenings is considered (i.e., $1 \leq n \leq N$), held in a same AoI **107** of which the number of persons in the respective crowd attending thereat is to be determined.

[0088] For each public happening *Sn,* an observation day *gn* during which the public happening *Sn* has been held, the start time *Tsn* and the end time *Ten* are defined. It should be noted that the start time *Tsn* and the end time *Ten* may vary from one public happening *Sn* to the other.

[0089] Moreover, for each public happening *Sn* a set of previous days *gpn* (where $1 \leq p \leq P$ and P is an integer number) preceding the observation day *gn* are considered. The number P of previous days *gpn* considered is preferably set by the administrator (through the administrator interface **120**). In an embodiment of the present invention, the administrator sets the number P of previous days *gpn* according to the storage capabilities of the repository **115** (i.e., in order to be able to store all the data regarding the P previous days *gpn*) and/or on the basis of computational capabilities of the computation engine **110** (i.e., in order to be able to process all the data regarding the P previous days *gpn*). Preferably, the administrator sets the number P of previous days *gpn* also on the basis of a statistical analysis of past public happenings of the same kind (i.e., cultural, entertaining, politics or sport shows).

[0090] The Applicant has found that by setting the number P of previous days *gpn* equal to 6 (i.e., P = 6) provides good results for most kind of public happenings (although this should not be construed as limitative for the present invention).

[0091] A first portion of the crowd estimation algorithm is configured to determine the optimum radius value *Ro* for the AoI radius *Ra* of the AoI **107** on the basis of the data regarding all the N public happening *Sn* considered.

[0092] Initially (step **502**) the AoI center *C*, the observation days *gn* and the start times *Tsn* and end times *Ten* are inputted to the system **100,** e.g. by a user through the user interface **125** or by the administrator through the administrator interface **120.**

[0093] Afterwards (step *504*), an iteration variable *k* is initialized to zero (i.e., *k* = 0), a detected number of happening variable *DSk* is initialized to zero as well (i.e., *DSk* = 0) and a calculated radius value *Rk* is initially set to the minimum radius value *Rmin* (i.e., *Rk* = *Rmin*)*.* The iteration variable *k* accounts for the number of iterations of the first portion of the algorithm, the detected number of happening variable *DSk* accounts for the number of public happenings *Sn* detected during the iterations of the first portions of the algorithm (as described in the following) and the calculated radius value *Rk* is used in determining the optimum radius value *Ro*.

[0094] Next (step **506**), the relevant cells **405a-d** for the AoI **107** having a AoI radius *Ra* equal to the calculated radius value *Rk* (*Ra* = *Rk*) are identified by means of the inequality (1) as described above.

[0095] Afterwards (step **508**), the day variable *n* is initialized, e.g. to unity (*n* = 1).

[0096] All the event records er_i referred to the observation day *gn* during an observation time interval [*Tsn, Ten*] and referred to the relevant cells **405a-d** determined at step **506** are retrieved (step **510**) from the repository **115**.

[0097] Subsequently (step **512**), a first UE number *Unk* is computed as the number of UEs corresponding to (i.e., being associated with) at least one event record er_i among the event records er_i referred to relevant cells **405a-d** that have been retrieved at previous step **506** (the first UE number *Unk* depends on the relevant cells and, therefore, on the calculated radius value *Rk*).

[0098] Similarly, all the event records er_i' referred to the previous days *gpn* during the observation time interval *[Tsn, Ten]* and having taken place within the relevant cells **405a-d** determined at step **506** are retrieved (step **514**) from the repository **115.**

[0099] Then (step **516**), it is computed a second UE number *Upnk* for each one of the previous days *gpn* as the number of UEs corresponding to at least one event record er_i' among the event records er_i' referred to relevant cells **405a-d** that have been retrieved at previous step **506** (the second UE numbers *Upnk* depends on the relevant cells and, therefore, on the calculated radius value *Rk*).

[0100] The second UE numbers *Upnk* just computed are combined (step **518**) in order to determine an average UE number μnk (with $\mu nk = \sum_{p=1}^{P} Upnk$) and a UE number standard deviation σnk (with $\sigma nk = \sqrt{\frac{\sum_{p=1}^{P}(Upnk - \mu nk)^2}{P}}$) of the UE number within the relevant cells **405a-d** during the observation time interval *[Tsn, Ten]* on the P previous days *gpn* considered.

[0101] The average UE number μnk and the UE number standard deviation σnk are combined (step **520**) with the first UE number *Unk* in order to obtain a (statistical) quantity defined z-score *Znk* (which depends on the calculated radius value Rk):

$$Znk = (Unk - \mu nk)/\sigma nk. \qquad (4)$$

[0102] The z-score *Znk just* computed is compared (step **522**) with a z-score threshold *Zth* and it is checked whether the z-score *Znk* is greater than the z-score threshold *Zth,* or:

$$Znk > Zth. \qquad (5)$$

[0103] The z-score threshold *Zth* is a value preferably defined by the administrator through the administrator interface **120** on the basis of statistical analysis of past public happenings of the same kind (e.g., cultural, entertaining, politics or sport happenings).

[0104] The Applicant has found that setting the z-score threshold *Zth* equal to 2 (i.e., *Zth* = 2) provides good results for most kind of public happenings (although this should not construed as limitative for the present invention).

[0105] In the affirmative case (exit branch **Y** of decision block **522**), i.e. the z-score *Znk* is greater than the z-score threshold *Zth* (i.e., *Znk* > *Zth*), one of the N public happenings *Sn* is detected and the detected number of happenings variable *DSk* is increased by unity (step **524;** i.e., *DSk* = *DSk* + 1) and operation proceeds at step **526** (described hereinbelow).

[0106] In the negative case (exit branch **N** of decision block **522**), i.e. the z-score *Znk* is equal to, or lower than, the z-score threshold *Zth* (i.e., *Znk* ≤ *Zth*), the happening variable *n* is increased by unity (step **526**; i.e., *n* = *n* + 1).

[0107] Then (step **528**), it is checked whether the happening variable *n* is lower than, or equal to, the number N of public happening *Sn*:

$$n \leq \mathrm{N}. \qquad (6)$$

[0108] In the affirmative case (exit branch **Y** of decision block **528**), i.e. the variable *n* is lower than, or equal to, the number N of overall public happenings *Sn* (*n* ≤ N), operation returns to step **510** for analyzing the event records er_i referred to the public happening *Sn* held on the next observation day *gn.*

[0109] In the negative case (exit branch **N** of decision block **528**), i.e. the happening variable *n* is greater than the number N of overall public happenings *Sn (n* > N; i.e., all the N public happenings *Sn* have been analyzed), the variable *k* is increased by unity (step **530;** i.e., *k* = *k* + 1) and the calculated radius value *Rk* is increased (step **532**):

$$Rk = Rmin + k\Delta, \qquad (7)$$

where Δ is an iteration width that may be defined by the administrator (e.g., Δ = 100m), thus each calculated radius value *Rk* is separated from the next calculated radius value by an iteration width Δ. It should be noted that the iteration width Δ define a maximum iteration value *kmax* for the iteration variable *k* - and, therefore, a maximum number of iterations for determining the optimum radius value Ro - as:

$$kmax = (|Rmin| + Rmax)/\Delta. \quad (8)$$

[0110] It should be noted that the iteration width Δ may be used by the system administrator to adjust a granularity (i.e., fineness) with which the optimum radius value *Ro* is determined, i.e. the smaller the iteration width Δ set by the administrator the higher the number of iterations defined by the maximum iteration value *kmax* and, thus, the finer a granularity of the crowd estimation algorithm.

[0111] In an embodiment of the present invention, since the minimum radius value *Rmin* is set to -1500m, the maximum radius value *Rmax* is set to 1500m and the iteration width Δ is set to 100m the maximum iteration value *kmax* for the iteration variable *k* results to be equal to 30 and, therefore, the maximum number of iterations for determining the optimum radius value Ro is limited to 30.

[0112] Afterwards, it is checked (step **534**) whether the calculated radius value *Rk* is lower than, or equal to, the maximum radius value *Rmax:*

$$Rk \leq Rmax. \quad (9)$$

[0113] In the affirmative case (exit branch **Y** of decision block **534**), i.e. the calculated radius value *Rk* is lower than, or equal to, the maximum radius value *Rmax* (i.e., *Rk* ≤ *Rmax*) operation returns to step **506** for starting a new iteration of the first portion of the algorithm based on the calculated radius value *Rk* just increased (at step **532**) by a further *k*-th iteration width Δ.

[0114] In the negative case (exit branch **N** of decision block **534**), i.e. the calculated radius value *Rk* is greater than the maximum radius value *Rmax* (i.e., *Rk* > *Rmax),* the optimum radius value *Ro* is computed (step **536**) as the average of the computed radius values *Rk* (with 1 ≤ *k* ≤ *kmax*) weighted by the number *DSk* of detected public happening *Sn* within the AoI **107** having the AoI radius *Ra* equal to the same computed radius values *Rk,* i.e. the detected number of happening variable *DSk,* or:

$$Ro = \frac{\sum_k Rk \cdot DSk}{\sum_k DSk}. \quad (10)$$

[0115] The steps **506** to **534** of the first portion of the crowd estimation algorithm are iterated until the calculated radius value *Rk* is greater than the maximum radius value *Rmax* (i.e., *Rk* > *Rmax),* and the optimum radius value *Ro* is computed (at step **536**).

[0116] With the computation of the optimum radius value *Ro* at step **536** the first portion of the crowd estimation algorithm ends and then a second portion of the crowd estimation algorithm starts (at step **538**, described in the following). At the end of the first portion of the crowd estimation algorithm, the AoI **107** is properly defined by the AoI center *C* and by the AoI radius *Ra* set equal to the optimum radius value *Ro* (*Ra* = *Ro*).

[0117] The second portion of the crowd estimation algorithm according to an embodiment of the present invention is configured to determine a number of persons in the crowds gathered at each one of the N public happenings *Sn* considered.

[0118] After the optimum radius value *Ro* has been computed at step **536**, a set of actually relevant cells **405a-d** is defined (step **538**) . This set includes all the cells **105b** of the mobile communication network **105** for which inequality (1) is verified when the AoI radius *Ra* is set equal to the optimum radius value *Ro*, or:

$$Dist(C, B) \leq |Rc + Ro|. \quad (11)$$

[0119] Then (step **540**), the happening variable *n* is initialized to unity (*n* = 1) anew and all the event records er_i referred to the observation day *gn* during the observation time interval [*Ts, Te*] and having taken place within the actually relevant cells **405a-d** determined at step **538** are retrieved (step **542**) from the repository **115.**

[0120] Subsequently (step **544**), a UE list *uLn* is build. The UE list *uLn* comprises an identifier of each UE associated with at least one event record er_i among the event records er_i referred to relevant cells that have been retrieved at previous step **542.**

[0121] The UE list *uLn* provides a first estimation of possible persons in the crowd attending at the public happening *Sn,* i.e. the owners of the UE comprised in the UE list *uLn.* Therefore, in a simplified embodiment of the invention, the crowd estimating algorithm may simply compute the UE list *uLn* for each one of the N overall public happenings *Sn* and provide the N resulting UE lists *uLn* to the user through the user interface **125.**

[0122] Once the UE list *uLn* has been built, a UE variable *j* is initialized to unity (i.e., *j* = 1) and a persons number *An* is initialized to zero (i.e., *An* = 0) (step **546**). The UE variable *j* is used for scanning all the users comprised in the UE list *uLn,* while the persons number *An* accounts for the number of persons in the crowd gathered for attending at the public happening *Sn* (as described in the following).

[0123] All the event records er_i' referred to a UE *UEj* recorded in each one of the previous days *gpn* during observation time interval *[Tsn, Ten]* and having taken place within any one of the cells **105b** of the mobile communication network **105** are retrieved (step **548**) from the repository **115.**

[0124] Then (step **550**), an average intermediate arrival time *iat* between consecutive event records er_i is computed for the UE *UEj.* In one embodiment of the invention, intermediate arrival times for the UE *UEj* are computed as the difference between time data (i.e., timestamps) of two consecutive event records er_i. Preferably, the average intermediate arrival time *iat* is computed on the basis of event records er_i recorded during the observation day *gn* retrieved at step **542** and the **P** previous days *gpn* retrieved at step **548.**

[0125] A first event record er_f and a last event record er_l referred to the observation day *gn* during the observation time interval *[Tsn, Ten]* and having took place within the effectively relevant cells **405a-d** determined at step **538** are identified for the UE *UEj* (step **552**) and a respective first observation time data tdn_f and last observation time data tdn_f are retrieved (step **554**) therefrom.

[0126] The first observation time data tdn_f, the last observation time data tdn_l and the average intermediate arrival time *iat* are combined (step **556**) in order to determine a first time fraction *fl* that the UE *UEj* has spent within the AoI **107** during the observation day *gn* during the observation time interval [*Tsn, Ten*]:

$$f1 = \frac{|tdn_l - tdn_f + iat|}{Ten - Tsn} \qquad (12)$$

[0127] Subsequently, a first event record er_f' and a last event record er_f' among all the event records er_i' referred to the P previous days *gpn* during the observation time interval *[Tsn, Ten]* and having took place within the effectively relevant cells **405a-d** determined at step **538** are identified for the UE *UEj* (step **558**) and a respective first previous time data $tdpn_f$ and last previous time data $tdpn_l$ are retrieved (step **560**) therefrom.

[0128] The first previous time data $tdpn_f$, the last previous time data $tdpn_l$ and the average intermediate arrival time *iat* are combined (step **562**) in order to determine a second time fraction *f2* that the UE *UEj* has spent within the AoI **107** during the P previous day *gpn*:

$$f2 = \frac{|tdpn_l - tdpn_f + iat|}{Tgpn}, \qquad (13)$$

where *Tgpn* is total duration of the P previous days *gpn,* which may be computed for example in seconds, minutes or hours according to the time unit (i.e., seconds, minutes or hours) used for time quantities (such as for example the first previous time data $tdpn_f$, the last previous time data $tdpn_l$ and the average intermediate arrival time *iat*) in the crowd estimation algorithm.

[0129] Afterwards (step **564**), a person probability *pj* that the owner of the UE *UEj* attended at the public happening *Sn* is computed by combining the first time fraction *f1* and the second time fraction *f2*:

$$pj = f1 * (1 - f2). \qquad (14)$$

[0130] Therefore, the first time fraction *f1* and the second time fraction *f2* may be considered as probabilities. Namely, the first time fraction *f1* may be construed as the probability that the owner of the UE *UEj* has been in the AoI **107** during the public happening *Sn,* while the second time fraction *f2* may be construed as the probability that the owner of the UE *UEj* has been in the AoI **107** during the previous days *gpn.*

[0131] The persons number *An* is then updated (step **566**) by adding the person probability *pj* to the actual value of the persons number *An,* or:

$$An = An + pj. \qquad (15)$$

[0132] It should be noted that the persons number *An* according to the present invention is computed as the sum of the persons probabilities *pj* referred to each respective owner of each UE *UEj* listed in the UE list *uLn.*

[0133] The UE variable *j* is increased by unity (step **568**; i.e., *j* = *j* + 1) and it is checked (step **570**) whether UE variable *j* is lower than, or equal to, a total number of listed UE J (where J is an integer number) listed in the UE list *uLn:*

$$j \leq \mathrm{J}. \qquad (16)$$

[0134] In the affirmative case (exit branch **Y** of decision block **570**), i.e. the UE variable *j* is lower than, or equal to, the number J of listed user J ($j \leq$ J), the operation returns to step **548** for analyzing the event records er_i referred to the next UE *UEj.*

[0135] In the negative case (exit branch **N** of decision block **570**), i.e. the UE variable *j* is greater than the total number of listed user J (*j* > J), the UE list *uLn* has been completely scanned. Therefore the persons number *An* referred to the public happening *Sn* held on the observation day *gn* is stored (step **572**) in the repository **115,** then the happening variable *n* is increased by unity (step **574;** i.e., *n* = *n* + 1) and it is checked (step **576**) whether the happening variable *n* is lower than, or equal to, the number N of public happenings *Sn* (in the same way as done at previous step **528**):

$$n \leq \mathrm{N}. \qquad (6)$$

[0136] In the affirmative case (exit branch **Y** of decision block **576**), i.e. the happening variable *n* is lower than, or equal to, the number N of public happenings *Sn* ($n \leq$ N), operation returns to step **542** in order to analyze the next public happening *Sn* held on the next happening day *gn.*

[0137] In the negative case (exit branch **N** of decision block **576**), i.e. the happening variable *n* is greater than the number N of overall public happenings *Sn* (*n* > N), all the N public happenings *Sn* have been analyzed and thus the crowd estimation algorithm may be terminated.

[0138] Preferably, the algorithm is terminated by providing (step **578**) the results, i.e. the N persons number *An* and, possibly, the N UE lists *uLn* and the respective first and second time fractions *f1* and *f2* for each UE of the UE lists *uLn* determined at step **544,** to the user through the user terminal **125** for inspection and/or further processing.

[0139] The steps **542** to **576** of the second portion of the crowd estimation algorithm are iterated until all the N public happenings *Sn* have been analyzed and thus the crowd estimation algorithm is terminated (at step **578**) with the provision of the results to the user through the user terminal **125.**

[0140] In summary, the crowd estimation algorithm comprises a first portion and a second portion.

[0141] In its turn, the first portion of the crowd estimation algorithm comprises two nested cycles. A first external cycle scans (steps **506** - **534**) all the computed radius values *Rk* between the minimum radius value *Rmin* and the maximum radius value *Rmax,* while a first internal cycle scans (steps **510** - **528**) scans all the N public happenings *Sn* to be analyzed. For each computed radius value *Rk* respective relevant cells **405a-d** and z-score *Znk* are determined. On the basis of such data (i.e., respective relevant cells **405a-d** and z-score *Znk*) the detected happening variable *DSk* is computed and the optimum radius value *Ro* is identified. At the end of the first portion of the crowd estimation algorithm, the AoI **107** having the optimum radius value Ro is defined.

[0142] The second portion of the algorithm comprises two nested cycles as well. A second external cycle scans (steps **542** - **576**) all the N public happening *Sn* held within the AoI **107**, while a second internal cycle scans (steps **548** - **570**) all the UE *UEj* that generated an event record er_i in at least one relevant cell **405a-d** (i.e., the AoI **107**) during the observation time interval *[Tsn, Ten]* in the observation day *gn.* For each UE *UEj* and for each one of the N public happenings *Sn,* it is determined a time spent (i.e., the first time fraction *f1*) by the UE owner within one or more of the relevant cells **405a-b** comprised within the AoI **107** having the AoI radius *Ra* equal to the optimum radius value *Ro* during the observation time interval *[Tsn, Ten]* on the observation day *gn* of the public happening *Sn* and a further time spent (i.e., the second time fraction *f2*) within the same AoI **107** during the P previous days *gpn.* On the basis of the knowledge of this times spent in the AoI **107** it is determined the probability that the owner of the UE *UEj* was a person in the crowd that attended at the public happening *Sn* and, on the basis of this probability, the number of persons in the crowd that attended at the public happening *Sn* is determined.

[0143] The crowd estimation system **100** and the crowd estimation algorithm according to an embodiment of the present invention allows *a posteriori* estimation of the number of persons in a crowd attending at one or more public happenings *Sn* in a reliable way and allows properly identifying (by determining the optimum radius value *Ro*) an effective extension of the AoI **107** associated with each of the one or more public happenings *Sn.*

Claims

1. A method, implemented by a system (100) coupled with a wireless telecommunication network (**105**), of estimating a number of persons that gathered at an Area of Interest (**107**) for attending a public happening during a time interval on a day, wherein said Area of Interest (**107**) is defined by an Area of Interest center and an Area of Interest radius and is covered by a mobile telecommunication network (**105**) having a plurality of communication stations (**105a**) each of which is adapted to manage communications of user equipment in one or more served areas (**105b**) in which the mobile telecommunication network (**105**) is subdivided, the method comprising the steps of:

    a) defining (**504, 506, 530 - 534**) a plurality of calculated radius values of the Area of Interest radius, and,

    for each calculated radius value:

    b) identifying (**510, 512**) a first number of user equipment associated with at least one event record of a corresponding event of interaction occurred between the user equipment and the mobile communication network (**105**) during the time interval on the day within the Area of Interest (**107**);
    c) identifying (**514, 516**) a second number of user equipment associated with at least one event record of a corresponding event of interaction occurred between the user equipment and the mobile communication network (**105**) during the time interval for each day of a predetermined number of previous days preceding the day within the Area of Interest (**107**);
    d) combining (**518, 520**) the first number of user equipment and the second numbers of user equipment for obtaining a statistical quantity;
    e) detecting (**522**, **524**) an occurrence of the public happening if the statistical quantity reaches a certain threshold;
    f) computing (536) an optimum radius value of the Area of Interest radius as the average of the calculated radius values within which the public happening is detected;
    g) counting (**538-578**) the number of persons, owners of user equipment, that gathered for attending at the public happening within the Area of Interest having the Area of Interest radius equal to the optimum radius values.

2. The method according to claim 1, wherein the public happening comprises a plurality of public happenings, the method further comprising the step of:

    h) iterating steps b) to e) for each one of the public happenings of the plurality of public happenings, and

    wherein the step f) of computing (**536**) an optimum radius value of the Area of Interest radius as the average of the computed radius values within which the public happening is detected, comprises:

    - computing (**536**) an optimum radius value of the Area of Interest radius as the average of the computed radius values weighted by a number of detected public happenings within the Area of Interest (**107**) having the Area of Interest radius equal to the same computed radius values, said number of detected public happenings being the sum of the public happenings determined by iterating step e).

3. The method according to claim 1 or 2, further comprising for each calculated radius value:

    i) identifying (**506**) a number of relevant served areas (**405a-d**) among the served areas (**105b**) of the mobile communication network (**105**), wherein said relevant served areas are served areas at least partially superimposed on the Area of Interest (**107**).

4. The method according to claim 3, wherein a served area (**105b**) is identified as a relevant served area (**405a-d**) if it verifies the following condition:

$$Dist(C, B) \leq |Rc + Rk|,$$

where C is the center of the Area of Interest (**107**), *B* is the center of the served area (**105b**), *Dist(C, B)* is the geographical distance between the center of the Area of Interest *C* and the center of the served area *B, Rc* is the radius of the served area, and *Rk* is the calculated radius value.

5. The method according to claim 3 or 4, wherein the step b) identifying (**510, 512**) a first number of user equipment comprises:

- identifying a user equipment of the first number of user equipment, within at least one of the relevant served areas (**405a-d**), and

wherein the step c) of identifying (**514, 516**) a second number of user equipment comprises:

- identifying a user equipment of the second number within at least one of the relevant served areas **(405a-d).**

6. The method according to any one of the preceding claims 1 to 5, wherein the step d) of combining **(518, 520)** the first number of user equipment and the second numbers of user equipment for obtaining a statistical quantity comprises:

- combining (**518**) the second UE numbers of each one of the previous days in order to determine an average UE number and a UE number standard deviation.

7. The method according to claim 6, wherein the step d) of combining **(518, 520)** the first number of user equipment and the second numbers of user equipment for obtaining a statistical quantity further comprises:

- computing the statistical quantity as:

$$Znk = (Unk - \mu nk)/\sigma nk,$$

wherein *Unk* is the first number, μnk is the average UE number and σnk is the UE number standard deviation.

8. The method according to any one of the preceding claims, wherein the plurality of calculated radius values ranges from a minimum radius value to a maximum radius value, each calculated radius value being separated from a next calculated radius value by an iteration width.

9. The method according to any one of the preceding claims, wherein the step g) of counting **(538-578)** a number of persons that gathered for attending at the public happening within the area of interest having the Area of Interest radius equal to the optimum radius value comprises:

j) identifying (**538**) a number of relevant served areas **(405a-d)** among the served areas **(105b)** comprised in the mobile communication network (**105**), wherein said relevant served areas are served areas at least partially superimposed on the Area of Interest (**107**) having the Area of Interest radius equal to the optimum radius value.

10. The method according to claim 9, wherein a served area (**105b**) is identified as a relevant served area **(405a-d)** if it verifies the following inequality:

$$Dist(C, B) \leq |Rc + Ro|,$$

where *C* is the center of the Area of Interest (**107**), *B* is the center of the served area (**105b**), *Dist(C, B)* is the geographical distance between the center of the Area of Interest *C* and the center of the served area *B, Rc* is the radius of the served area, and *Ro* is the optimum radius value.

11. The method of any one of the preceding claims 1 to 10, wherein the step g) of counting (**538-578**) a number of persons that gathered for attending at the public happening within the area of interest having the Area of Interest radius equal to the optimum radius value further comprises:

k) building (**542,544**) a user equipment list comprising an identifier of each user equipment associated with at least one event record among the event records occurred in the time interval on the day within the AoI (**107**).

12. The method according to claim 11, wherein the step g) of counting (**538-578**) a number of persons that gathered for attending at the public happening within the area of interest having the AoI radius equal to the optimum radius value further comprises for each user equipment of the user equipment list:

1) computing (**550**) an average intermediate arrival time between consecutive event records associated with the user equipment.

13. The method according to claim 12, wherein the average intermediate arrival time is computed on the basis of event records occurred on both the day and on the previous days.

14. The method according to claim 12 or 13, wherein the step g) of counting (**538-578**) a number of persons that gathered for attending at the public happening within the area of interest having the Area of Interest radius equal to the optimum radius value further comprises for each user equipment of the user equipment list:

m) identifying (**552,554**) a first time data and last time data referred to a first event record and a last event record, respectively, occurred in the time interval on the day within the AoI (**107**), and
n) combining (**556**) the first time data, the last time data and the average intermediate arrival time in order to determine a first time fraction , indicating a time period that the user equipment has spent within the AoI (**107**) on the day during the time interval.

15. The method according to any one of the preceding claims 12 to 14, wherein the step g) of counting (**538-578**) a number of persons that gathered for attending at the public happening within the area of interest having the Area of Interest radius equal to the optimum radius value further comprises for each user equipment of the user equipment list:

o) identifying (**558,560**) a first previous time data and last previous time data referred to a first event record and a last event record, respectively, occurred in the time interval on the previous days within the Area of Interest (**107**), and
p) combining (**562**) the first previous time data, the last previous time data and the average intermediate arrival time in order to determine a second time fraction, indicating a time period that the user equipment has spent within the AoI (**107**) during the previous days.

16. The method according to claim 15, as depending on claim 14, wherein the step g) of counting (**538-578**) a number of persons that gathered for attending at the public happening within the area of interest having the Area of Interest radius equal to the optimum radius value further comprises for each user equipment of the user equipment list:

q) combining (**564**) the first time fraction and the second time fraction in order to determine a probability that the owner of the user equipment attended at the public happening.

17. The method according to claim 16, wherein the step g) of counting (**538-578**) a number of persons that gathered for attending at the public happening within the area of interest having the Area of Interest radius equal to the optimum radius value further comprises:

r) computing (**566**) a persons number that gathered for attending at the public happening as the sum of probabilities determined for each user equipment of the user equipment list.

18. The method according to claim 17, as depending on claim 2, further comprising the step of:

s) iterating (**574,576**) steps j) to r) for each one of the public happenings.

19. A system (**100**) coupled with a wireless telecommunication network (**105**) for estimating a number of persons that gathered at an Area of Interest (**107**), the system comprising:

a computation engine (**110**) adapted to process data retrieved from a mobile telephony network (**105**);
a repository (**115**) adapted to store data regarding interactions between the user equipment and the mobile telephony network, computation results generated by the computation engine and, possibly, any processing

data generated by and/or provided to the system, and
an administrator interface (**120**) operable for modifying parameters and/or algorithms used by the computation engine and/or accessing data stored in the repository,
characterized by
further comprising a memory element (**110a**) storing a software program product configured for implementing the method of any one of claims 1 to 18 through the system (**100**).

20. The system according to claim 19, further comprising at least one user interface (**125**) adapted to receive inputs from, and to provide output to a user of the system, the user comprising one or more human beings and/or one or more external computing systems subscriber of the services provided by the system.

Patentansprüche

1. Verfahren, das durch ein System (100), das mit einem drahtlosen Telekommunikationssystem (105) gekoppelt ist, umgesetzt wird und darin besteht, eine Anzahl von Personen zu schätzen, die sich in einem Interessenbereich (107) versammelt haben, um an einer öffentlichen Veranstaltung während eines Zeitintervalls an einem Tag teilzunehmen, wobei der Interessenbereich (107) durch einen Mittelpunkt des Interessenbereichs und einen Radius des Interessenbereichs definiert ist und durch ein mobiles Telekommunikationsnetzwerk (105) abgedeckt wird, das eine Mehrzahl von Kommunikationsstationen (105a) aufweist, die jeweils geeignet sind, um die Kommunikationen von Endgeräten in einem oder mehreren bedienten Bereichen (105b) zu verwalten, in den bzw. die das mobile Telekommunikationsnetzwerk (105) unterteilt ist, wobei das Verfahren folgende Schritte umfasst:

a) Definieren (504, 506, 530 bis 534) einer Mehrzahl von berechneten Radiuswerten des Radius des Interessenbereichs, und,

für jeden berechneten Radiuswert:

b) Identifizieren (510, 512) einer ersten Anzahl von Endgeräten, die mit mindestens einem Ereigniseintrag eines entsprechenden Interaktionsereignisses verknüpft sind, das zwischen den Endgeräten und dem mobilen Kommunikationsnetzwerk (105) während des Zeitintervalls an dem Tag innerhalb des Interessenbereichs (107) vorgekommen ist;
c) Identifizieren (514, 516) einer zweiten Anzahl von Endgeräten, die mit mindestens einem Ereigniseintrag eines entsprechenden Interaktionsereignisses verknüpft sind, das zwischen den Endgeräten und dem mobilen Kommunikationsnetzwerk (105) während des Zeitintervalls für jeden einer vorbestimmten Anzahl von vorhergehenden Tagen vor dem Tag innerhalb des Interessenbereichs (107) vorgekommen ist;
d) Kombinieren (518, 520) der ersten Anzahl von Endgeräten und den zweiten Anzahlen von Endgeräten zum Erzielen einer statistischen Größe;
e) Detektieren (522, 524) eines Vorkommens der öffentlichen Veranstaltung, falls die statistische Größe eine gewisse Schwelle erreicht;
f) Berechnen (536) eines optimalen Radiuswertes des Radius des Interessenbereichs als Durchschnitt der berechneten Radiuswerte, in denen die öffentliche Veranstaltung detektiert wird;
g) Zählen (538 bis 578) der Anzahl von Personen, die Endgeräte besitzen, die sich versammelt haben, um an der öffentlichen Veranstaltung innerhalb des Interessenbereichs teilzunehmen, der einen Radius des Interessenbereichs aufweist, der gleich den optimalen Radiuswerten ist.

2. Verfahren nach Anspruch 1, wobei die öffentliche Veranstaltung eine Mehrzahl von öffentlichen Veranstaltungen umfasst, wobei das Verfahren ferner folgende Schritte umfasst:

h) Iterieren der Schritte b) bis e) für jede der öffentlichen Veranstaltungen der Mehrzahl von öffentlichen Veranstaltungen, und

wobei der Schritt f) des Berechnens (536) eines optimalen Radiuswertes des Radius des Interessenbereichs als Durchschnitt der berechneten Radiuswerte, in denen die öffentliche Veranstaltung detektiert wird, Folgendes umfasst:

- Berechnen (536) eines optimalen Radiuswertes des Radius des Interessenbereichs als Durchschnitt der berechneten Radiuswerte, die mit einer Anzahl von detektierten öffentlichen Veranstaltungen in dem Interessenbereich (107), der einen Radius des Interessenbereichs aufweist, der gleich den gleichen berechneten Radiuswerten ist, gewichtet werden, wobei die Anzahl von detektierten öffentlichen Veranstaltungen die Summe der öffentlichen Veranstaltungen ist, die durch das Iterieren von Schritt e) bestimmt wird.

3. Verfahren nach Anspruch 1 oder 2, ferner umfassend für jeden berechneten Radiuswert:

i) Identifizieren (506) einer Anzahl von betreffenden bedienten Bereichen (405a bis d) unter den bedienten Bereichen (105b) des mobilen Kommunikationsnetzwerks (105), wobei die betreffenden bedienten Bereiche bediente Bereiche sind, die mindestens teilweise dem Interessenbereich (107) überlagert sind.

4. Verfahren nach Anspruch 3, wobei ein bedienter Bereich (105b) als ein betreffender bedienter Bereich (405a bis d) identifiziert wird, falls er die folgende Bedingung erfüllt:

$$\mathrm{Dist}(C, B) \leq |Rc + Rk|,$$

wobei C der Mittelpunkt des Interessenbereichs (107) ist, B der Mittelpunkt des bedienten Bereichs (105b) ist, Dist(C, B) der geografische Abstand zwischen dem Mittelpunkt des Interessenbereichs C und dem Mittelpunkt des bedienten Bereichs B ist, Rc der Radius des bedienten Bereichs ist, und Rk der berechnete Radiuswert ist.

5. Verfahren nach Anspruch 3 oder 4, wobei der Schritt b) des Identifizierens (510, 512) einer ersten Anzahl von Endgeräten Folgendes umfasst:

- Identifizieren eines Endgeräts der ersten Anzahl von Endgeräten innerhalb mindestens eines der betreffenden bedienten Bereiche (405a bis d), und

wobei der Schritt c) des Identifizierens (514, 516) einer zweiten Anzahl von Endgeräten Folgendes umfasst:

- Identifizieren eines Endgeräts der zweiten Anzahl innerhalb mindestens eines der betreffenden bedienten Bereiche (405a bis d).

6. Verfahren nach einem der vorhergehenden Ansprüche 1 bis 5, wobei der Schritt d) des Kombinierens (518, 520) der ersten Anzahl von Endgeräten und der zweiten Anzahlen von Endgeräten zum Erzielen einer statistischen Größe Folgendes umfasst:

- Kombinieren (518) der zweiten UE-Anzahlen jedes der vorhergehenden Tage, um eine durchschnittliche UE-Anzahl und eine Standardabweichung der UE-Anzahl zu bestimmen.

7. Verfahren nach Anspruch 6, wobei der Schritt d) des Kombinierens (518, 520) der ersten Anzahl von Endgeräten und der zweiten Anzahlen von Endgeräten zum Erzielen einer statistischen Größe ferner Folgendes umfasst:

- Berechnen der statistischen Größe als:

$$Znk = (Unk - \mu nk)/\sigma nk,$$

wobei Unk die erste Anzahl ist, μnk die durchschnittliche UE-Anzahl ist, und σnk die Standardabweichung der UE-Anzahl ist.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Mehrzahl von berechneten Radiuswerten von einem Mindestradiuswert bis zu einem Höchstradiuswert reicht, wobei jeder berechnete Radiuswert von einem nächsten Radiuswert durch eine Iterationsbreite getrennt ist.

9. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt g) des Zählens (538 bis 578) einer Anzahl von Personen, die sich versammelt haben, um an der öffentlichen Veranstaltung innerhalb des Interessenbereichs teilzunehmen, der einen Radius des Interessenbereichs aufweist, der gleich dem optimalen Radiuswert ist, Folgendes umfasst:

j) Identifizieren (538) einer Anzahl von betreffenden bedienten Bereichen (405a bis d) unter den bedienten Bereichen (105b), die in dem mobilen Kommunikationsnetzwerk (105) enthalten sind, wobei die betreffenden bedienten Bereiche bediente Bereiche sind, die mindestens teilweise dem Interessenbereich (107) überlagert sind, der einen Radius des Interessenbereichs aufweist, der gleich dem optimalen Radiuswert ist.

10. Verfahren nach Anspruch 9, wobei ein bedienter Bereich (105b) als ein betreffender bedienter Bereich (405a bis d) identifiziert wird, falls er die folgende Ungleichheit erfüllt:

$$\mathrm{Dist}(C,\ B) \leq |Rc + Ro|,$$

wobei C der Mittelpunkt des Interessenbereichs (107) ist, B der Mittelpunkt des bedienten Bereichs (105b) ist, Dist(C, B) der geografische Abstand zwischen dem Mittelpunkt des Interessenbereichs C und dem Mittelpunkt des bedienten Bereichs B ist, Rc der Radius des bedienten Bereichs ist, und Ro der optimale Radiuswert ist.

11. Verfahren nach einem der vorhergehenden Ansprüche 1 bis 10, wobei der Schritt g) des Zählens (538 bis 578) einer Anzahl von Personen, die sich versammelt haben, um an der öffentlichen Veranstaltung innerhalb des Interessenbereichs teilzunehmen, der einen Radius des Interessenbereichs aufweist, der gleich dem optimalen Radiuswert ist, ferner Folgendes umfasst:

k) Anlegen (542, 544) einer Endgerätliste, die eine Kennung jedes Endgeräts umfasst, das mit mindestens einem Ereigniseintrag unter den Ereigniseinträgen, die in dem Zeitintervall an dem Tag innerhalb des Interessenbereichs (107) vorgekommen sind, verknüpft ist.

12. Verfahren nach Anspruch 11, wobei der Schritt g) des Zählens (538 bis 578) einer Anzahl von Personen, die sich versammelt haben, um an der öffentlichen Veranstaltung innerhalb des Interessenbereichs teilzunehmen, der einen Radius des Interessenbereichs aufweist, der gleich dem optimalen Radiuswert ist, ferner für jedes Endgerät der Endgerätliste Folgendes umfasst:

1) Berechnen (550) einer durchschnittlichen Zwischenankunftszeit zwischen aufeinanderfolgenden Ereigniseinträgen, die mit dem Endgerät verknüpft sind.

13. Verfahren nach Anspruch 12, wobei die durchschnittliche Zwischenankunftszeit auf der Grundlage von Ereigniseinträgen berechnet wird, die sowohl an dem Tag als auch an den vorhergehenden Tagen vorgekommen sind.

14. Verfahren nach Anspruch 12 oder 13, wobei der Schritt g) des Zählens (538 bis 578) einer Anzahl von Personen, die sich versammelt haben, um an der öffentlichen Veranstaltung innerhalb des Interessenbereichs teilzunehmen, der einen Radius des Interessenbereichs aufweist, der gleich dem optimalen Radiuswert ist, für jedes Endgerät der Endgerätliste ferner Folgendes umfasst:

m) Identifizieren (552, 554) von ersten Zeitdaten und letzten Zeitdaten, die sich jeweils auf einen ersten Ereigniseintrag und einen letzten Ereigniseintrag beziehen, die in dem Zeitintervall an dem Tag innerhalb des Interessenbereichs (107) vorgekommen sind, und
n) Kombinieren (556) der ersten Zeitdaten, der letzten Zeitdaten und der durchschnittlichen Zwischenankunftszeit, um einen ersten Zeitabschnitt zu bestimmen, den einen Zeitraum angibt, den das Endgerät innerhalb des Interessenbereichs (107) an dem Tag während des Zeitintervalls verbracht hat.

15. Verfahren nach einem der vorhergehenden Ansprüche 12 bis 14, wobei der Schritt g) des Zählens (538 bis 578) einer Anzahl von Personen, die sich versammelt haben, um an der öffentlichen Veranstaltung innerhalb des Interessenbereichs teilzunehmen, der einen Radius des Interessenbereichs aufweist, der gleich dem optimalen Radiuswert ist, für jedes Endgerät der Endgerätliste ferner Folgendes umfasst:

o) Identifizieren (558, 560) erster vorheriger Zeitdaten und letzter vorheriger Zeitdaten, die sich jeweils auf einen ersten Ereigniseintrag und einen letzten Ereigniseintrag beziehen, die in dem Zeitintervall an den vorhergehenden Tagen innerhalb des Interessenbereichs (107) vorgekommen sind, und
p) Kombinieren (554) der ersten vorherigen Zeitdaten, der letzten vorherigen Zeitdaten und der durchschnittlichen Zwischenankunftszeit, um einen zweiten Zeitabschnitt zu bestimmen, den einen Zeitraum angibt, den das Endgerät innerhalb des Interessenbereichs (107) während der vorhergehenden Tage verbracht hat.

16. Verfahren nach Anspruch 15 in Abhängigkeit von Anspruch 14, wobei der Schritt g) des Zählens (538 bis 578) einer Anzahl von Personen, die sich versammelt haben, um an der öffentlichen Veranstaltung innerhalb des Interessenbereichs teilzunehmen, der einen Radius des Interessenbereichs aufweist, der gleich dem optimalen Radiuswert ist, für jedes Endgerät der Endgerätliste ferner Folgendes umfasst:

q) Kombinieren (564) des ersten Zeitabschnitts und des zweiten Zeitabschnitts, um eine Wahrscheinlichkeit zu bestimmen, dass der Besitzer des Endgeräts an der öffentlichen Veranstaltung teilgenommen hat.

17. Verfahren nach Anspruch 16, wobei der Schritt g) des Zählens (538 bis 578) einer Anzahl von Personen, die sich versammelt haben, um an der öffentlichen Veranstaltung innerhalb des Interessenbereichs teilzunehmen, der einen Radius des Interessenbereichs aufweist, der gleich dem optimalen Radiuswert ist, ferner Folgendes umfasst:

r) Berechnen (566) einer Anzahl von Personen, die sich versammelt haben, um an der öffentlichen Veranstaltung teilzunehmen, als die Summe von Wahrscheinlichkeiten, die für jedes Endgerät der Endgerätliste bestimmt wird.

18. Verfahren nach Anspruch 17 in Abhängigkeit von Anspruch 2, ferner umfassend folgenden Schritt:

s) Iterieren (574, 576) der Schritte j) bis r) für jede der öffentlichen Veranstaltungen.

19. System (100), das mit einem drahtlosen Telekommunikationsnetzwerk (105) gekoppelt ist, um eine Anzahl von Personen, die sich in einem Interessenbereich (107) versammelt haben, zu schätzen, wobei das System Folgendes umfasst:

eine Rechen-Engine (110), die geeignet ist, um Daten zu verarbeiten, die von einem mobilen Telefonnetzwerk (105) abgerufen werden;
ein Archiv (115), das geeignet ist, um Daten bezüglich Interaktionen zwischen den Endgeräten und dem mobilen Telefonnetzwerk, Rechenergebnisse, die durch die Rechen-Engine generiert werden, und möglicherweise eventuelle Verarbeitungsdaten, die durch das System generiert und/oder diesem bereitgestellt werden, zu speichern, und
eine Administratorschnittstelle (120), die betriebsfähig ist, um die Parameter und/oder Algorithmen zu verändern, die durch die Rechen-Engine verwendet werden, und/oder um auf Daten zuzugreifen, die in dem Archiv gespeichert sind;
dadurch gekennzeichnet, dass
es ferner ein Speicherelement (110a) umfasst, das ein Software-Programmprodukt speichert, das konfiguriert ist, um das Verfahren nach einem der Ansprüche 1 bis 18 durch das System (100) umzusetzen.

20. System nach Anspruch 19, ferner umfassend mindestens eine Benutzerschnittstelle (125), die geeignet ist, um Eingaben von einem Benutzer des Systems zu empfangen und diesem eine Ausgabe bereitzustellen, wobei der Benutzer einen oder mehrere Menschen und/oder ein oder mehrere externe Rechensysteme umfasst, welche die Dienste abonniert haben, die durch das System bereitgestellt werden.

Revendications

1. Procédé, mis en oeuvre par un système (100) couplé à un réseau de télécommunications sans fil (105), destiné à l'estimation d'un nombre de personnes qui se sont rassemblées dans une Zone Etudiée (107) pour assister à un événement public pendant un intervalle de temps au cours d'une journée, dans lequel ladite Zone Etudiée (107) est délimitée par un centre de Zone Etudiée et un rayon de Zone Etudiée et est couverte par un réseau de télécommunications mobiles (105) doté d'une pluralité de stations de communication (105a), dont chacune est conçue pour gérer des communications d'équipements utilisateur dans une ou plusieurs zone(s) desservie(s) (105b) en lesquelles le réseau de télécommunications mobiles (105) est subdivisé, ledit procédé comprenant les étapes consistant à :

a) définir (504, 506, 530-534) une pluralité de valeurs de rayon calculées du rayon de Zone Etudiée et,

pour chaque valeur de rayon calculée :

b) identifier (510, 512) un premier nombre d'équipements utilisateur associés à au moins un enregistrement d'événement d'un événement d'interaction correspondant qui s'est produit entre l'équipement utilisateur et le

réseau de télécommunications mobiles (105) au cours de l'intervalle de temps pendant la journée à l'intérieur de la Zone Etudiée (107),
c) identifier (514, 516) un second nombre d'équipements utilisateur associés à au moins un enregistrement d'événement d'un événement d'interaction correspondant qui s'est produit entre l'équipement utilisateur et le réseau de télécommunications mobiles (105) au cours de l'intervalle de temps pour chaque journée d'un nombre prédéfini de jours précédents qui précèdent la journée à l'intérieur de la Zone Etudiée (107),
d) combiner (518, 520) le premier nombre d'équipements utilisateur et le second nombre d'équipements utilisateur afin d'obtenir une grandeur statistique,
e) détecter (522, 524) une occurrence de l'événement public si la grandeur statistique atteint un certain seuil,
f) calculer (536) une valeur de rayon optimale du rayon de Zone Etudiée sous la forme de la moyenne des valeurs de rayon calculées à l'intérieur duquel l'événement public est détecté,
g) compter (538-578) le nombre de personnes, possesseurs d'un équipement utilisateur, qui se sont rassemblées pour assister à l'événement public à l'intérieur de la Zone Etudiée dont le rayon de Zone Etudiée est égal aux valeurs de rayon optimales.

2. Procédé selon la revendication 1, dans lequel l'événement public comprend une pluralité d'événements publics, ledit procédé comprenant en outre l'étape consistant à :

h) itérer les étapes b) à e) pour chacun des événements publics de la pluralité d'événements publics et

dans lequel l'étape f) de calcul (536) d'une valeur de rayon optimale du rayon de Zone Etudiée sous la forme de la moyenne des valeurs de rayon calculées à l'intérieur duquel l'événement public est détecté, comprend :

- le calcul (536) d'une valeur de rayon optimale du rayon de Zone Etudiée sous la forme de la moyenne des valeurs de rayon calculées pondérée par un nombre d'événements publics détectés à l'intérieur de la Zone Etudiée (107) ayant le rayon de Zone Etudiée égal aux mêmes valeurs de rayon calculées, ledit nombre d'événements publics détectés étant la somme des événements publics déterminés par itération de l'étape e).

3. Procédé selon la revendication 1 ou 2, comprenant en outre, pour chaque valeur de rayon calculée une étape consistant à :

i) identifier (506) un nombre de zones desservies concernées (405a-d) parmi les zones desservies (105b) comprises dans le réseau de télécommunications mobiles (105), dans lequel lesdites zones desservies concernées sont des zones desservies au moins partiellement superposées sur la Zone Etudiée (107).

4. Procédé selon la revendication 3, dans lequel une zone desservie (105b) est identifiée en tant que zone desservie concernée (405a-d) si elle vérifie la condition suivante :

$$Dist(C, B) \leq |Rc + Rk|,$$

où *C* est le centre de la Zone Etudiée (107), *B* est le centre de la zone desservie (105b), *Dist(C,B)* est la distance géographique qui sépare le centre de la Zone Etudiée C et le centre de la zone desservie *B, Rc* est le rayon de la zone desservie et *Rk* est la valeur de rayon calculée.

5. Procédé selon la revendication 3 ou 4, dans lequel l'étape b) d'identification (510, 512) d'un premier nombre d'équipements utilisateur comprend :

- l'identification d'un équipement utilisateur du premier nombre d'équipements utilisateur à l'intérieur d'au moins l'une des zones desservies concernées (405a-d) et

dans lequel l'étape c) d'identification (514, 516) d'un second nombre d'équipements utilisateur comprend :

- l'identification d'un équipement utilisateur du second nombre à l'intérieur d'au moins l'une des zones desservies concernées (405a-d).

6. Procédé selon l'une quelconque des revendications 1 à 5 précédentes, dans lequel l'étape d) de combinaison (518, 520) du premier nombre d'équipements utilisateur et du second nombre d'équipements utilisateur pour obtenir une grandeur statistique comprend :

- la combinaison (518) des seconds nombres d'EU de chacun des jours précédents afin de déterminer un nombre d'EU moyen et un écart type de nombres d'EU (équipements utilisateurs).

7. Procédé selon la revendication 6, dans lequel l'étape d) de combinaison (518, 520) du premier nombre d'équipements utilisateur et du second nombre d'équipements utilisateur pour obtenir une grandeur statistique comprend en outre :

- le calcul d'une grandeur statistique sous la forme de :

$$Znk = (Unk - \mu nk)/\sigma nk,$$

où *Unk* est le premier nombre, μnk est le nombre d'EU moyen et σnk est l'écart type du nombre d'EU.

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel la pluralité de valeurs de rayon calculées est comprise entre une valeur de rayon minimale et une valeur de rayon maximale, chaque valeur de rayon calculée étant séparée d'une valeur de rayon calculée suivante d'une largeur d'itération.

9. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'étape g) de comptage (538-578) d'un nombre de personnes qui se sont rassemblées pour assister à l'événement public à l'intérieur de la Zone Etudiée ayant le rayon de Zone Etudiée égal à la valeur de rayon optimale comprend :

j) l'identification (538) d'un nombre de zones desservies concernées (405a-d) parmi les zones desservies (105b) comprises dans le réseau de télécommunications mobile (105), dans lequel lesdites zones desservies concernées sont des zones desservies au moins partiellement superposées sur la Zone Etudiée (107) ayant le rayon de Zone Etudiée égal à la valeur de rayon optimale.

10. Procédé selon la revendication 9, dans lequel une zone desservie (105b) est identifiée comme étant une zone desservie concernée (405a-d) si elle vérifie l'inégalité suivante :

$$Dist(C, B) \leq |Rc + Ro|,$$

où C est le centre de la Zone Etudiée (107), *B* est le centre de la zone desservie (105b), *Dist(C,B)* est la distance géographique qui sépare le centre de la Zone Etudiée *C* et le centre de la zone desservie *B, Rc* est le rayon de la zone desservie et *Ro* est la valeur de rayon optimale.

11. Procédé selon l'une quelconque des revendications 1 à 10 précédentes, dans lequel l'étape g) de comptage (538-578) d'un nombre de personnes qui se sont rassemblées pour assister à l'événement public à l'intérieur de la Zone Etudiée ayant le rayon de Zone Etudiée égal à la valeur de rayon optimale comprend en outre :

k) l'établissement (542, 544) d'une liste d'équipements utilisateur comprenant un identifiant de chaque équipement utilisateur associé à au moins un enregistrement d'événement parmi les enregistrements d'événements qui se sont produits pendant l'intervalle de temps pendant ladite journée, à l'intérieur de la ZE (107).

12. Procédé selon la revendication 11, dans lequel l'étape g) de comptage (538-578) d'un nombre de personnes qui se sont rassemblées pour assister à l'événement public à l'intérieur de la Zone Etudiée (107) ayant le rayon de ZE égal à la valeur de rayon optimale comprend en outre, pour chaque équipement utilisateur de la liste d'équipements utilisateur :

1) le calcul (550) d'une heure d'arrivée intermédiaire moyenne entre des enregistrements d'événement consécutifs associés à l'équipement utilisateur.

13. Procédé selon la revendication 12, dans lequel l'heure d'arrivée intermédiaire moyenne est calculée sur la base d'enregistrements d'événements qui se sont produits à la fois pendant ladite journée et les jours précédents.

14. Procédé selon les revendications 12 ou 13, dans lequel l'étape g) de comptage (538-578) d'un nombre de personnes qui se sont rassemblées pour assister à l'événement public à l'intérieur de la Zone Etudiée ayant le rayon de Zone Etudiée égal à la valeur de rayon optimale comprend en outre, pour chaque équipement utilisateur de la liste d'équipements utilisateur :

m) l'identification (552, 554) des premières données de temps et des dernières données de temps auxquelles il est fait référence en tant que premier enregistrement d'événement et dernier enregistrement d'événement, respectivement qui s'est produit pendant l'intervalle de temps de ladite journée à l'intérieur de la ZE (107) et
n) la combinaison (556) des premières données de temps, des dernières données de temps et de l'heure d'arrivée intermédiaire moyenne afin de déterminer une première fraction de temps, indiquant une période de temps que l'équipement utilisateur a passé à l'intérieur de la ZE (zone étudiée) (107) au cours de ladite journée, pendant ledit intervalle de temps.

15. Procédé selon l'une quelconque des revendications 12 à 14 précédentes, dans lequel l'étape g) de comptage (538-578) d'un nombre de personnes qui se sont rassemblées pour assister à l'événement public à l'intérieur de la Zone Etudiée ayant le rayon de Zone Etudiée égal à la valeur de rayon optimale comprend en outre, pour chaque équipement utilisateur de la liste d'équipements utilisateur :

o) l'identification (558, 560) des premières données de temps précédentes et des dernières données de temps précédentes auxquelles il est fait référence en tant que premier enregistrement d'événement et dernier enregistrement d'événement, respectivement qui s'est produit pendant l'intervalle de temps les jours précédents à l'intérieur de la Zone Etudiée (107) et
p) la combinaison (562) des premières données de temps précédentes, des dernières données de temps précédentes et de l'heure d'arrivée intermédiaire moyenne afin de déterminer une seconde fraction de temps, indiquant une période de temps que l'équipement utilisateur a passé à l'intérieur de la ZE (107) au cours des jours précédents.

16. Procédé selon la revendication 15, lorsqu'elle est dépendante de la revendication 14, dans lequel l'étape g) de comptage (538-578) d'un nombre de personnes qui se sont rassemblées pour assister à l'événement public à l'intérieur de la Zone Etudiée ayant le rayon de Zone Etudiée égal à la valeur de rayon optimale comprend en outre, pour chaque équipement utilisateur de la liste d'équipements utilisateur :

q) la combinaison (564) de la première fraction de temps et de la seconde fraction de temps afin de déterminer une probabilité que le possesseur de l'équipement utilisateur a assisté à l'événement public.

17. Procédé selon la revendication 16, dans lequel l'étape g) de comptage (538-578) d'un nombre de personnes qui se sont rassemblées pour assister à l'événement public à l'intérieur de la Zone Etudiée ayant le rayon de Zone Etudiée égal à la valeur de rayon optimale comprend en outre :

r) le calcul (566) d'un nombre de personnes qui se sont rassemblées pour assister à l'événement public sous la forme de la somme des probabilités déterminée pour chaque équipement utilisateur de la liste des équipements utilisateur.

18. Procédé selon la revendication 17, lorsqu'elle est dépendante de la revendication 2, comprenant en outre l'étape consistant à :

s) itérer (574, 576) les étapes j) à r) pour chacun des événements publics.

19. Système (100) couplé à un réseau de télécommunications sans fil (105) destiné à l'estimation d'un nombre de personnes qui se sont rassemblées dans une Zone Etudiée (107), ledit système comprenant :

un moteur de calcul (110) conçu pour traiter des données extraites d'un réseau de téléphonie mobile (105),
un référentiel (115) conçu pour stocker des données relatives à des interactions entre l'équipement utilisateur et le réseau de téléphonie mobile, les résultats de calcul générés par le moteur de calcul et, éventuellement, toutes les données de traitement générées par le système et/ou fournies à celui-ci et
une interface administrateur (120) qui peut fonctionner pour modifier des paramètres et/ou des algorithmes utilisés par le moteur de calcul et/ou accéder à des données stockées dans le référentiel,
caractérisé en ce qu'il comprend en outre un élément de mémoire (110a) qui stocke un produit informatique logiciel configuré pour mettre en oeuvre le procédé selon l'une quelconque des revendications 1 à 18 sur

l'ensemble du système (100).

20. Système selon la revendication 19, comprenant en outre au moins une interface utilisateur (125) conçue pour recevoir des entrées envoyées par, et pour fournir des sorties à un utilisateur du système, ledit utilisateur comprenant un ou plusieurs être(s) humain(s) et/ou un ou plusieurs abonné(s) à un système de calcul externe des services proposés par le système.

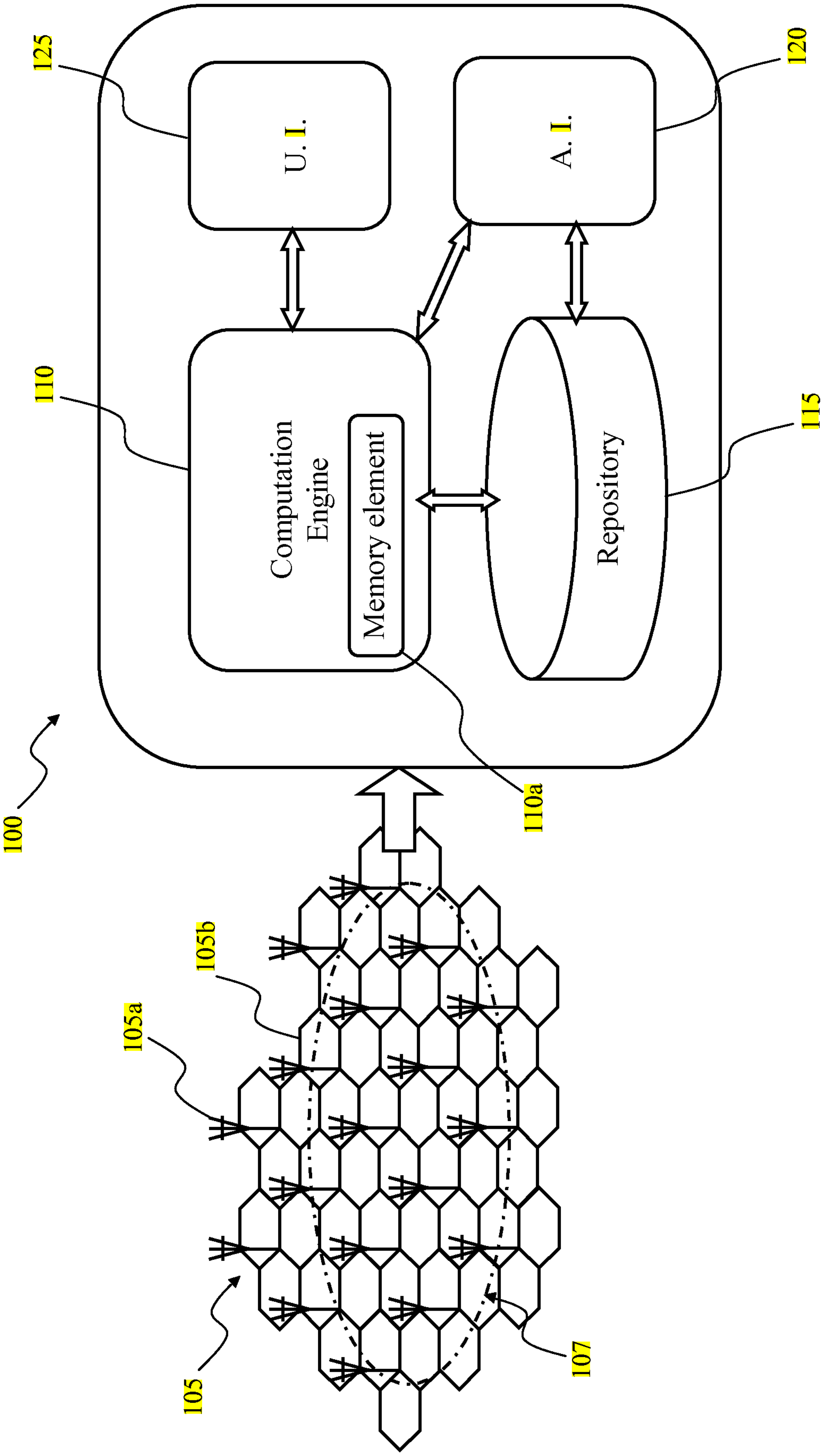

100
125
U. I.
120
A. I.
110
Computation Engine
Memory element
110a
115
Repository
105
105a
105b
107

FIG.1

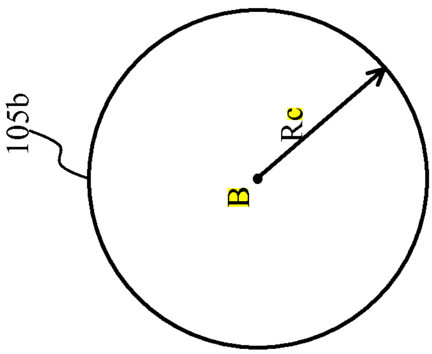


FIG.2A

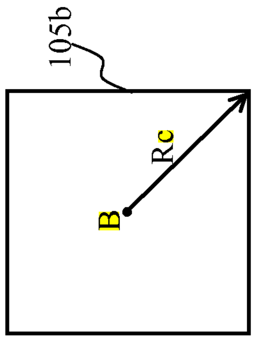


FIG.2B

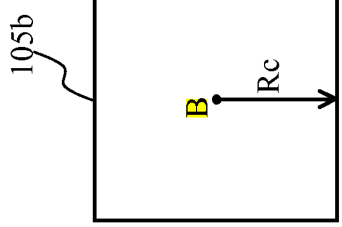


FIG.2C

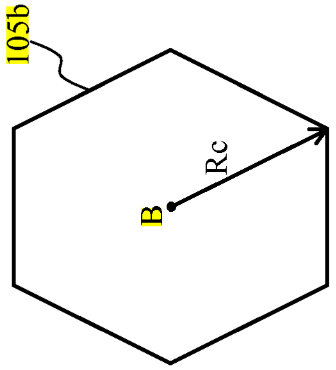


FIG.2D

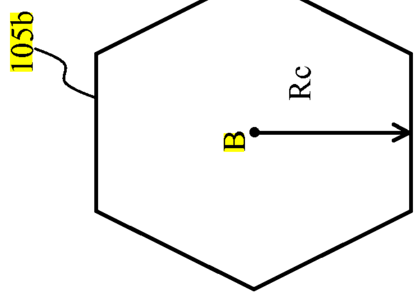


FIG.2E

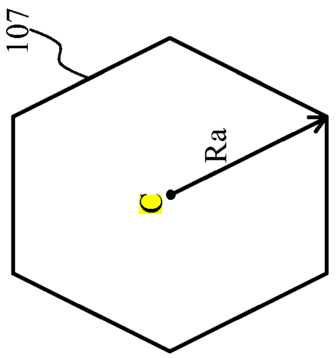


FIG.3D

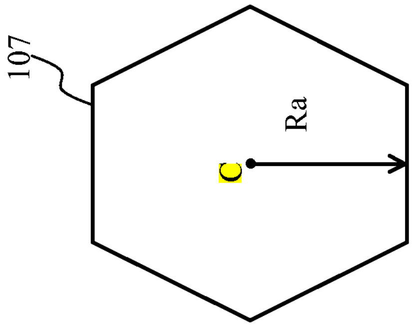


FIG.3E

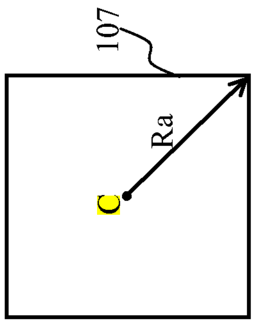


FIG.3B

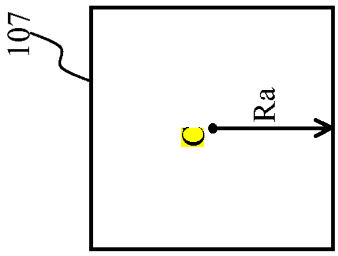


FIG.3C

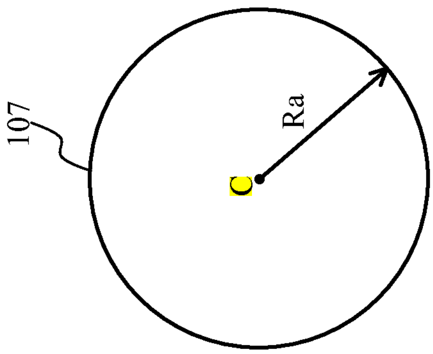


FIG.3A

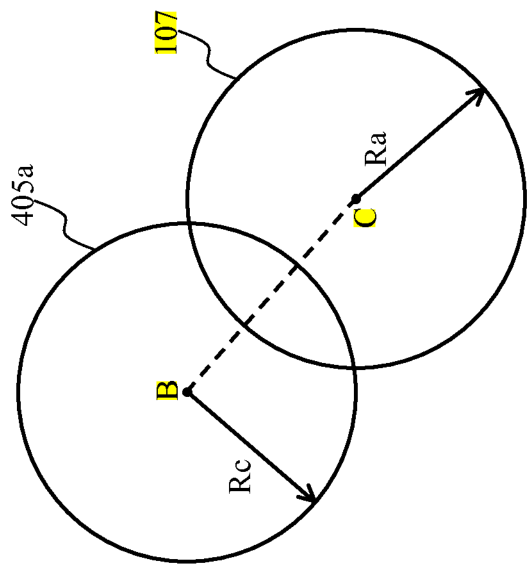


FIG.4A

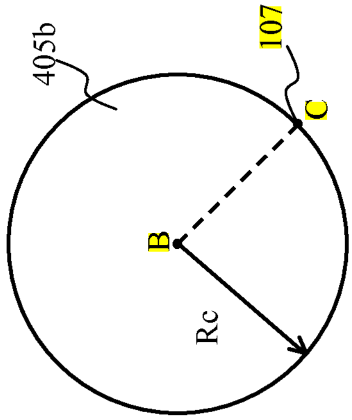


FIG.4B

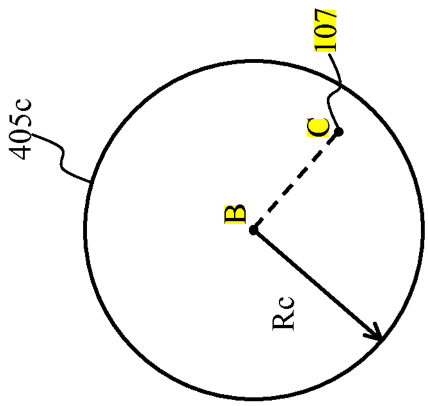


FIG.4C

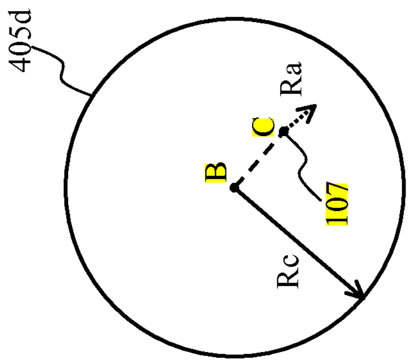
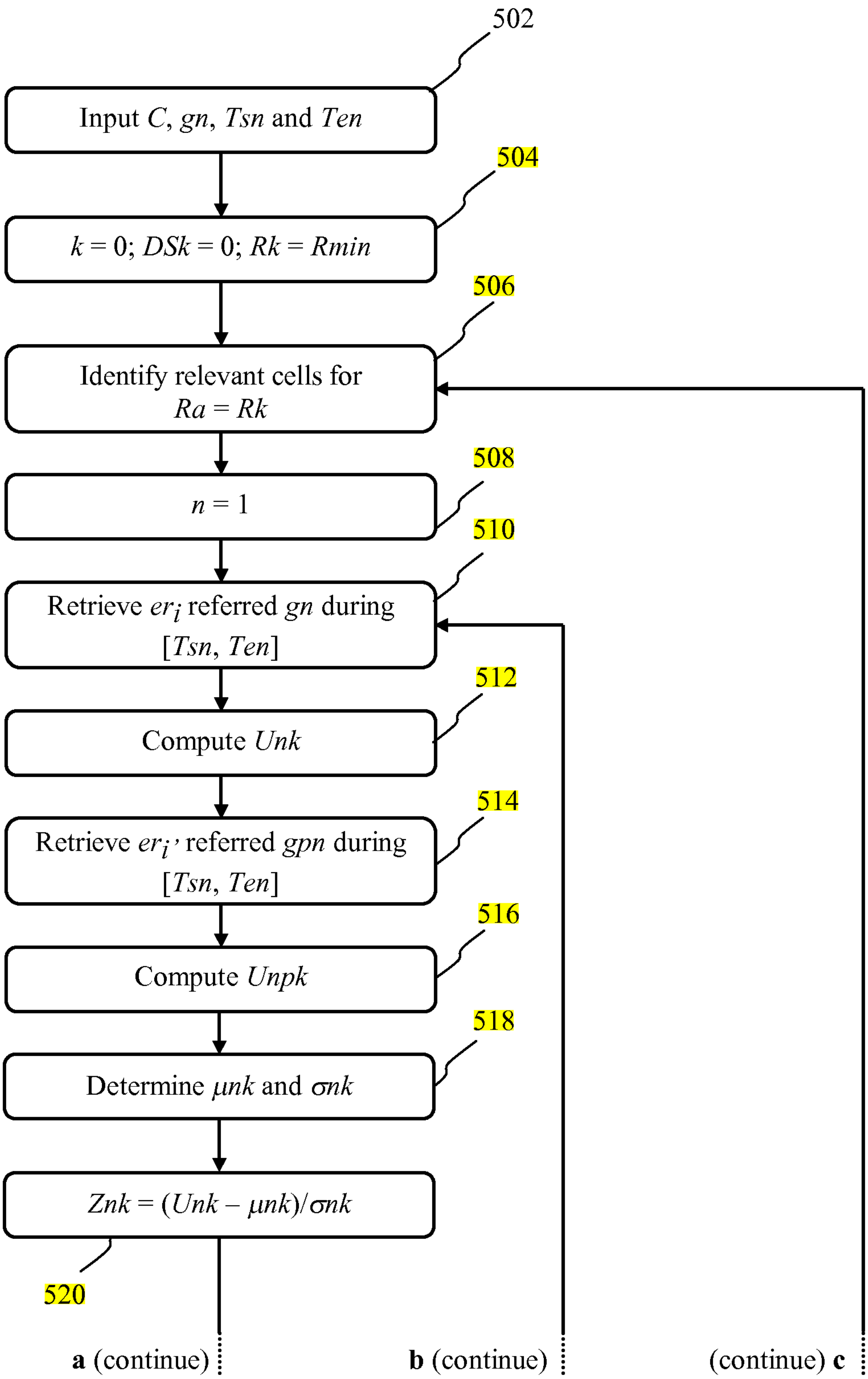


FIG.4D

FIG.5A


502
Input C, gn, Tsn and Ten
504
k = 0; DSk = 0; Rk = Rmin
506
Identify relevant cells for Ra = Rk
508
n = 1
510
Retrieve er_i referred gn during [Tsn, Ten]
512
Compute Unk
514
Retrieve er_i' referred gpn during [Tsn, Ten]
516
Compute Unpk
518
Determine μnk and σnk
Znk = (Unk – μnk)/σnk
520
a (continue)
b (continue)
(continue) c

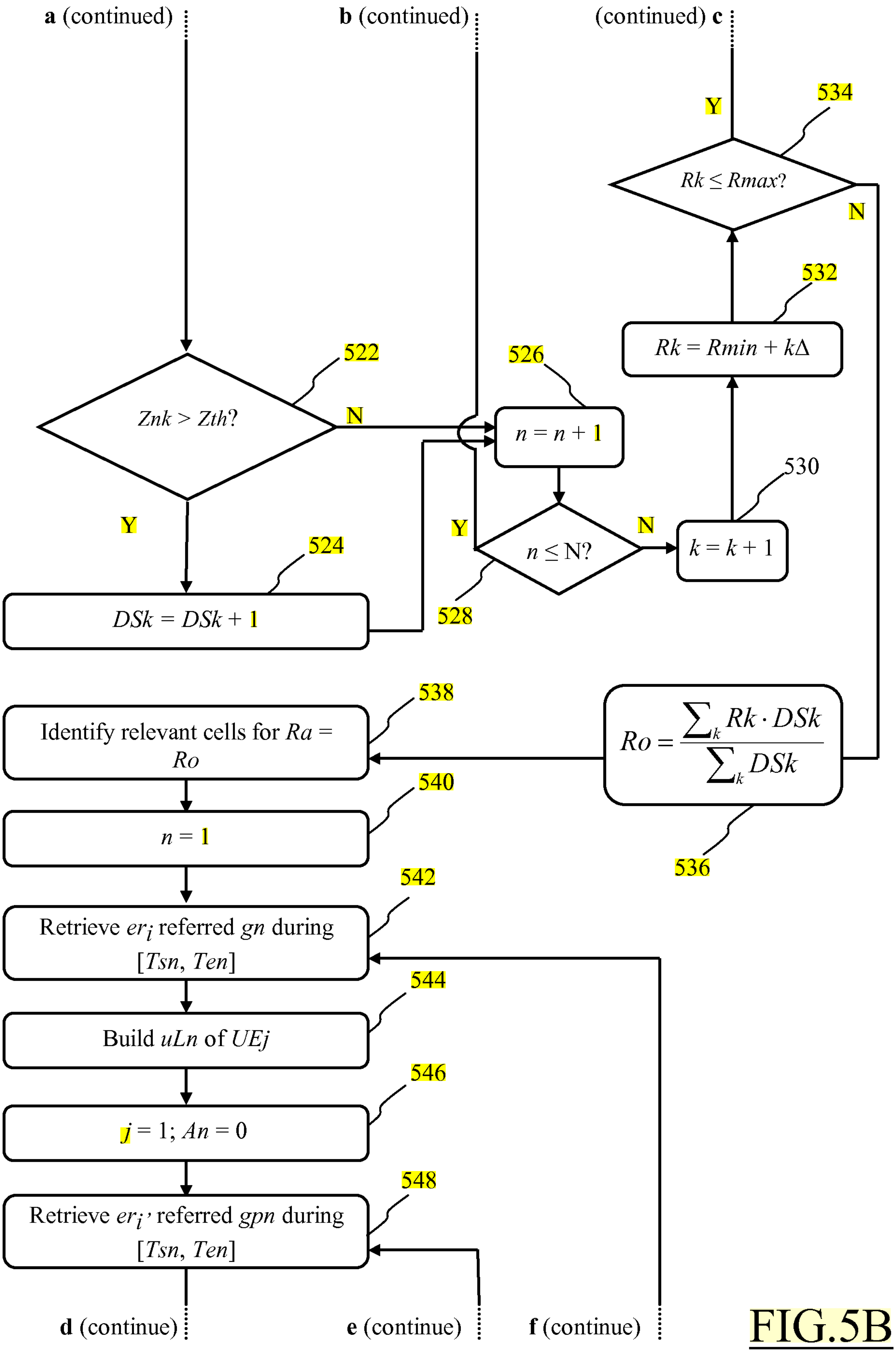

a (continued)
b (continued)
(continued) c
Y
534
Rk ≤ Rmax?
N
532
Rk = Rmin + kΔ
522
526
Znk > Zth?
N
n = n + 1
530
Y
Y
N
n ≤ N?
k = k + 1
524
528
DSk = DSk + 1
538
Identify relevant cells for Ra = Ro
$Ro = \frac{\sum_k Rk \cdot DSk}{\sum_k DSk}$
540
n = 1
536
542
Retrieve er_i referred gn during [Tsn, Ten]
544
Build uLn of UEj
546
j = 1; An = 0
548
Retrieve er_i' referred gpn during [Tsn, Ten]
d (continue)
e (continue)
f (continue)

FIG.5B

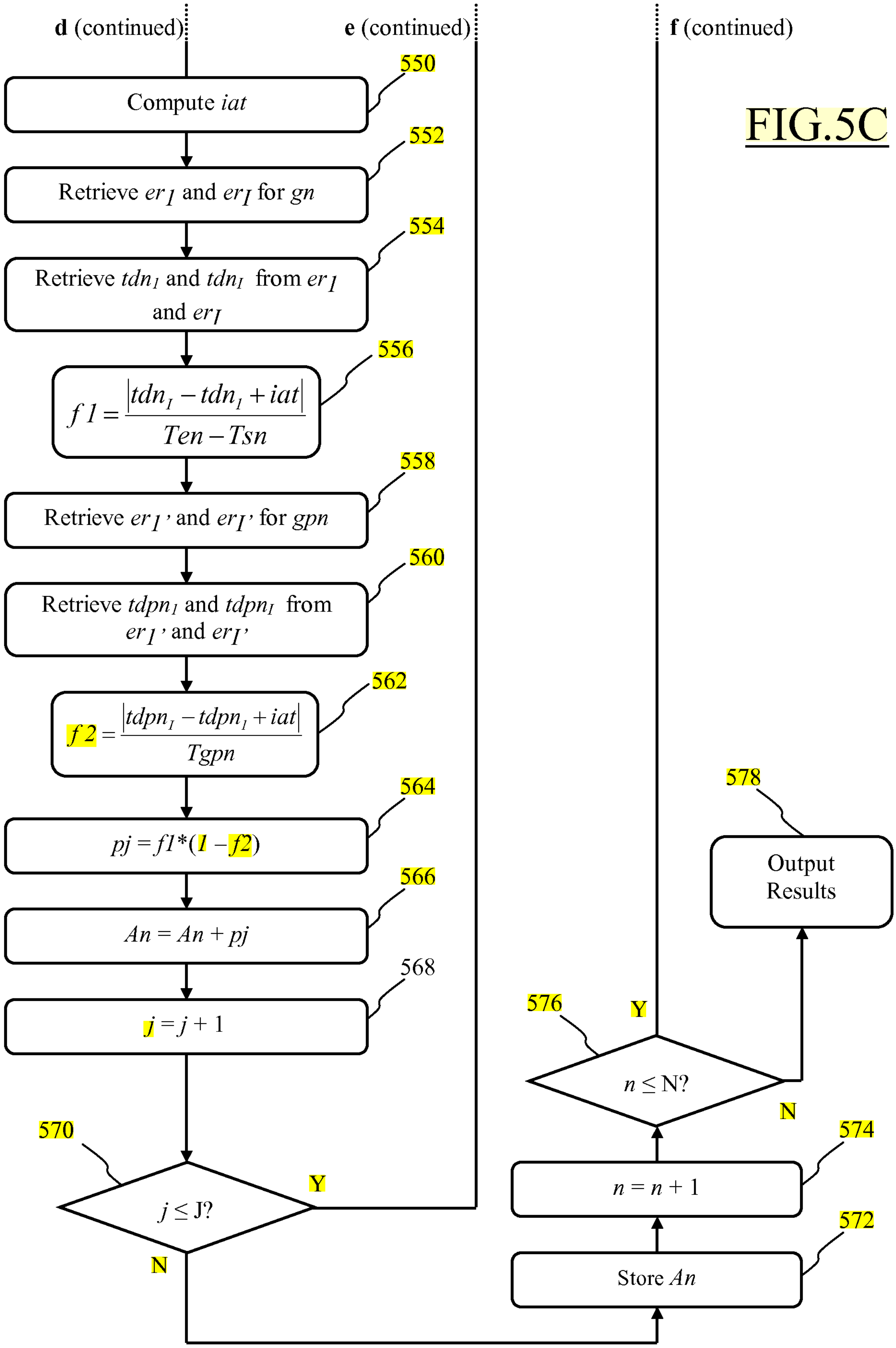

d (continued)
e (continued)
f (continued)
550
Compute iat
552
Retrieve er_I and er_J for gn
554
Retrieve tdn_I and tdn_J from er_I and er_J
556
f1 = |tdn_J − tdn_I + iat| / (Ten − Tsn)
558
Retrieve er_I' and er_J' for gpn
560
Retrieve tdpn_I and tdpn_J from er_I' and er_J'
562
f2 = |tdpn_J − tdpn_I + iat| / Tgpn
564
pj = f1*(1 − f2)
566
An = An + pj
568
j = j + 1
570
j ≤ J?
Y
N
576
Y
n ≤ N?
N
578
Output Results
574
n = n + 1
572
Store An

FIG.5C

REFERENCES CITED IN THE DESCRIPTION

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