(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 March 2003 (20.03.2003)

PCT

(10) International Publication Number
WO 03/024132 A1

(51) International Patent Classification[7]: H04Q 7/20

(21) International Application Number: PCT/US02/29385

(22) International Filing Date: 13 September 2002 (13.09.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/318,858 13 September 2001 (13.09.2001) US

(71) Applicant: **AIRSAGE, INC.** [US/US]; 441 Langley Oaks Drive, Marietta, GA 30067 (US).

(72) Inventors: **SMITH, Cyrus W.**; 441 Langley Oaks Drive, Marietta, GA 30067 (US). **WILKINSON, IV, Clayton**; 5855 Sunset Maple Drive, Alpharetta, GA 30005 (US). **CARLSON, Kirk**; 407 La Fox River Drive, Algonquin, IL 60102 (US). **WRIGHT, Michael P.**; 2511 N. Potomac Street, Arlington, VA 22201 (US). **SANGAL, Rahul**; 794 N.W. 103 Terrace, Apt. 204, Pembroke Pines, FL 33026 (US).

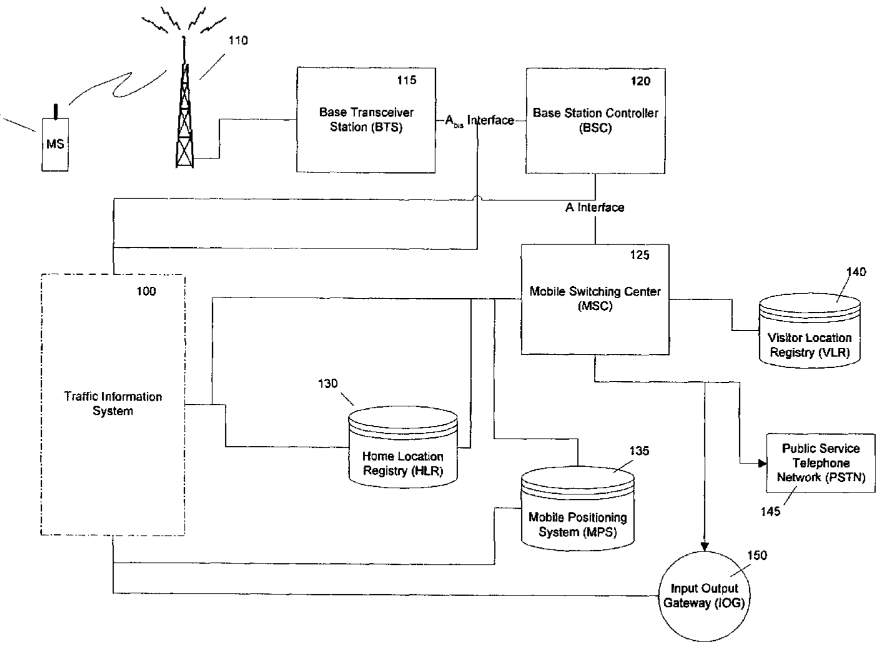
(74) Agent: **NEUFELD, Robert, T.**; 191 Peachtree Street, Atlanta, GA 30303 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR PROVIDING TRAFFIC INFORMATION USING OPERATIONAL DATA OF A WIRELESS NETWORK



(57) Abstract: Providing traffic information by using operational data developed by a wireless communication network to generate traffic information. Location information from the network can be combined with computerized street maps to measure the time it takes to get from one geographic area to another. By aggregating and analyzing anonymous data from thousands of devices, the present invention is able to determine real-time and historical travel times and velocities between cities, intersections and along specific routes.

WO 03/024132 A1

Published:
— *with international search report*

SYSTEM AND METHOD FOR PROVIDING TRAFFIC INFORMATION USING OPERATIONAL DATA OF A WIRELESS NETWORK

STATEMENT OF RELATED PATENT APPLICATIONS

This non-provisional patent application claims priority under 35 U.S.C. § 119 to U.S. Provisional Patent Application No. 60/318,858, titled *System and Method for Providing Traffic Information Using Operational Data at a Wireless Network*, filed September 13, 2001. This provisional application is hereby fully incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to a system and method for providing traffic information. More particularly, this invention relates to using operational data developed by a wireless telephony communication network to generate traffic information.

BACKGROUND OF THE INVENTION

Traffic congestion has reached crisis levels in most major cities throughout the U.S. and is becoming a major problem in smaller cities and rural areas as well. Not only is traffic congestion a source of frustration for commuters, this congestion is also costly and a significant contributor to air pollution. The Texas Transportation Institute's 2001 Urban Mobility Report estimates that the total congestion costs for 68

U.S. urban areas from New York City down to those cities with populations of 100,000 is $78 billion, which was the value of 4.5 billion hours of delay and 6.8 billion gallons of excess fuel consumed. From 1982 to 1999, the time that travelers wasted in traffic increased from 12 hours to 36 hours per year.

Research has shown that meaningful travel information can reduce commute times by 13% and demand for traffic data is growing exponentially. A recent Gallup study showed that nearly 30% of all commuters and through travelers are willing to pay $1 to $5 per use and nearly 50% of commercial vehicle operators are willing to pay $10 per month; however, the data is simply not available.

Currently, transportation agencies collect highway traffic data from radar devices, video cameras, roadside sensors, and other hardware requiring expensive field installation and maintenance. Transportation agencies currently spend more than $1 billion per year for traffic monitoring systems covering less than 10% of our national highway system. Data is delivered to a Traffic Management Center (TMC) via high-speed fiber-optic communications where it is organized, analyzed, and then delivered to the public by overhead or roadside message boards, Department of Transportation Web sites, and through partnerships with radio, television, and other media outlets. This hardware-oriented field equipment approach to collecting traffic data and providing information is costly and is practical in select urban areas only.

An emerging concept is the idea of using a Global Positioning System (GPS) device to determine a series of positions of mobile communication devises and transmit these data via a wireless network to a central computer processor. The processor can then calculate the speed and direction of the device for use in determining traffic flow. While this approach can give very accurate information for a small number of devices, any attempt to gather positioning information from a large number of devices will use up large amounts of scarce bandwidth from the wireless network and prove to be very costly. Additionally, GPS data is not available for most of the wireless networks operating today. Although some nationwide trucking companies have GPS location devices in their trucks, these vehicles represent a small fraction of the number of vehicles using the roadways.

While most wireless telephony networks do not have GPS data capabilities, they do have a vast infrastructure of communication facilities. These facilities generate data routinely to enable the system to properly function, *e.g.*, to enable cellular phone users to place and receive calls and stay connected to these calls as they move though the cell sectors of a system. Examples of these data include call detail records (CDR), handover messages, and registration messages.

In September of 1999, the FCC ordered wireless carriers to begin selling and activating phones that could be located to within 100 meters in the event of a 911 call. This requirement is referred to as Enhanced or Phase II 911. Phase II 911 is not expected to be fully implemented until 2005. This system uses GPS or signal characteristics to locate the cellular phone. Regardless of the process used, limited network capacity makes it impractical to monitor traffic using this capability as the primary source of location data.

In view of the foregoing, there is a need for a traffic information system that is capable of using existing data types generated routinely by wireless telephony communication networks that can be extracted from the wireless network's infrastructure without adversely affecting the performance of the wireless system or taxing the networks' resources.

SUMMARY OF THE INVENTION

The present invention overcomes the deficiencies of other systems and methods for providing traffic information by using operational data extracted from existing wireless telephony communication network infrastructure without adversely impacting network resources.

A wireless telephony communications network consists of base stations or cell towers that communicate with mobile phones and other wireless communications devices using licensed radio frequencies. When a mobile phone is powered on it periodically registers its location with the network so that calls can be processed without delay. Additionally, the mobile phone is in contact with the wireless network when the phone makes or receives phone calls.

The present invention uses location information from the network, combined with computerized street maps, to measure the time it takes to get from one geographic location to another. By aggregating and analyzing anonymous data from thousands of wireless communications devices, the present invention is able to determine real-time and historical travel times and velocities between cities, intersections and along specific routes.

The aspects of the present invention may be more clearly understood and appreciated from a review of the following detailed description of the disclosed embodiments and by reference to the drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts the operating environment of an exemplary embodiment of the present invention.

Figure 2a presents a block diagram showing the main components of an exemplary embodiment of the present invention.

Figure 2b presents an overall process flow diagram of an exemplary embodiment of the present invention.

Figure 3a shows the relationship between a Data Extraction Module and a Data Analysis Node in an exemplary embodiment of the present invention.

Figure 3b shows the relationship between Data Extraction Modules and a Data Analysis Node in an alternative embodiment of the present invention.

Figure 3c shows the relationship between a Data Extraction Module and Data Analysis Nodes in an alternative embodiment of the present invention.

Figure 3d shows the relationship between Data Extraction Modules and Data Analysis Nodes in an alternative embodiment of the present invention.

Figure 4 depicts a process-level block diagram of the Data Extraction Module of an exemplary embodiment of the present invention.

Figure 5 presents a block diagram of the Data Extraction Module of an exemplary embodiment of the present invention, focusing on a Data Input and Processing function.

Figure 6 presents a process flow diagram for a File Polling and Parsing Process of an exemplary embodiment of the present invention.

Figure 7 presents a process flow diagram for a Privacy Process of an exemplary embodiment of the present invention.

Figure 8 presents a process flow diagram for a Movement Filtering and Detection Process of an exemplary embodiment of the present invention.

Figure 9 presents a block diagram of a Data Extraction Module of an exemplary embodiment of the present invention, focusing on the Configuration and Monitoring function.

Figure 10 depicts a process-level block diagram of a Data Analysis Node of an exemplary embodiment of the present invention.

Figure 11 presents a process flow diagram for a Route Generation Process of an exemplary embodiment of the present invention.

Figure 12 presents a process flow diagram for a Route Processing Process of an exemplary embodiment of the present invention.

Figure 13a presents an illustrative example of a cell sector/roadway overlay.

Figure 13b presents an enhanced view of an illustrative example of a cell sector/roadway overlay.

Figure 14 presents an actual example of a cell sector/roadway overlay.

Figure 15 presents a process flow diagram for a Route Selection Process of an exemplary embodiment of the present invention.

Figure 16 presents a process flow diagram for a Route Trimming Process of an exemplary embodiment of the present invention.

Figure 17 presents a process flow diagram for a Velocity Estimation Process of an exemplary embodiment of the present invention.

Figure 18 presents a process flow diagram for a Mobile Positioning System Determination Process of an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Exemplary embodiments of the present invention provide a system and method for using operational data from existing wireless telephony communications networks to estimate traffic movement throughout a traffic system. Figure 1 presents the wireless telephony communications network operating environment for an exemplary embodiment of the present invention, the Traffic Information System **100**. Mobile station (MS) **105** transmits signals to and receives signals from the radiofrequency transmission tower **110** while within a geographic cell covered by the tower. These cells vary in size based on anticipated signal volume. A Base Transceiver System (BTS) **115** is used to provide service to mobile subscribers within its cell. Several Base Transceiver Systems are combined and controlled by a Base Station Controller (BSC) **120** through a connection called the A_{bis} Interface. The Traffic Information System **100** can interface with the A_{bis} Interface line. A Mobile

Switching Center (MSC) **125** does the complex task of coordinating all the Base Station Controllers, through the A Interface connection, keeping track of all active mobile subscribers using the Visitor Location Register (VLR) **140**, maintaining the home subscriber records using the Home Location Register (HLR) **130**, and connecting the mobile subscribers to the Public Service Telephone Network (PSTN) **145**.

In an Enhanced or Phase II 911 system, the location of a mobile station **105** can be determined by embedding a GPS chip in the mobile station **105**, or by measuring certain signaling characteristics between the mobile station **105** and the BTS **115**. In either scenario, the process of locating a mobile station **105** with the degree of accuracy needed for the Enhanced or Phase II 911 system is managed with a Mobile Positioning System (MPS) **135**. The MPS **135** uses the same network resources that are used to manage and process calls, which makes its availability somewhat limited.

The Input Output Gateway (IOG) **150** processes call detail records (CDRs) to facilitate such actions as mobile subscriber billing. The IOG **150** receives call-related data from the MSC **125** and can interface with the Traffic Information System **100**.

In the exemplary embodiment of the present invention shown in Figure 1, the Traffic Information System **100** may receive data from a variety of locations in the wireless network. These locations include the BSC **120** and its interface, through the A_{bis} Interface, with the BTS **115**, MSC **125**, the HLR **130**, and the MPS **135**.

The input communications processes monitor the wireless service provider's network elements and extract the relevant information from selected fields of selected records. The Traffic Information System **100** can use data from any network element that contains at a minimum the mobile station identifier number, cell ID and a time stamp. Some of the more common data sources are discussed below.

CDRs may be requested from billing distribution centers or the distribution centers may autonomously send the records via file transfer protocol (FTP).

Alternatively the CDRs may be extracted as they are routinely passed from the IOG **150** to a billing gateway, possibly utilizing a router that duplicates the packets. The specific method used will depend on the equipment and preferences of the wireless service provider.

Handover and Registration messages may be obtained by monitoring the proprietary or standard A-interface signaling between the MSC **125** and the BSCs **120** that it controls. The Traffic Information System **100** may monitor that signaling directly or it may obtain signaling information from a signal monitoring system such as a protocol analyzer. In the latter case the signaling information may already be filtered to remove extraneous information (see Figure 7 for a discussion of the Privacy process for the exemplary embodiment of the present invention). Alternatively, these messages may be extracted from a Base Station Manager that continuously monitors message streams on the BTS **115**.

Turning to Figure 2a, in an exemplary embodiment, an existing wireless telephony communications network **220**, otherwise referred to as a Wireless Network, exchanges information with Data Extraction Modules **240** of the Traffic Information System **100**. The Data Extraction (DEX) Modules **240** exchange information with Data Analysis Nodes (DAN) **260**, which in turn exchanges information to end users **280** of the traffic information. In an alternative embodiment of the present invention, the DEX Modules could exchange information directly with End Users **280**. In still another alternative embodiment of the present invention, a process other than DEX Module **240** may supply movement vectors to the DAN Module **260** for analysis for an end user **280**. The end users **280** may include the departments of transportation, media outlets, private transportation companies, or information service providers. Details on the types of information exchanged between the modules are discussed below.

Figure 2b presents an overview of the traffic information system process **200** for an exemplary embodiment of the present invention. The DEX Module **240** interacts with the Wireless Network **220** to extract vehicular movement information from operational data on wireless communication devices. In step **241**, the DEX Module **240** polls the Wireless Network **220** at preset time intervals to identify flat files and FTP files containing operational data, including location movement data, created by the Wireless Network **220** since the last polling. Independent of, and parallel to, this polling step, step **242** continuously receives operations data files that include location movement data from Wireless Network **220**. In step **243**, the DEX Module requests mobile station location data from the MPS on the Wireless Network **220** in response from a request from the DAN Module **260**. At step **244**, the data files received from the Wireless Network **220** are sent to parsers configured to receive each specific data file type. The parsers extract data for the Privacy and Movement Filtering and Detection modules. In step **245**, the parsed data records are sent to the Privacy module.

In step **247** of the exemplary embodiment, the Privacy module acts on the parsed data, removing any personal identifying information about the mobile station associated with the data record. The process assigns a unique serial number, or otherwise referred to as a unique identifier number, to the record, replacing the mobile station identifier number. Additionally, if the record is associated with a phone call and the number dialed is included in the parsed data record, the call is categorized. Categories may include emergency calls (911), traveler information calls (511), operator assistance calls (411), or other calls. In step **248**, the cleansed data records are sent to the Movement Filtering and Detection module.

In step **249**, the Movement Filtering and Detection module creates a movement record associated with each unique serial number contained in the data records. These movement records are then stored in a Movement Record Hashtable and serve as the output of the DEX Module **240**.

In step **246**, the Configuration and Monitoring module constantly monitors operations of the other DEX Module components. If operations are outside a preset range of expected operations, then an e-mail or other type of alert is sent to a system administrator. Also, reports on configuration and operation status can be sent to the system administrator. This administrator can also access the DEX Module **240** and modify the configuration parameters.

In this exemplary embodiment, the DAN Module **260** analyzes movement records from the DEX Module **240** to estimate traffic velocities along predetermined travel routes. In step **261**, the DAN Module **260** receives cell sector coverage maps from the Wireless Network **220** and roadway maps from the transportation department or commercial vendor. These maps are received periodically, whenever they have been updated. In step **262**, these maps are used by the DAN Configuration Module, or otherwise referred to as the analysis configuration module, to generate cell sector/roadway overlay maps. The overlay maps identify which road segments are contained in which cell sectors. From these maps, all possible traffic routes between cell sectors are identified and stored in a Route Database and the route velocities and standard deviations are initialized.

In step **263**, the Traffic Modeler receives the cell sector/roadway overlay maps from the DAN Configuration Module and movement records from the DEX Module **240**. In step **264**, the Traffic Modeler determines the traffic route traveled by individual mobile stations associated with the movement record and the velocity of the mobile station along that route. The Route Database is updated with the new route velocity information.

In step **265** (for Wireless Networks **220** with MPS capabilities), the MPS Determination module monitors the Traffic Modeler. The MPS Determination module evaluates the statistical quality of the data used by the Traffic Modeler. If the Traffic Modeler velocity estimates are based on a number of data records less than a threshold value needed to meet statistical quality requirements, then the MPS Determination module requests mobile station location data from the MPS on the Wireless Network **220** through the DEX Module **240**. These data are then processed as any other data in the DEX Module **240**.

Figure 3 presents alternative embodiments of the relationship between the Data Extraction Module **240** and Data Analysis Node **260**. In one embodiment **300**, shown in Figure 3a, a single Data Extraction Module **240a** may be paired with a single Data Analysis Node **260a**. As shown in an embodiment **310** in Figure 3b, multiple Data Extraction Modules **240a, b, and c** can exchange information with a single Data Analysis Node **260a**. For example, Data Extraction Modules located at different wireless network operators in a metropolitan area can exchange information with a single Data Analysis Node that processes the traffic information for the entire metropolitan area. Figure 3c depicts the alternative embodiment **320** in which a single Data Extraction Module **240a** exchange information with multiple Data Analysis Nodes **260a, b, and c**. For example, a Data Extraction Module at a wireless service provider can exchange information with Data Analysis Nodes located at unique end users. Figure 3d depicts the alternative embodiment **330** in which multiple Data Extraction Modules **240a, b, and c** exchange information with multiple Data Analysis Nodes **260a, b, and c**. For example, Data Extraction Modules at multiple wireless service providers can exchange information with Data Analysis Nodes located at unique end users.

Figure 4 presents a process-level block diagram of an exemplary DEX Module **240.** A Data Input and Processing module **442** exchanges information with the Wireless Network **220**. Data received from the Wireless Network **220** is sent through a Privacy module **444**, where personal identifying data about the network subscriber are removed. Data Input and Processing module **442** and Privacy module **444** comprise the Processor Module **441**. The cleansed data are then sent to a Movement Filtering and Detection module **446**. The In the exemplary embodiment of the present invention, this module converts the cleansed wireless network data to movement records associated with a mobile station. The movement records are sent to the Data Analysis Node **260** through a HTTP Query Interface **450**. The HTTP Query Interface **450** also sends information queries through the Data Input and Processing module **442** to the Wireless Network **220**. A Configuration and

Monitoring component **448** provides the means to monitor the performance of the Traffic Information System and set system operating parameters.

Figure 5 highlights a Data Input and Processing module **442** of the exemplary embodiment of the present invention. A Data Input and Processing module **442** exchanges data with a Wireless Network **220.** A Data Input and Processing module **442** includes file interfaces. These interfaces may be specific for a certain file type. In the exemplary embodiment depicted in Figure 5, a Data Input and Processing module **442** includes a Flat File Interface **542** and an FTP File Interface **544.** These interfaces can poll a Wireless Network **220**, each polling the network component that contains the specific file type, data files on a local storage drive (flat files) and files at an FTP server (FTP files) in this exemplary embodiment.

Additionally, a Wireless Network **220** may send a continuous stream of data to an Other Continuous File Interface **546**, *i.e.*, a Data Input and Processing module **442** does not need to poll this data source. These data are taken from a BSC **522**, MSC and VLR **524**, and HLR **526** and may include call detail records, handover messages, and registration messages. One skilled in the art will appreciate that a Data Input and Processing module **442** can be configured to collect information in whatever form a Wireless Network **220** generates.

In the exemplary embodiment, a Data Input and Processing module **442** is also capable of receiving positioning data from Wireless Network **220** that include a mobile positioning system. An MPS Interface **548** interacts directly with an MPS Gateway **528** to request specific mobile station location data, based on a request from a Data Analysis Node **260** delivered through an HTTP Query Interface **450.** The MPS Interface **548** delivers the mobile station location data directly to the Parsing Engine **550.** Details on this request are provided later in this description, in connection with Figure 18. Also discussed with respect to Figures 11-14 is the use of cell sector coverage maps **530** by the Data Analysis Nodes **260.**

The file interfaces in a Data Input and Processing module **442** send the data to a working directory. Files in the working directory cause events to be generated and sent to a Parsing Engine **550** for processing. The message contains the file name of the data file to be parsed. From this name, the most appropriate parser syntax is selected and the file is parsed. The program directory for the exemplary embodiment of the present invention contains a parser's subdirectory. Jar files containing parsers are placed in this directory. The name of the jar file must match a class name in the jar file and that class must implement the parser interface. Once implemented, the parser converts the extracted data into a format that can be used by the Privacy module **442** and Movement Filtering and Detection module **446**. When the processing of the file is complete, the file is moved to a processed directory. Upon startup of the Data Input and Processing module **442**, all the files in the processed directory are purged if they are older than a specified number of days.

Figure 6 presents details on the polling and parsing process **241** under an exemplary embodiment of the Data Input and Processing module. In step **615** of the process, Wireless Network Data **610**, or otherwise referred to as operational data, flows continuously from the network to a designated data storage location on the Traffic Information System **100** for other data formats **636**. These data files are parsed, at step **640**, based on the specific file type. Parallel to step **615**, step **620** periodically polls the Wireless Network's FTP server and local flat file storage drives for operational data. If new data files are found in decision step **625**, the files are sorted in step **627**. For example, BTS activity data is send to file storage location **632** for that data type, CDRs are sent to storage location **634** and A Interface and A_{bis} Interface data are sent to storage location **636**. One skilled in the art would appreciate that the present invention can accommodate a wide variety of file data types in this step, as evidenced by other data types **638**. If no new files are found at step **625**, the process returns to step **620** and polls the Wireless Network Data **610** at the next preset time interval.

Data files are then sent from the storage locations **632**, **634**, and **636** to the parser in step **640**. In this step, the algorithm is specific to the data type parsed. For example, a unique algorithm would be used for CDRs as compared to BTS activity data. The parsed data is then sent to a Mobile Station Data Record file **645**. Each data record in this file is read in step **650** and the data needed to support a Traffic Information System **100**, the traffic data record, otherwise referred to as raw data record, is extracted in step **655** and sent to the Privacy module in step **670**. This traffic data record contains wireless telephony communications network operational data used for assessing vehicular traffic movement. In the exemplary embodiment of the present invention, this traffic data record may include the start and end times for a call, the cell ID or specific locations for the start and end of the call, the mobile station identifier number, the number dialed, the call category, and the number of handoffs and the cell IDs and times for the handoffs. One skilled in the art would appreciate other data can be included in the raw data record.

Figure 7 presents how data is processed **247** in the Privacy module for an exemplary embodiment of the present invention. Traffic data records associated with a mobile station are received from the Data Input and Processing module in step **710**. In step **720**, the hashtable **730** is searched for the mobile station identifier number contained in the data record. Hashtable **730** contains mobile station identifier numbers matched to a unique serial number assigned to that identifier by the Privacy module. In decision step **740**, if the mobile station identifier number is not in the hashtable **730**, then a unique serial number is assigned to that mobile station identifier number and the serial number/identifier pair is stored in the hashtable **730** at step **742**. In an exemplary embodiment, the serial number is generated with the following algorithm in Table I. One skilled in the art would appreciate that a variety of techniques could be used to generate a unique alphanumeric indicator to represent the mobile station ID.

Table I

$$S = ((d * 1000) + \text{mod}(r, 100)) * (\log_{10}(n) * 10) + n$$

Where:

S	=	unique serial number
d	=	day of year (1-365)
r	=	number of restarts counter
mod	=	modulo function
n	=	number of entries in the serial number hashtable

In step **744**, the serial number associated with that identifier number is retrieved from the hashtable **730**. These steps cleanse the record of personal identifying information. In this embodiment, the Traffic Information System **100** does not associate movement records with a specific mobile station identifier number. In an alternative embodiment of the present invention, however, this cleansing step could be omitted. One possible application for this alternative embodiment is to enable the system to track a given mobile station as it moves, for example a parent tracking the location of a child with a cellular phone.

In decision step **750**, a determination is made whether the phone number dialed is part of the raw data record. If so, then step **760** categorizes the call based on the characteristics of the dialed number and the process moves to step **770**. Table II below summarizes the categorization for the exemplary embodiment.

Table II. Cellular Phone Call Categories

Dialed Number	**Category**
911	EMERGENCY_911
511,*X[1]	TRAVELER_INFO
411, 0X	OPERATOR_ASST
Others	DIALED_CALL

1. "X" is any string of dialed numbers

If the phone number is not part of the traffic data record, the process moves directly from decision step **750** to step **770**. In step **770**, the Privacy module **444** creates a Location Record. This record is passed to the Movement Filtering and Detection module **446** in step **780**. In the exemplary embodiment of the present invention, this location record may include the start and end times for a call, the cell ID or specific locations for the start and end of the call, serial number, the number dialed, the call category, registration information, whether the call was handed off or handed over, and the number of handoffs and the cell IDs and times for the handoffs. One skilled in the art would appreciate other data can be included in the Location Record.

Figure 8 depicts the Movement Filtering and Detection process **249**. As shown in Figure 8, in step **810**, the Movement Filtering and Detection module **446** receives location records from the Privacy module **444**. At step **820**, each location record is loaded. For each record, step **840** interrogates the Location Hashtable **830** and retrieves the last know location for the serial number associated with the record. In decision step **850**, the location indicated on the location record is compared to the last know location for that serial number as recorded in the Location Hashtable **830**. If the location differs, a Movement Record is generated and stored in cache in step **860**. Then, in step **870**, the Location Hashtable is updated and the movement record is recorded in the Movement Record Hashtable **880**. If the last known position is not different from the current position at step **850**, step **860** is skipped and the process moves to step **870**. This process is repeated for all location records.

Figure 9 outlines processing **246** performed by a Configuration and Monitoring module **448** in a DEX Module **240**. A Configuration and Monitoring module **448** interacts with each other module in a DEX Module **240** to assess system operations. A Configuration and Monitoring module **448** of an exemplary embodiment functions to alert a system administrator if the DEX Module **240** is functioning outside a preset operational range **916** and to allow a system administrator to set configuration parameters **916**. In the exemplary embodiment, a

System Administrator can configure the Traffic Information System **100** over an intranet or a virtual private network (VPN) by conducting configuration activity **916** using a secure connection, *e.g.*, passwords or Secure Sockets Layer (SSL) certificates. This configuration activity **916** may include the following tasks, as shown in Table III.

Table III

- setting the frequency of polling the Wireless Network **220**;
- setting the maximum time a mobile station can sit in one place before its serial number is released;
- setting the maximum amount of time that individual cached record can reside on the DEX before it is discarded;
- setting the minimum time between position requests. This is used to pace requests to the mobile positioning system of the Wireless Network **220**;
- setting the minimum time between position requests for the same MS. This setting is used to pace requests to the mobile positioning center;
- setting the locations authorized to be delivered to the DAN **260** for each event notification (*e.g.*, nothing, area, cell, edge, or position);
- authorizing the details of a dialed number to be delivered to the DAN **260** for each event notification (*e.g.*, nothing, a classification, the three-digit NPA, the six-digit office code, or the entire called number);
- authorizing the details of a number for incoming calls to be delivered to the DAN **260** for each event notification (*e.g.*, nothing, a classification, the three-digit NPA, the six-digit office code, or the entire called number); and
- Identification of the mobile stations that have given permission to release CPNI information for the application in this DAN **260**.

Additionally, the Performance Statistics Cache **914** can store statistics on system performance as defined by the system administrator. This statistics cache can result in alert and reporting activity **918** to report monitored system behavior, either containing routine information or alerting the administrator that the system is performing outside specifications. This alert and reporting activity **918** can be transmitted by way of e-mail, pagers, telephone, instant messages, or other similar alert or reporting actions. In the exemplary embodiment, the cached statistics may include the following information, as shown in Table IV.

Table IV

- number of CDRs processed;
- number of A-interface messages processed, *i.e.*, BTS interface data;
- number of cell-based position requests solicited;
- number of cell-based position requests cancelled;
- number of mobile station identifier-base position requests solicited;
- number of mobile station identifier-based position requests cancelled;
- number of solicited position requests launched;
- number of solicited position request responses received;
- number of unsolicited position request responses received;
- number of event notifications generated for each DAN **260**;
- number of event notifications delivered to each DAN **260**; and
- number of bytes delivered to each DAN **260**.

Figure 10 presents the process-level block diagram for the Data Analysis Node **260** in an exemplary embodiment. A DAN Module **260** comprises a DAN Configuration Module **1050**, a DAN Traffic Modeler **1060**, and DAN MPS

Determination module **1070**. A DAN Configuration Module **1050** receives data in the form of cell sector coverage maps **530**, from the Wireless Network **220** provider, and roadway maps **1040**, from the transportation department or a commercial vendor. These maps are used to define routes used by the Traffic Modeler **1060** to translate the cell sector ID to a physical location. How the maps are used is detailed further below, in association with Figures 11-14. These data are updated whenever the data source changes. For example, if the Wireless Network **220** changes their infrastructure resulting in a new cell sector coverage map **1030**, the new data is provided to the DAN Configuration Module **1050**.

In an exemplary embodiment, a DAN Traffic Modeler **1060** accepts movement records from a Movement Record Hashtable **880** in a DEX Module **240**. A DAN Traffic Modeler's **1060** function is to output traffic information in the form of travel velocity estimates along designated routes. This information is stored in a Route Database **1080**. A DAN Traffic Modeler **1060** develops these estimates by determining the route taken by a mobile station based on the movement records and the routes generated in a DAN Configuration Module **1050**. A DAN Traffic Modeler **1060** then chooses one route out of potential routes and uses timing data associated with the movement record to estimate the velocity along the chosen route. Potential routes are identified from the Route Database **1080** and modified, or trimmed, if necessary. Route identification and trimming are discussed in association with Figures 15 and 16, respectively.

A DAN Module **260** also augments the movement records **880** it receives from a DEX Module **240** with mobile station location data from an MPS on a Wireless Network **220**. A MPS Determination module **1070** functions to routinely evaluates the quantity and quality of the velocity estimates from the Traffic Modeler **1060** and, if needed, sends a request for specific mobile station location data through the DEX Module **240**. The MPS Determination module **1070** is used with wireless telephony communications networks that support MPS.

Figure 11 shows the route generation process **262a** in a DAN Configuration Module **1050** for an exemplary embodiment. The cell sector coverage maps are stored, by cell sector, in a database **530**. In step **1110**, a cell sector is selected from the database **530**. In step **1140**, the geographic information system database containing roadway maps **1040** is queried to determine all road segments that intersect the cell sector. The results from this query are boundary road segments **1150** associated with the cell sector , *i.e.*, road segments that cross the boundary of a cell sector, connecting a cell sector to an adjacent cell sector. The boundary road segments **1150** serve as the input for route processing **1160**, discussed below in association with Figure 12. The results from route processing return at step **1170**. The overall process is repeated for each cell sector in the database at step **1180**. As discussed in more detail below, this process generates a database of potential routes used by the Traffic Modeler **1060**. The route generation process **262** is run by a DAN Configuration Module **1050** whenever the cell sector coverage maps or the roadway maps are updated.

Figure 12 details the routing process **262b** by a DAN Configuration Module **1050** for the exemplary embodiment. In step **1210**, the routes comprising the boundary segments are stored in the Route Database **1240**. For example, a boundary segment that connects Cell Sector A with Cell Sector B is a route from Cell Sector A to Cell Sector B. These routes serve as the initial building blocks for the routes in the Route Database **1240**. In step **1215**, the intra-sector route between two boundary segments is determined. This route is the shortest path, in terms of distance, from one boundary segment to another boundary segment over existing roadways. This path is determined from a GIS database of roadways. This database will define road segments between the boundary segments. The GIS database may use one of a variety of ways to define the road segments. For example, a segment can be a stretch of road from one intersection to another or a change in road name. The present invention can use the GIS data in whatever form the database has been established.

The shortest path between boundary segments defines an inter-sector route, a route from one sector through an adjacent sector, to a third sector. Figures 13a and b depict an illustrative example of cell sectors and roadways. For illustrative purposes, the cell sectors have been defined as squares of uniform size and alignment. Figure 13a shows sixteen cell sectors, labeled "A" to "P." The dark lines indicate roadways. Figure 13b shows an enlarged image of cell sector C and the adjacent sectors. In this example, an inter-section route would be from cell sector A to cell sector D over the roadway from point **1310** to point **1330** to point **1320**. Another inter-sector route would be from cell sector A to cell sector F over the roadway from point **1310** to point **1320** to point **1340**. A third inter-sector route would be from cell sector D to cell sector F over the roadway from point **1330** to point **1320** to point **1340**.

Figure 13 depicts a simplified representation of a cell sector/roadway overlay. Figure 14 presents a more realistic depiction. The shaded polygons represent unique cell sectors. As can be seen in Figure 14, the cell sectors vary in size and the roadways within a sector can be complex.

Returning to Figure 12, step **1220** initiates a loop for each defined inter-segment traffic route developed in step **1215**. In step **1225**, the segment velocity is initialized to the posted speed limit for the segment plus or minus a variance of twenty-five percent of that posted speed limit. This initialization step is performed for each of the 168 hours in a week. In an alternative embodiment, the time increments can be set to every 15 minutes, for a total of 672 increments. One skilled in the art would appreciate that the number of time increments can be based on any time division, *e.g.*, per hour, per half-hour, per fifteen minutes, or per minute. The calculation for a per hour time division is as follows:

$$v_{s,I} = Vp_s$$
$$\mathrm{var}_{s,I} = 0.5 * Vp_s$$

Where:

I	=	the hour of the week, from 1 to 168, with the hour between 12:00 am and 1:00 am Sunday being 1
s	=	road segment s
$v_{s,I}$	=	average velocity at hour I
Vp_s	=	posted speed limit for segment s
$\mathrm{var}_{s,I}$	=	variance range of velocity at hour I for segment s, which represents the range from -25% to +25%

As stated above, the GIS database defines what comprises a segment. In the illustrative example in Figure 13, a segment may be the length of roadway from point **1310** to **1320** and another segment the length of roadway from **1320** to **1340**. The entire route from A to F would be the length of roadway defined by those two segments. In step **1230**, the route velocity is initialized to the weighted average velocity for the traffic route, weighted by the normalized length of each segment. The calculation is as follows:

$$v_{r,I} = \frac{\sum\left(v_{s,I} * \frac{d_s}{d_r}\right)}{d_r}$$

Where:

$v_{r,I}$	=	average velocity for route r for hour I
s	=	road segment s where the route r is defined by the connection of each segment
$v_{s,I}$	=	average velocity at hour I
d_s	=	distance of road segment
d_r	=	distance of route = $\sum d_s$

In step **1233**, the process initializes the variance of the traffic route velocity to plus or minus twenty-five percent of the weighted average velocity calculated at step **1230**. The calculation is as follows.

$$\text{var}_{r,I} = v_{r,I} * 0.5$$

Where:

$\text{var}_{r,I}$ = variance of velocity for route r for hour I

$v_{r,I}$ = average velocity for route r for hour I

The traffic routes and initialized velocities for those routes for each of the 168 hours in a week, the time increment in this exemplary embodiment, are stored at step **1235** in the Route Database **1080**. At step **1240**, the number of handoffs for each route is calculated. The number of handoffs is the number of times a route crosses over a cell sector boundary. For example, in Figure 13, the route from cell sector A to cell sector E would have three handoffs, one when the mobile station moves from sector A to C, one when it moves from C to F, and one when it moves from F to E. In step **1245**, the sector where the route terminates, the "to sector," and the sector where the route originates, the "from sector," together with the route ID and number of handoffs, are stored in the Route Database **1080**. The process is repeated for each inter-sector route associated with the boundary segment. The process then returns to the Route Generation process in step **1255**. This process is discussed above. The entire Route Generation process is repeated at step **1250**, and builds on prior routes, until the Route Database **1080** contains all possible routes from each cell sector to each cell sector.

Figure 15 presents the Route Selection process **264a** for an exemplary embodiment of the present invention. This process **264a** defines the traffic route for a mobile station and is performed by the Traffic Modeler **1060**. In step **1505**, movement vectors are retrieved from the DEX for a given serial number. In the exemplary embodiment of the present invention, these vectors are retrieved periodically at specified time intervals, time intervals based on the configuration of the DEX.

In Step **1510**, a polyline of the movement locations associated with the mobile station is generated. Referring to the illustrative example in Figure 13, assume that a mobile station places a call at time t_1 while in cell sector D. The call terminates at time t_2 while the mobile station is in sector G. The same mobile station a short time later, time t_3, places a call from sector M and the call terminates at time t_4 in sector O. The DEX would have developed three movement vectors, one from sector D at t_1 to sector G at t_2, one from sector G at t_2 to sector M at t_3, and one from sector M at t_3 to sector O at t_4. The polyline associated with this movement would be from D to G to M to O.

In step **1515**, the polyline is broken into start and end sector pairs. In the example presented in the previous paragraph, the start and end sector pairs would be DG, DM, DO, GM, GO, and MO. In other words, the start and finish pairs comprise the combination of all points that comprise the polyline. For each of these start and end sector pairs, step **1520** of the process queries the database for all traffic routes between that start and end sector pair. This query returns all information about the route stored in the Route Database **1525**. In the exemplary embodiment of the present invention, this information includes the route ID, the average velocity and variance of the velocity over that route for each of the 168 hours in a week, the beginning and ending sectors associated with that route, and the expected number of handoffs associated with the route.

The exemplary process analyzes each of the possible routes, as shown by the loop initiated in step **1530**. In step **1535**, the handoff score is calculated. The handoff score is an exemplary technique that evaluates how likely it is that the mobile station traveled the route being analyzed. The score is calculated as follows:

$$\text{Handoff Score} = \frac{B_H + (\omega \times H)}{1 + \Delta_h} \times \frac{1}{1 + n_R}$$

Where:

H = the number of handoffs for the given polyline

Δ_h = absolute difference between observed handoffs and expected handoffs

n_R = number of routes where $\Delta_h = 0$

B_H = base handoff score (default is 0.9)

ω = handoff weight (default is 0.01)

In step **1540**, the handoff score is compared to a cutoff value. If yes, the route is saved at step **1545**. If not, the route is discarded at step **1550**. For saved routes, the velocity over that route is calculated in step **1555** and is based on the length of the route and the beginning and ending timestamps associated with the movement vector as supplied by the Data Extraction Module. The velocity is:

$$v_r = \frac{d_r}{t_2 - t_1}$$

Where:

v_r = velocity of route

d_r = distance of route

t_2 = time of timestamp_2, the end of the movement

t_1 = time of timestamp_1, the start of the movement

In steps **1560** and **1563**, this velocity is compared to the maximum and minimum cutoffs for the velocity for that route. These cutoff values are based on velocities and variances contained in the Route Database **1080** and a preset tolerance level, in terms of the number of standard deviations used to calculate the maximum and minimum cutoff values. For example, a system with a wide tolerance may set the number of standard deviations in the acceptable range to three or four, while a system with a narrow tolerance may set the number of standard deviations to one or two. The maximum and minimum cutoff values are calculated as follows:

$$v_{\max} \leq v_{r,t_1} + \left(C_v * \sqrt{\mathrm{var}_{r,t_1}}\right)$$

Where:

$v_{\max}$ = maximum cutoff velocity

v_{r,t_1} = velocity of route at hour t_1

C_v = cutoff for velocity comparison in number of standard deviations

var_{r,t_1} = variance of velocity for route r at hour t_1

t_1 = time of timestamp_1, the start of the movement

$$v_{\min} \leq v_{r,t_1} - \left(C_v * \sqrt{\mathrm{var}_{r,t_1}}\right)$$

Where:

$v_{\min}$ = minimum cutoff velocity

v_{r,t_1} = velocity of route at hour t_1

C_v = cutoff for velocity comparison in number of standard deviations

var_{r,t_1} = variance of velocity for route r at hour t_1

t_1 = time of timestamp_1, the start of the movement

Routes with velocities that are less than the maximum cutoff velocity and greater than the minimum cutoff velocity are saved at step **1570**. Routes with velocities that exceed the maximum cutoff move to decisional step **1565** to determine if the route can be trimmed. A route can be trimmed if it is comprised of multiple segments. If the route can be trimmed, the process moves to step **1575**. If not, the route is discarded at step **1550**. The results from the route trimming process return to the route selection process **264** at step **1580**. For routes that are saved at step **1570**, the process moves to decision step **1585**. If another route must be evaluated, the process returns to step **1530**. If not, the process moves to velocity estimation at step **1590**.

Figure 16 presents the process for route trimming **264b** for an exemplary embodiment of the present invention. This process **264b** is a loop that compares the calculated route velocity with the maximum cutoff velocity for that route. The process then removes segments from the route and compares the new velocity with the cutoff velocity. In the initial calculation of velocity, the Traffic Modeler **1060** assumes that the mobile station is at the farthest end of a cell sector in relation to the end sector location and similarly that the mobile station ends at the farthest part of the ending sector in relation to the starting sector. These assumptions make the route distance the longest it possibly can be. By removing a segment at either end of the route, the route becomes shorter and the velocity calculated by the Traffic Modeler **1060** decreases (a shorter route traveled over a fixed time period yields a lower average route velocity). In the process step **1610**, the first loop (counter equal to 0, set at step **1605**) is the velocity value calculated in the route selection process (see Figure 15).

Decision step **1615** looks to determine if the route velocity is less than the maximum velocity for the route. For route velocities that are less then the maximum velocity, the process returns to the route selection process at step **1620**. For route velocities that are equal to or greater than the maximum velocity cutoff at step **1615**, the process looks at the loop counter at step **1630**. If the loop counter is even, the process looks at the beginning sector in the route. At step **1625**, the process determines if there are more than two segments comprising the route in the beginning cell sector. If so, the process removes the first segment from the route, at step **1645**. The process increments the loop counter at step **1660**. If there are not more than two segments at the beginning of the route, the process moves to decision step **1640**. If the answer to step **1640**, is loop counter odd, is yes, then the process moves to step **1650** and returns an invalid route. This step exists because the process just came from the "loop counter is even" branch, so a yes result means that the process is flawed. If the result in step **1640** is no, the process moves to step **1635**.

Step **1635** determines if there are more than two segments comprising the route in the ending cell sector. If so, then the process removes the last segment at step **1655**, increments the loop counter at step **1660** and is returned to the beginning of the process at step **1670**. The process returns to the Route Selection process when there are not more than two road segments at either the beginning sector ending sector of the route or when sufficient segments are removed so that the velocity is below the cutoff.

The Traffic Modeler **1060** estimates a velocity, based on the possible routes the mobile station followed, as indicated in Figure 17. In step **1710**, the velocity estimation process **264c** is triggered by the route selection process **264b**. In step **1720** the best route is selected from all the possible routes that survived the Route Selection process (see Figure 15). In the exemplary embodiment of the present invention, the "best" route is based on a statistical analysis of the velocities and handoff scores for each possible route. The statistical analysis results in a z score for each possible route. One skilled in the art would appreciate that a variety of statistical analyses could be performed to select the "best" route. The best route is the route with the minimum of the following expression:

$$Min\left(\left(\omega_z * z^{hour(t_1)}{}_v\right) + (\omega_h * h)\right)$$

Where:

ω_z	=	weight of z-score default is 0.3
ω_h	=	weight of handoff score default is 0.7
z	=	z-score of velocity at time t_1
h	=	handoff score
t_1	=	timestamp$_1$, the start of the movement

For the best route, the process then calculates the route velocity at step **1730.** The velocity is calculated as follows:

$$v_{r,I} = \frac{\sum\left(v_{s,I} * \frac{d_s}{d_r}\right)}{d_r}$$

Where:

$v_{r,I}$ = average velocity for route r for hour I

s = road segment s where the route r is defined by the connection of each segment

$v_{s,I}$ = average velocity at hour I

d_s = distance of road segment

d_r = distance of route = $\sum d_s$

At step **1740**, the process calculates the route velocity based on the overall route distance and time. In other words, the route velocity is the ratio of the total length of the route to the time it took the mobile station to move from the initial location to the ending location. Step **1745** begins a loop for all route segments. At step **1750**, the difference of these two velocity estimates is calculated. This difference, v_{diff}, is used in step **1760** to calculate a new segment velocity, as follows:

$$v_s^{\,0} = v_s^{hour(t_1)} + v_{diff} * \left(\frac{\mathrm{var}_s^{\,hour(t_1)}}{\sum \mathrm{var}_{seg}^{t_1}}\right)$$

Where:

$v_s^{\,0}$ = the current velocity on road segment s

$v_s^{hour(t_1)}$ = average velocity for segment s for time stamp$_1$

v_{diff} = the difference of the observed velocity and the calculated

var_s = variance of the velocity for road segment s at hour t_1

$\sum \mathrm{var}_{seg}^{t_1}$ = sum of the variances for each of the segments in route r

The difference in the two velocity estimates is a measure of the variance in the velocity and the calculation above establishes a new variance (as compared to the initialized variance from step **1225**, Figure 12) based on the calculated difference.

In step **1780** the average velocity by segment and variance is updated in the database. These values are determined by the following equations:

$$n_s^{hour(t_1)} = n_s^{hour(t_1)} + 1$$

$$v_s^{hour(t_1)} = \left(v_s^{hour(t_1)} * \frac{n_s^{hour(t_1)} - 1}{n_s^{hour(t_1)}} \right) + \left(v_s^{0} * \frac{1}{n_s^{hour(t_1)}} \right)$$

$$\mathrm{var}_s^{hour(t_1)'} = \frac{\left(\mathrm{var}_s^{hour(t_1)} * \left(n_s^{hour(t_1)} - 2\right)\right) + \left(v_s^{0} - v_s^{hour(t_1)'}\right)^2}{n_s^{hour(t_1)} - 1}$$

Where:

$n_s^{hour(t_1)}$ = number of samples for the segment s at hour t_1

$v_s^{hour(t_1)}$ = average velocity for segment s for timestamp$_1$

$\mathrm{var}_s^{hour(t_1)}$ = variance of velocity at hour t_1 for segment s

At step **1790**, the process updates the average velocity and variance for the entire route. These updates are based on the following calculation:

$$n_r^{hour(t_1)} = n_r^{hour(t_1)} + 1$$

$$v_r^{hour(t_1)} = \frac{\sum \left(v_s^{hour(t_1)} * \frac{d_s}{d_r} \right)}{d_r}$$

$$\mathrm{var}_r^{hour(t_1)} = \frac{\left(\mathrm{var}_r^{hour(t_1)} * \left(n_r^{hour(t_1)} - 2\right)\right) + \left(v_r^{0} - v_r^{hour(t_1)'}\right)^2}{n_r^{hour(t_1)} - 1}$$

Where:

s	=	road segment s where r is defined by the connection of all segments
d_s	=	distance of road segment
d_r	=	distance of route = $\sum d_s$
$n_r^{hour(t_1)}$	=	number of samples for the route r at hour t_1
$v_s^{hour(t_1)}$	=	average velocity for segment s for $timestamp_1$
$\mathrm{var}_s^{hour(t_1)}$	=	variance of velocity at hour t_1 for segment s

In the exemplary embodiment of the present invention, a separate module, the MPS Determination module **1070** of the DAN Module **260**, operates to assess the quality of the velocity estimates from the Traffic Modeler **1060**, based on the number of samples used to generate the velocity estimates. Step 1795 from the velocity estimation process **264c** serves as a gateway for the MPS Determination module **1070** polling the Traffic Modeler **1060**. Figure 18 presents the operation of the MPS Determination module **1070**. In step **1805**, the process polls the Traffic Modeler, extracting the updated segment velocity and variance data from the velocity estimation process **264c** (see Figure 17 at **1795**). Step **1810** initiates a loop for each road segment analyzed in the velocity estimation process **264c**, the MPS Determination module **1070** determines, at step **1815**, the number of samples needed for the desired level of precision and determines, at **1820**, if that level is met. The required number of samples for a given precision level is calculated as follows:

$$n = \frac{z_{\alpha/2}^2 \mathrm{var}_s^{hour(t_1)}}{E^2}$$

Where

$z_{\alpha/2}$	=	is the z-score of the confidence interval desired (e.g. 90% or z = 1.645)
$\mathrm{var}_s^{hour(t_1)}$	=	variance of the velocity of the road segment
E	=	is half the width of the range (e.g. +/- 10 MPH)

If the number of samples used in the Traffic model is equal to or greater than the target number calculated at step **1815**, then the segment is not considered further, at step **1825**. If not, the segment is added to the MPS request list at step **1835** and the loop is repeated at step **1840** for each segment. Once all the segments have been evaluated, the process, at step **1845**, retrieves from the Route Database **1830** all routes that contain the segments in the MPS request list from **1835**. At step **1850**, the process issues a request to the DEX for mobile station location data for mobile stations on traffic routes containing the listed segments. This limited use of MPS data minimizes the load on the Wireless Networks' resources, revealing a desired element of the exemplary embodiment of the present invention.

In summary, the present invention relates to a Traffic Information System **100**. An exemplary embodiment of the system comprises two main components, a DEX Module **240** and a DAN Module **260**. In this embodiment, a DEX Module **240** extracts data related to communication activity of mobile stations from an existing Wireless Network **220** with minimal impact on the operations of the Wireless Network **220**. In an exemplary embodiment, a DEX Module **240** processes that data to remove personal identifying information about the mobile station. In this procession, the traffic data record may be categorized based on the type of phone call made. These traffic data records are further processed to generate movement records associated with individual mobile stations.

In an exemplary embodiment, a DAN Module **260** combines the movement records from the DEX Module **240** with data associated with the geographic layout of cell sectors and roadways to estimate travel velocities along specific travel routes. With the data associated with the geographic layout of cell sectors and roadways, a DAN Module **260** generates maps that overly the cell sector grid onto roadway maps. These overlay maps are used to generate all possible travel routes between any two cell sectors. The DAN Module **260** may also retrieve mobile station location data from an MPS on a Wireless Network **220** to improve the statistical quality of the velocity estimates.

CLAIMS

What is claimed is:

1. A system for extracting vehicular movement information using operational data for mobile stations operating in a wireless telephony communication network the system comprising:

a processor module, logically coupled to the telephony wireless communication network, operable to generate a plurality of traffic data records based on the operational data obtained from the telephony wireless communication network, each traffic data record identifying a location within the cell sector coverage area of the telephony wireless communication network for one of the mobile stations at a particular time; and

a movement filtering and detection module, logically coupled to the processor module, operable to generate a movement record in response to processing a pair of the traffic data records associated with a wireless communication activity by a same one of the mobile stations, each movement record comprising first and second locations within the telephony wireless communication network for the same mobile station at different times and reflecting movement by the same mobile station via a vehicle.

2. The system of claim 1, wherein the processor module comprises a privacy module adapted to remove a mobile station identifier number identifying one of the mobile stations from each of the traffic data records, to replace the mobile station identifier number in the traffic data record with a unique identifying number, and to maintain a relationship between the unique identifying number and the replaced mobile station identifier number.

3. The system of claim 1 further comprising a configuration and monitoring module, logically coupled to the processor module and to the movement and filtering detection module, operative to configure the operational activity of the processor module and the movement and filtering detection module and to monitor the operational activity of the processor module and the movement and filtering detection module.

4. The system of claim 1 wherein the processor module comprises: a plurality of file interfaces to extract location movement data from the operational data for the mobile stations as obtained from the telephony wireless communication network; and

a parsing engine logically coupled to the interfaces to generate the plurality of traffic data records in response to the extracted location movement data.

5. The system of claim 1 further comprising an HTTP query interface, logically coupled to the movement filtering and detection module, adapted to communicate each movement record to a data analysis node to assist an evaluation of vehicular traffic characteristics for a vehicular traffic area associated with the cell sector coverage area of the telephony wireless communication network.

6. A system for determining traffic velocities along a plurality of traffic routes by using operational data associated with mobile stations operating in a wireless telephony communications network comprising a cell sector coverage area having a plurality of cell sectors, the system comprising:

an analysis configuration module, logically coupled to at least one database comprising cell sector coverage area information for the wireless telephony communications network and geographic information for roadways within the cell sector coverage area of the wireless telephony communications network, operable to generate the plurality of traffic routes between any two of the cell sectors by processing the cell sector coverage area information and the geographic information for roadways; and

a traffic modeler module, logically coupled to the analysis configuration module, operable to generate a plurality of data records by processing movement records for the mobile stations within a context provided by the plurality of traffic routes, each movement record comprising first and second locations within the telephony wireless communication network for the same mobile station at different times and reflecting movement within the cell sector coverage area by the same mobile station, each data record comprising an identification of the average velocity for a vehicle along a particular one of the traffic routes at a specific time.

7. The system of claim 6 further comprising a mobile position system determination module, logically coupled to the traffic modeler module and a mobile positioning system for the telephony wireless communication network, operable to request mobile station location data from the mobile positioning system if the average velocity along the traffic route associated with the particular data record at the specific time is based on a number of the movement records less then a threshold value.

8. The system of claim 6 further comprising a route database, logically coupled to the traffic modeler module, operable to store the plurality of data records for access by an end user.

9. A method for extracting movement information using operational data for mobile stations operating in a wireless telephony communication network, comprising the steps of:

generating a plurality of traffic data records based on the operational data from the telephony wireless communication network, each traffic data record identifying a location within the cell sector coverage area of the telephony wireless communication network for one of the mobile stations at a particular time; and

generating a movement record in response to processing a pair of the traffic data records associated with a wireless communication activity by a same one of the mobile stations, each movement record comprising first and second locations within the telephony wireless communication network for the same mobile station at different times and reflecting movement by the same mobile station.

10. The method of claim 9 further comprising the step of receiving a continuous flow of the operational data from the wireless telephony communication network.

11. The method of claim 9 further comprising the step of processing the plurality of traffic data records by removing certain confidential information associated with the operational data for the mobile stations operating within the telephony wireless communication network, the processing step comprising, for each of the traffic data records, the steps of

replacing the mobile station identifier in the traffic data record with a unique identifying number; and maintaining a relationship between the replaced mobile station identifier and the unique identifying number to assist the tracking of movement records generated for the same mobile station.

12. A method for determining traffic velocities along traffic routes based on movement of mobile stations operating within a wireless telephony communications network comprising a cell sector coverage area overlapping with the traffic routes and having a plurality of cell sectors, comprising the steps of:

creating a plurality of traffic routes between any two of the cell sectors by processing cell sector coverage area information for the wireless telephony communications network and geographic information for roadways within the cell sector coverage area of the wireless telephony communications network, and

identifying a particular one of the traffic routes traveled by a vehicle associated with one of the mobile stations by processing movement records for the mobile station within a geographical context defined by the plurality of traffic routes, each movement record comprising first and second locations within the telephony wireless communication network for a same one of the mobile stations at different times and reflecting movement of the same mobile station; and

calculating an estimate of an average velocity and a standard deviation of velocity of the vehicle associated with the mobile station along the particular traffic route at a specific time.

13. The method of claim 12 wherein the step of creating a plurality of traffic routes comprises, for each of the cell sectors, the steps of:

determining all road segments intersecting one of the cell sectors based upon the geographic information for roadways;

determining a plurality of boundary road segments for the cell sector based upon all road segments intersecting the cell sector; and

calculating the traffic routes between each boundary road segment in the cell sector.

14. The method of claim 12 wherein the step of identifying a particular one of the traffic routes traveled by a vehicle associated with one of the mobile stations comprises the steps of:

identifying start and end cell sector pairs from a polyline of movement locations associated with the movement records for the same mobile station;

for each start and end cell sector pairs, determining all of the traffic routes between the cell sectors in the cell sector pair;

calculating a cell handoff score for each traffic route between the cell sectors in the cell sector pair;

eliminating any of the traffic routes between the cell sectors in the cell sector pair that are not within an acceptable range of the handoff scores;

calculating a velocity along each traffic route between the cell sectors in the cell sector pair that are not eliminated by the handoff score using time stamps in the movement record;

trimming each traffic route for which a velocity was calculated in the event that the calculated velocity exceeds a maximum velocity cutoff;

eliminating any traffic routes for which a velocity was calculated in the event that the calculated velocity exceeds the maximum velocity cutoff and the traffic route cannot be trimmed;

eliminating any traffic route for which a velocity was calculated in the event that the calculated velocity is less than a minimum velocity cutoff;

calculating a z-score of the calculated velocity for all of the remaining ones of the traffic routes that not been eliminated; and

selecting the particular traffic route from the remaining traffic routes based on the z-score of the calculated velocity and the handoff score.

15. The method of claim 12 wherein the step of calculating an estimate of an average velocity and standard deviation of velocity of vehicular traffic along the particular traffic route for a specific time further comprises the steps of:

determining an average velocity of a vehicle for each route segment in the particular traffic route by using the movement records associated with the particular traffic route segment;

determining an average velocity of a vehicle for a traffic route comprising a plurality of route segments by using a distance of the particular traffic route and the travel time over the distance by using the movement records associated with the particular traffic route;

determining the standard deviation of the average velocity for a vehicle for each route segment in the particular traffic route by using the difference of the sum of the average velocity of a vehicle for each route segment comprising a traffic route of the particular traffic route and the average velocity of a vehicle for a traffic route.

16. The method of claim 12 further comprising the step of determining if mobile positioning system data are needed for calculating an estimate of the average velocity and the standard deviation of velocity of vehicular traffic along the particular traffic route for a specific time, this step further comprising the steps of:

determining whether the estimate of the average velocity of vehicular traffic along the particular traffic route for a specific time is based on a number of movement records at or above a threshold;

for those traffic routes where the velocity estimate is based on a number of movement records below a threshold, requesting mobile station location data from the wireless telephony communication network associated with the particular traffic route at the specific time;

receiving the requested mobile station location data from the wireless telephony communication network; and

revising the calculation of the estimate of the average velocity and standard deviation of velocity of vehicular traffic along the particular traffic route for the specific time by using the received mobile station location data.

17. A system for determining traffic velocities along a plurality of traffic routes by using operational data associated with mobile stations operating in a wireless telephony communications network overlapping the traffic routes and comprising a cell sector coverage area having a plurality of cell sectors, the system comprising:

a processor module, logically coupled to the telephony wireless communication network, operable to generate a plurality of traffic data records based on operational data obtained from the telephony wireless communication network, each traffic data record identifying a location within the telephony wireless communication network for one of the mobile stations at a particular time;

a movement filtering and detection module, logically coupled to the processor module, operable to generate a movement record in response to processing a pair of the traffic data records associated with a wireless communication activity by a same one of the mobile stations, each movement record comprising first and second locations within the telephony wireless communication network for the same mobile station at different times and reflecting movement by the same mobile station;

an analysis configuration module, logically coupled to at least one database comprising cell sector coverage area information for the wireless telephony communications network and geographic information for roadways within the cell sector coverage area of the wireless telephony communications network, operable to generate the plurality of traffic routes between any two of the cell sectors by processing the cell sector coverage area information and the geographic information for roadways; and

a traffic modeler module, logically coupled to the movement filtering and detection module and to the analysis configuration module, operable to generate a plurality of data records by processing the locations for the mobile stations as identified by the movement records within a geographical context provided by the plurality of traffic routes, each data record comprising an identification of the average velocity along a particular one of the traffic routes at a specific time.

18. The system of claim 17, wherein the processor module comprises a privacy module adapted to remove a mobile station identifier number identifying one of the mobile stations from each of the traffic data records, to replace the mobile station identifier number in the traffic data record with a unique identifying number, and to maintain a relationship between the unique identifying number and the replaced mobile station identifier number.

19. The system of claim 17 further comprising a configuration and monitoring module, logically coupled to the processor module and to the movement and filtering detection module, operative to configure the operational activity of the processor module and the movement and filtering detection module and to monitor the operational activity of the processor module and the movement and filtering detection module.

20. The system of claim 17 wherein the processor module comprises:

a plurality of file interfaces to extract location movement data from the operational data obtained from the telephony wireless communication network; and

a parsing engine logically coupled to the interfaces to generate the plurality of traffic data records in response to the extracted location movement data.

21. The system of claim 17 further comprising an HTTP query interface, logically coupled to the movement filtering and detection module and to the traffic modeler module, adapted to communicate each movement record from the movement filtering and detection module to the traffic modeler module.

22. The system of claim 17 further comprising a mobile position system determination module, logically coupled to the traffic modeler module and a mobile positioning system for the telephony wireless communication network, operable to request mobile station location data from the mobile positioning system if the average velocity along the traffic route associated with the particular data record at the specific time is based on a number of the movement records less then a threshold value.

23. The system of claim 17 further comprising a route database, logically coupled to the traffic modeler module, operable to store the plurality of data records for access by an end user.

24. A method for determining traffic velocities along a plurality of traffic routes by using operational data associated with mobile stations operating in a wireless telephony communications network overlapping the traffic routes and comprising a cell sector coverage area having a plurality of cell sectors,, comprising the steps of:

generating a plurality of traffic data records based on the operational data from the telephony wireless communication network, each traffic data record identifying a location within the telephony wireless communication network for one of the mobile stations at a particular time; and

generating a movement record in response to processing a pair of the traffic data records associated with a wireless communication activity by a same one of the mobile stations, each movement record comprising first and second locations within the telephony wireless communication network for the same mobile station at different times and reflecting movement by the same mobile station;

creating a plurality of traffic routes between any two of the cell sectors by processing cell sector coverage area information for the wireless telephony communications network and geographic information for roadways within the cell sector coverage area of the wireless telephony communications network;

identifying from the plurality of traffic routes a particular one of the traffic routes traveled by a vehicle associated with one of the mobile stations by processing movement records for the mobile station, each movement record comprising first and second locations within the telephony wireless communication network for the same mobile station at different times and reflecting movement of the vehicle associated with the same mobile station; and

calculating an estimate of an average velocity and a standard deviation of velocity of vehicular traffic along the particular traffic route for a specific time by using the movement records associated with the particular traffic route.

25. The method of claim 24 further comprising the step of receiving a continuous flow of the operational data from the wireless telephony communication network.

26. The method of claim 24 further comprising the step of processing the plurality of traffic data records by removing certain confidential information associated with the operational data for the mobile stations operating within the telephony wireless communication network, the processing step comprising, for each of the traffic data records, the steps of

replacing the mobile station identifier number in the traffic data record with a unique identifying number; and

maintaining a relationship between the replaced mobile station identifier number and the unique identifying number to assist the tracking of movement records generated for the same mobile station.

27. The method of claim 24 wherein the step of creating a plurality of traffic routes by processing the cell sector coverage area information and the geographic information for roadways comprises, for each cell sector, the steps of:

determining all road segments intersecting the cell sector from the geographic information for roadways;

determining a plurality of boundary road segments for the cell sector from all road segments intersecting the cell sector; and

calculating the particular one of the traffic routes between each boundary road segment in the cell sector and all other cell sectors.

28. The method of claim 24 wherein the step of identifying a particular one of the traffic routes traveled by a vehicle associated with one of the mobile stations comprises the steps of:

identifying start and end cell sector pairs from a polyline of movement locations associated with the movement records for the same mobile station;

for each start and end cell sector pairs, determining all of the traffic routes between the cell sectors in the cell sector pair;

calculating a cell handoff score for each traffic route between the cell sectors in the cell sector pair;

eliminating any of the traffic routes between the cell sectors in the cell sector pair that are not within an acceptable range of the handoff scores;

calculating a velocity along each traffic route between the cell sectors in the cell sector pair that are not eliminated by the handoff score using time stamps in the movement record;

trimming each traffic route for which a velocity was calculated in the event that the calculated velocity exceeds a maximum velocity cutoff;

eliminating any traffic routes for which a velocity was calculated in the event that the calculated velocity exceeds the maximum velocity cutoff and the traffic route cannot be trimmed;

eliminating any traffic route for which a velocity was calculated in the event that the calculated velocity is less than a minimum velocity cutoff;

calculating a z-score of the calculated velocity for all of the remaining ones of the traffic routes that not been eliminated; and

selecting the particular traffic route from the remaining traffic routes based on the z-score of the calculated velocity and the handoff score.

29. The method of claim 24 wherein the step of calculating an estimate of an average velocity and standard deviation of velocity of vehicular traffic along the particular traffic route for a specific time further comprises the steps of:

determining an average velocity of a vehicle for each route segment in the particular traffic route by using the movement records associated with the particular traffic route segment;

determining an average velocity of a vehicle for a traffic route comprising a plurality of route segments by using a distance of the particular traffic route and the travel time over the distance by using the movement records associated with the particular traffic route;

determining the standard deviation of the average velocity for a vehicle for each route segment in the particular traffic route by using the difference of the sum of the average velocity of a vehicle for each route segment comprising a traffic route of the particular traffic route and the average velocity of a vehicle for a traffic route.

30. The method of claim 24 further comprising the step of determining if mobile positioning system data are needed for calculating an estimate of the average velocity and the standard deviation of velocity of vehicular traffic along the particular traffic route for a specific time, this step further comprising the steps of:

determining whether the estimate of the average velocity of vehicular traffic along the particular traffic route for a specific time is based on a number of movement records at or above a threshold;

for those traffic routes where the velocity estimate is based on a number of movement records below a threshold, requesting mobile station location data from the wireless telephony communication network associated with the particular traffic route at the specific time;

receiving the requested mobile station location data from the wireless telephony communication network; and

revising the calculation of the estimate of the average velocity and standard deviation of velocity of vehicular traffic along the particular traffic route for the specific time by using the received mobile station location data.

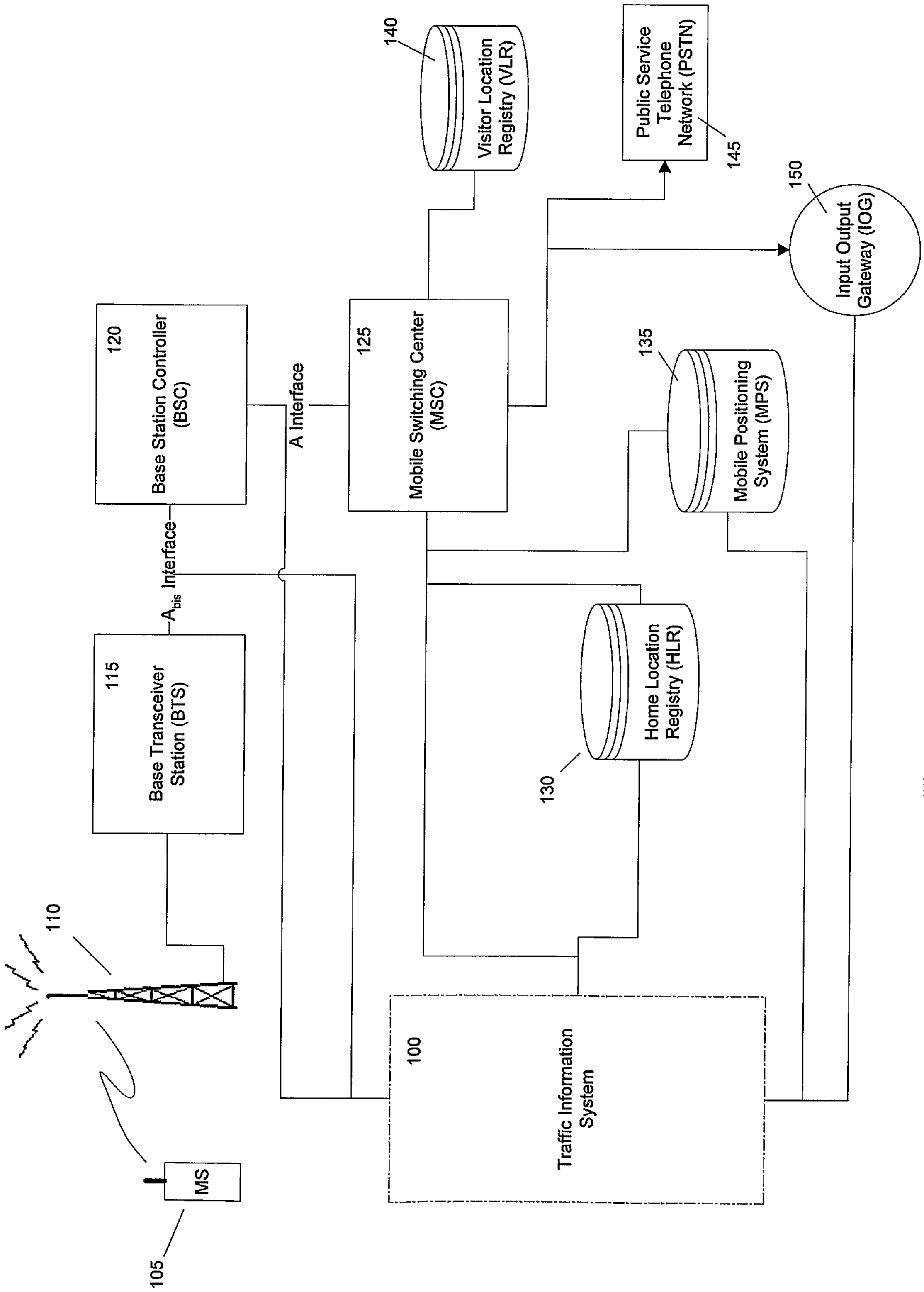


Figure 1: Operating Environment

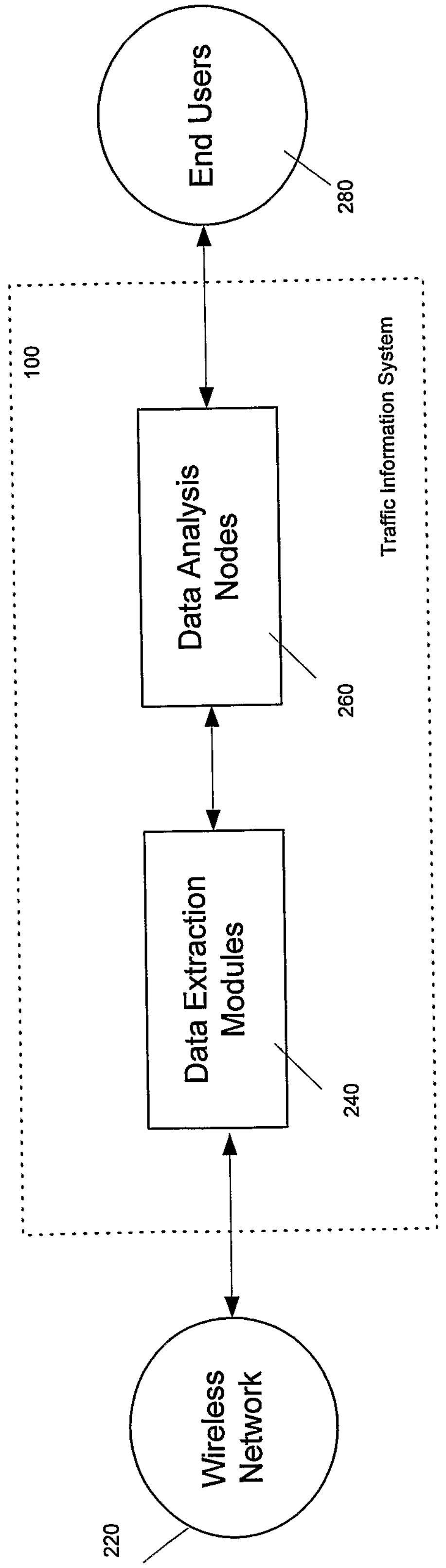


Figure 2a: Traffic Information System Block Diagram

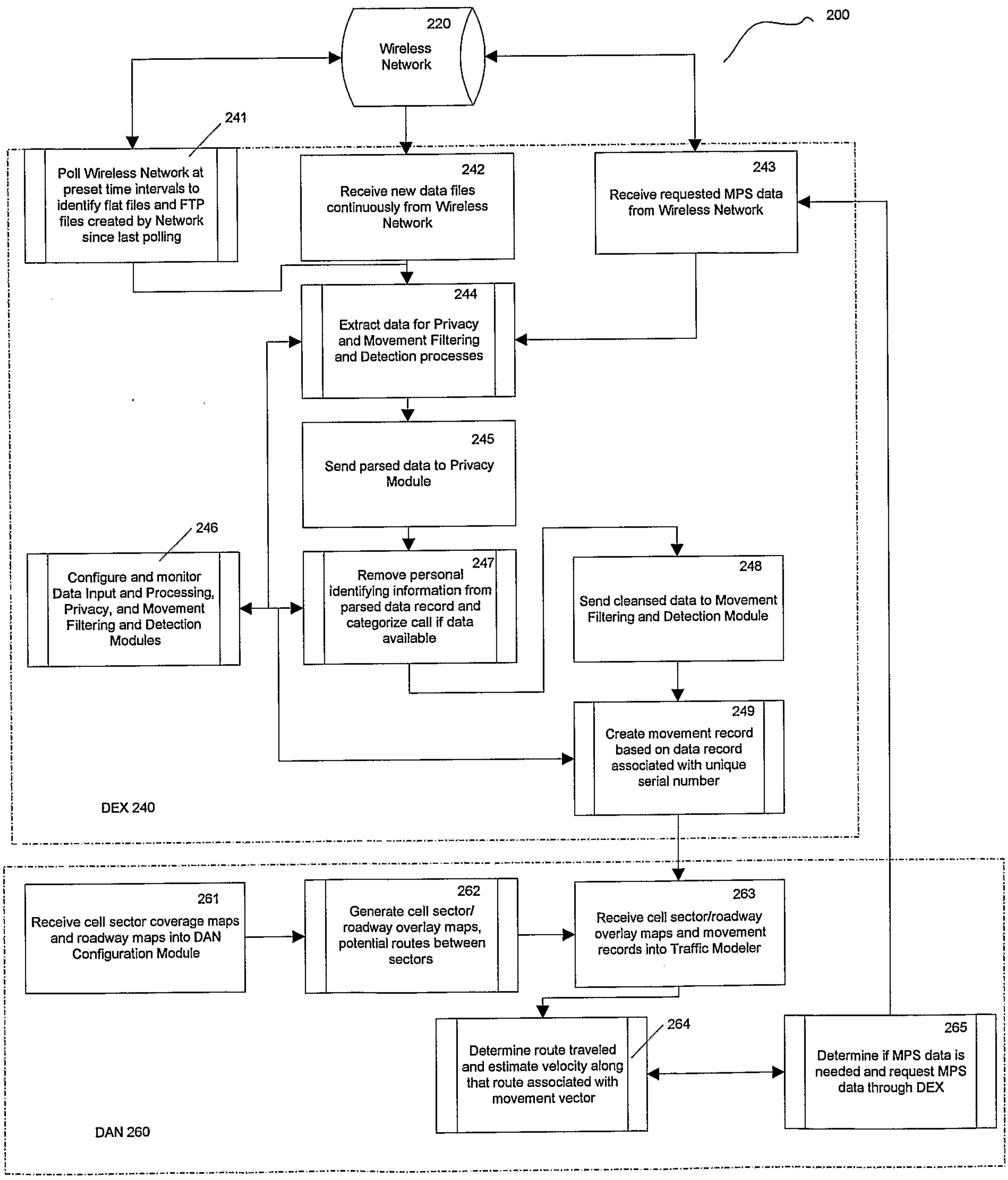


Figure 2b: Overall Process of a Traffic Information System

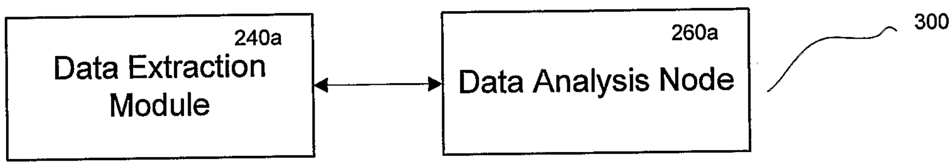


Figure 3a: Single Data Extraction Module Paired with Single Data Analysis Node

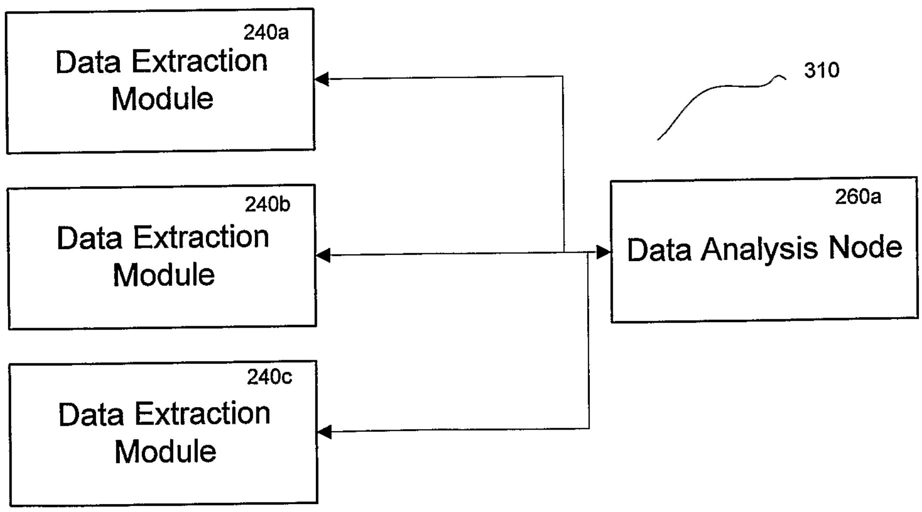


Figure 3b: Multiple Data Extraction Modules Linked with Single Data Analysis Node

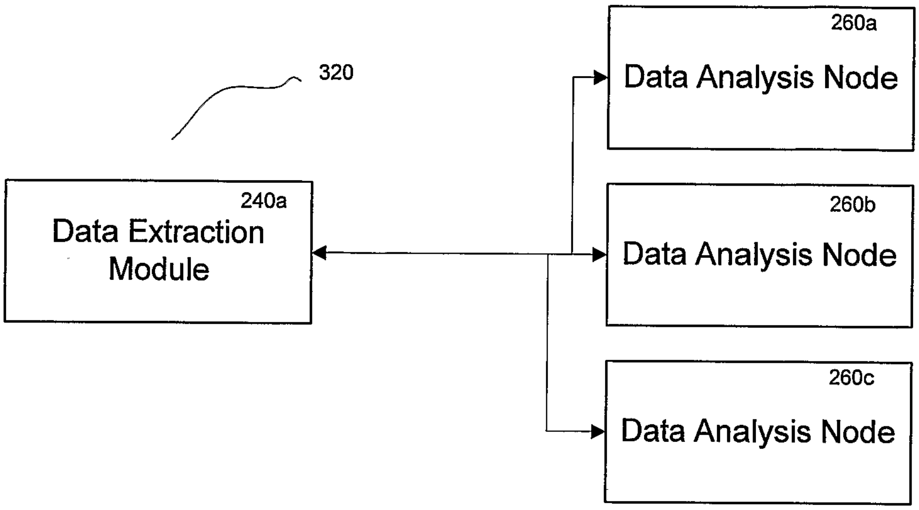


Figure 3c: Single Data Extraction Module Linked with Multiple Data Analysis Nodes

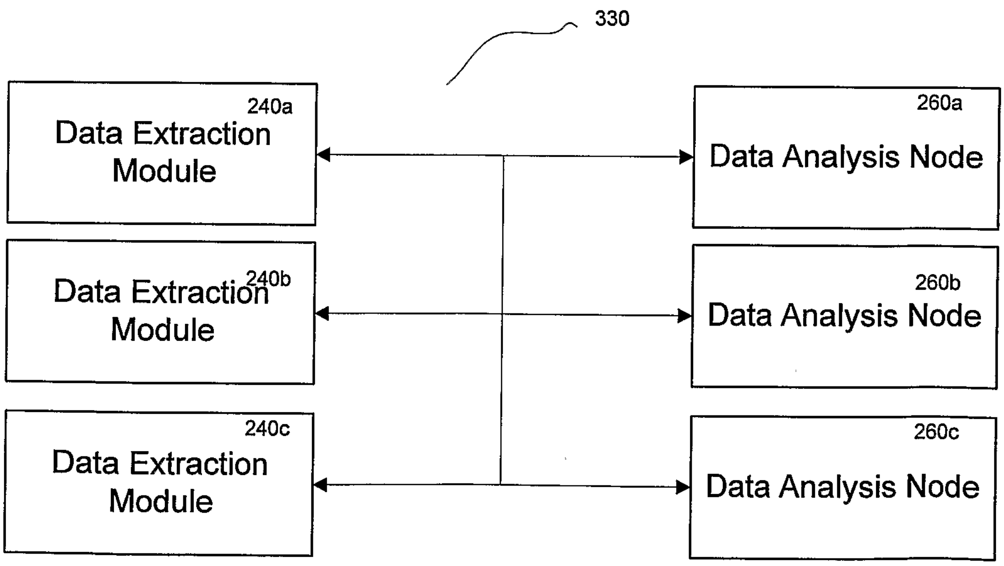


Figure 3d: Multiple Data Extraction Modules Linked with Multiple Data Analysis Nodes

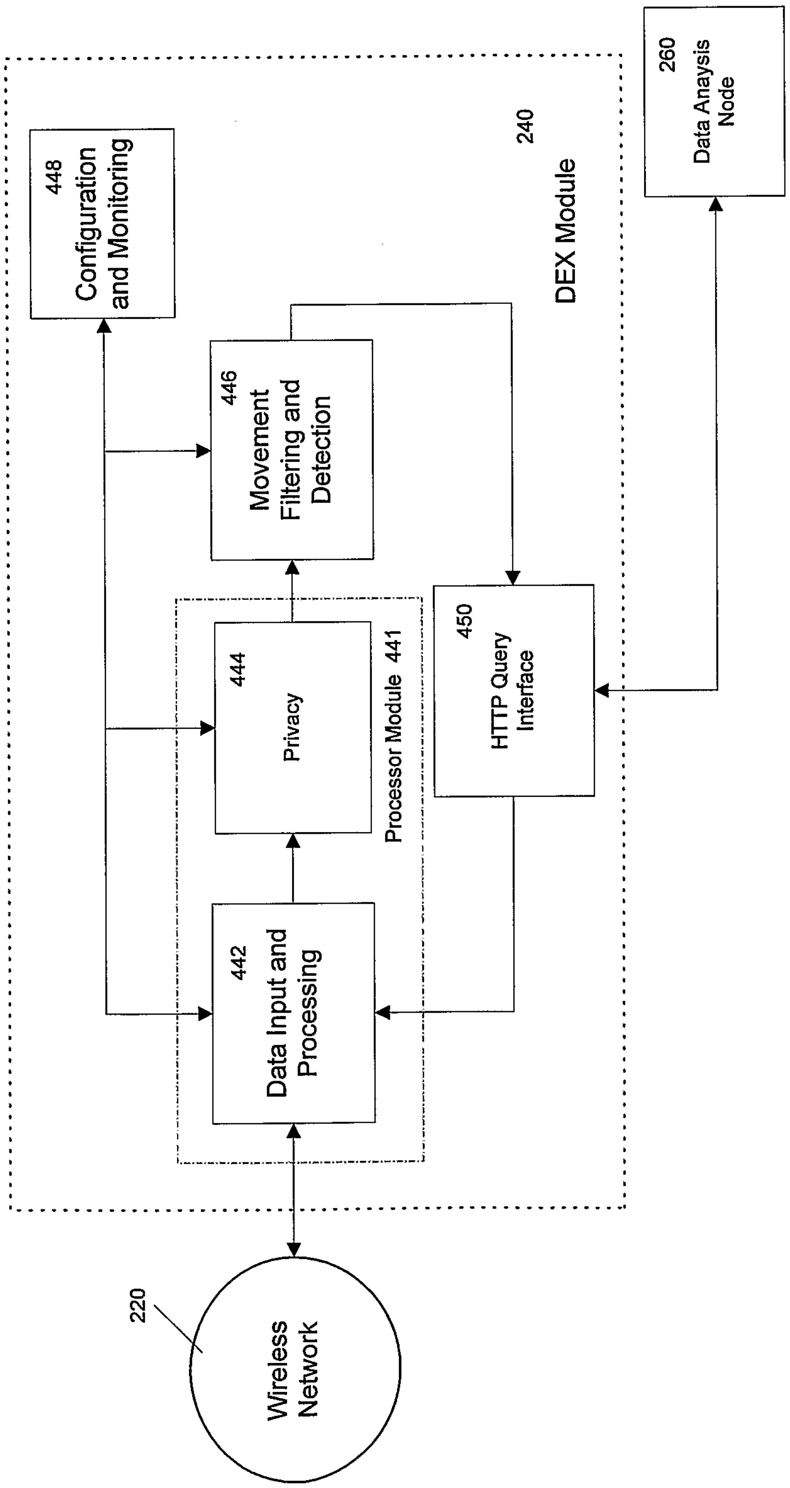


Figure 4: DEX Process-Level Block Diagram

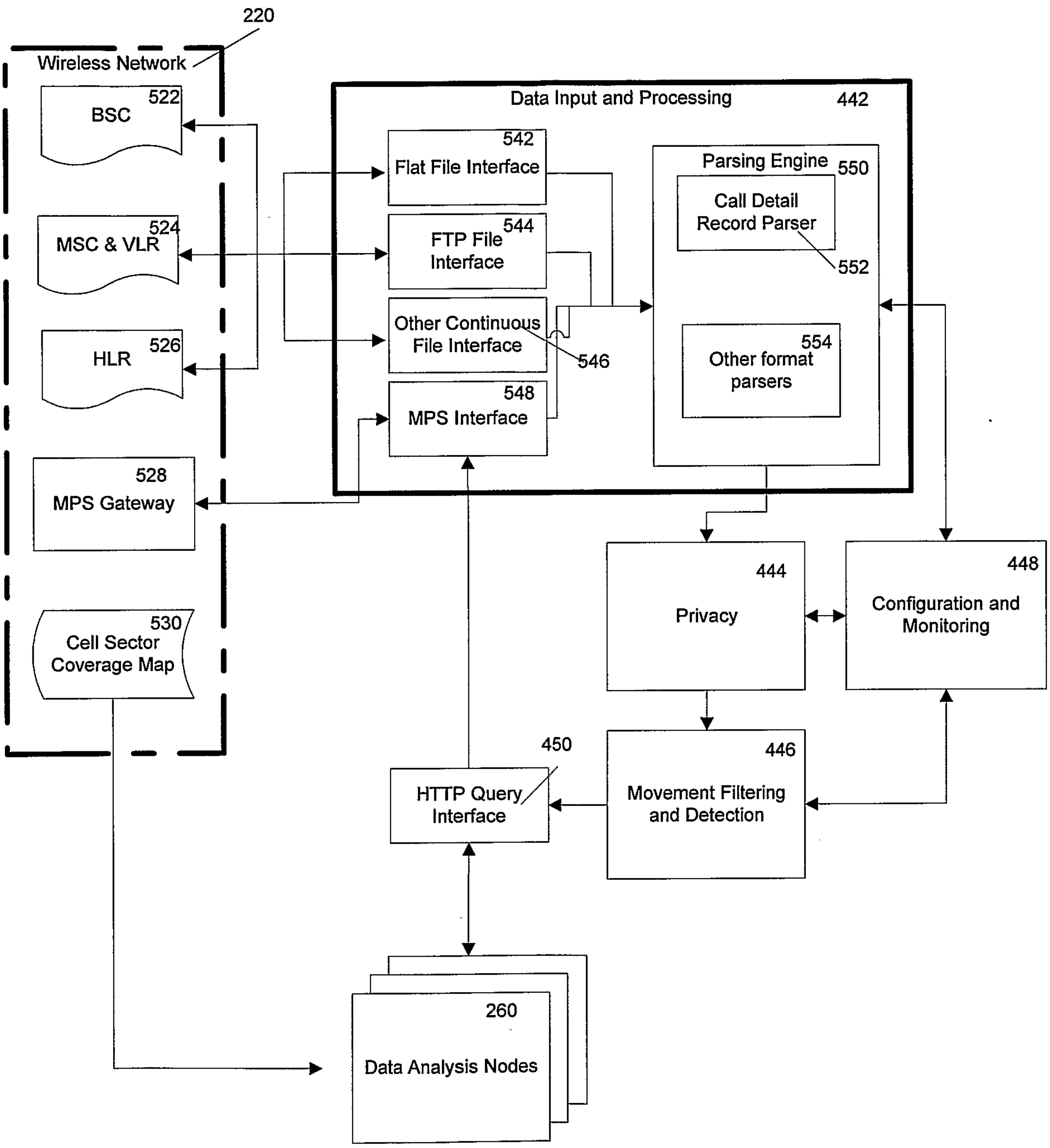


Figure 5: DEX Data Input and Processing

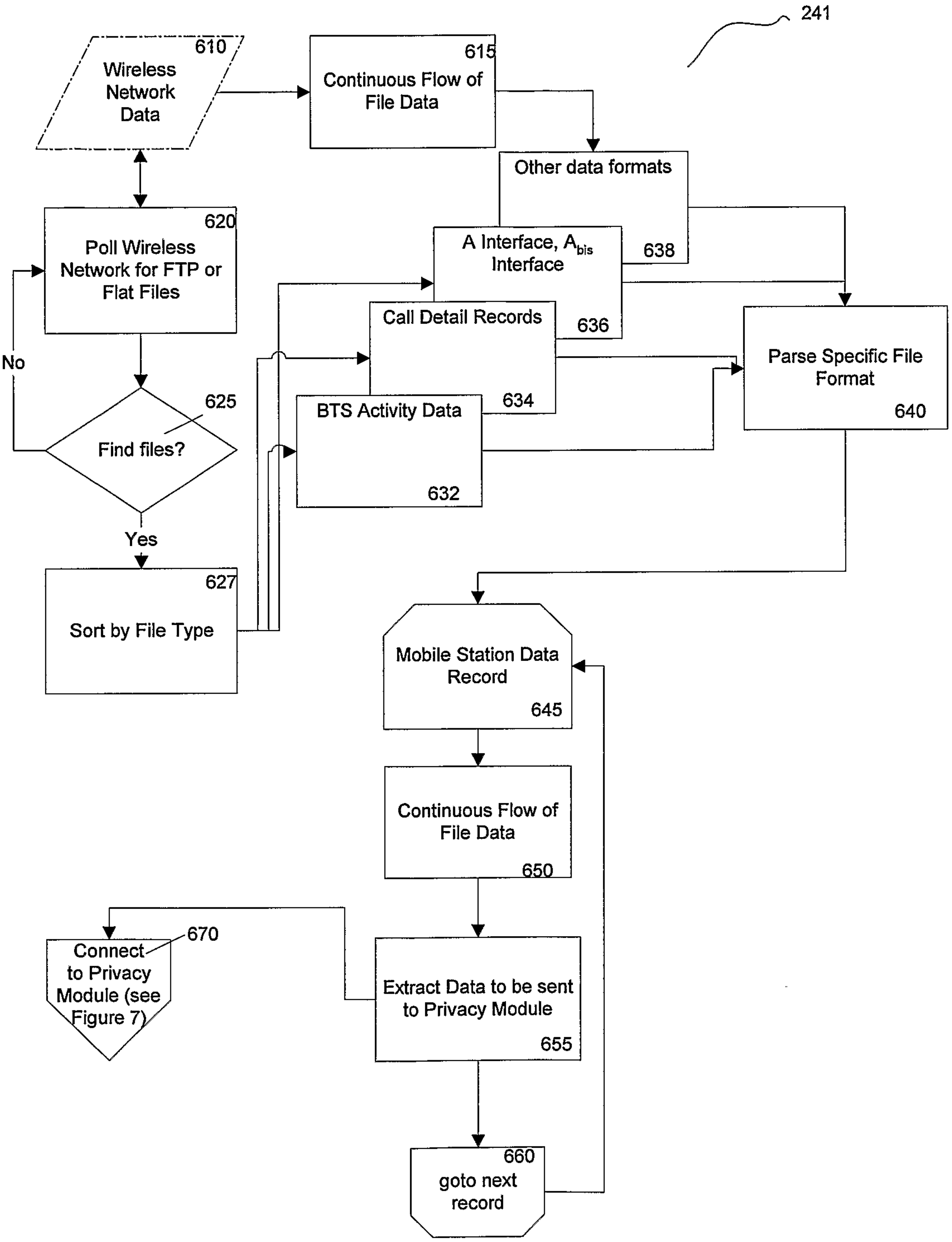


Figure 6: File Polling and Parsing Process

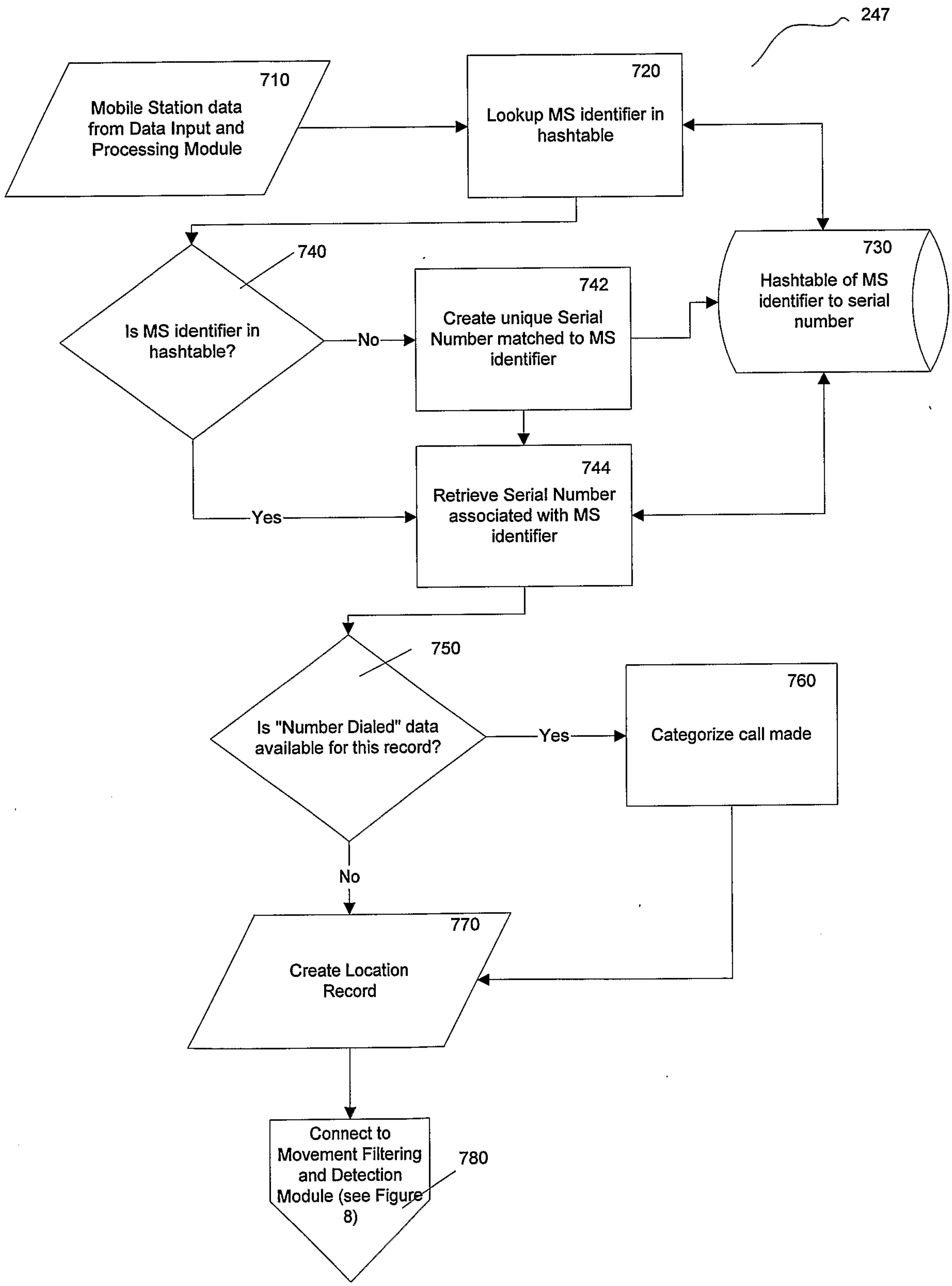


Figure 7: Privacy Module Process

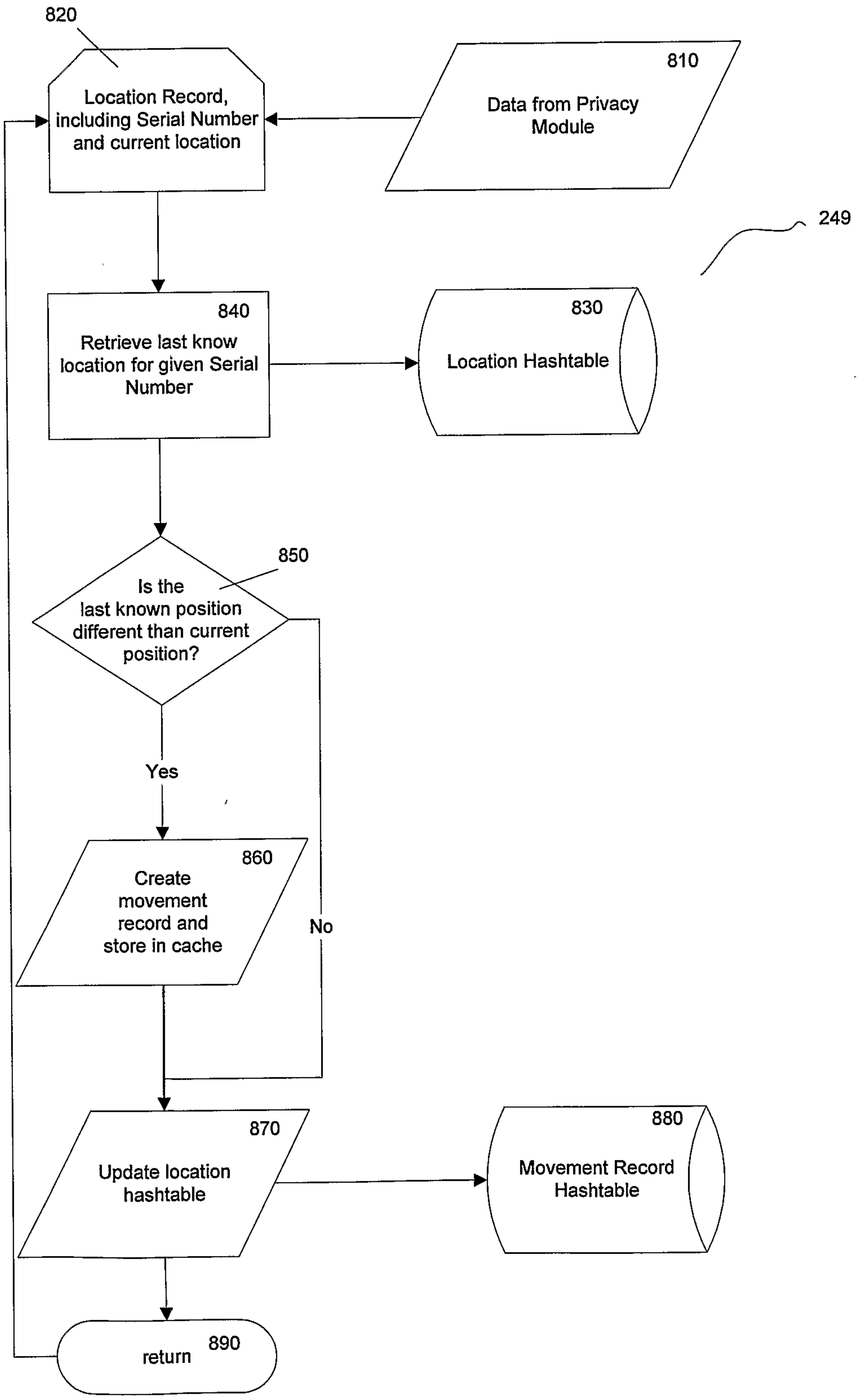


Figure 8: Movement Filtering and Detection

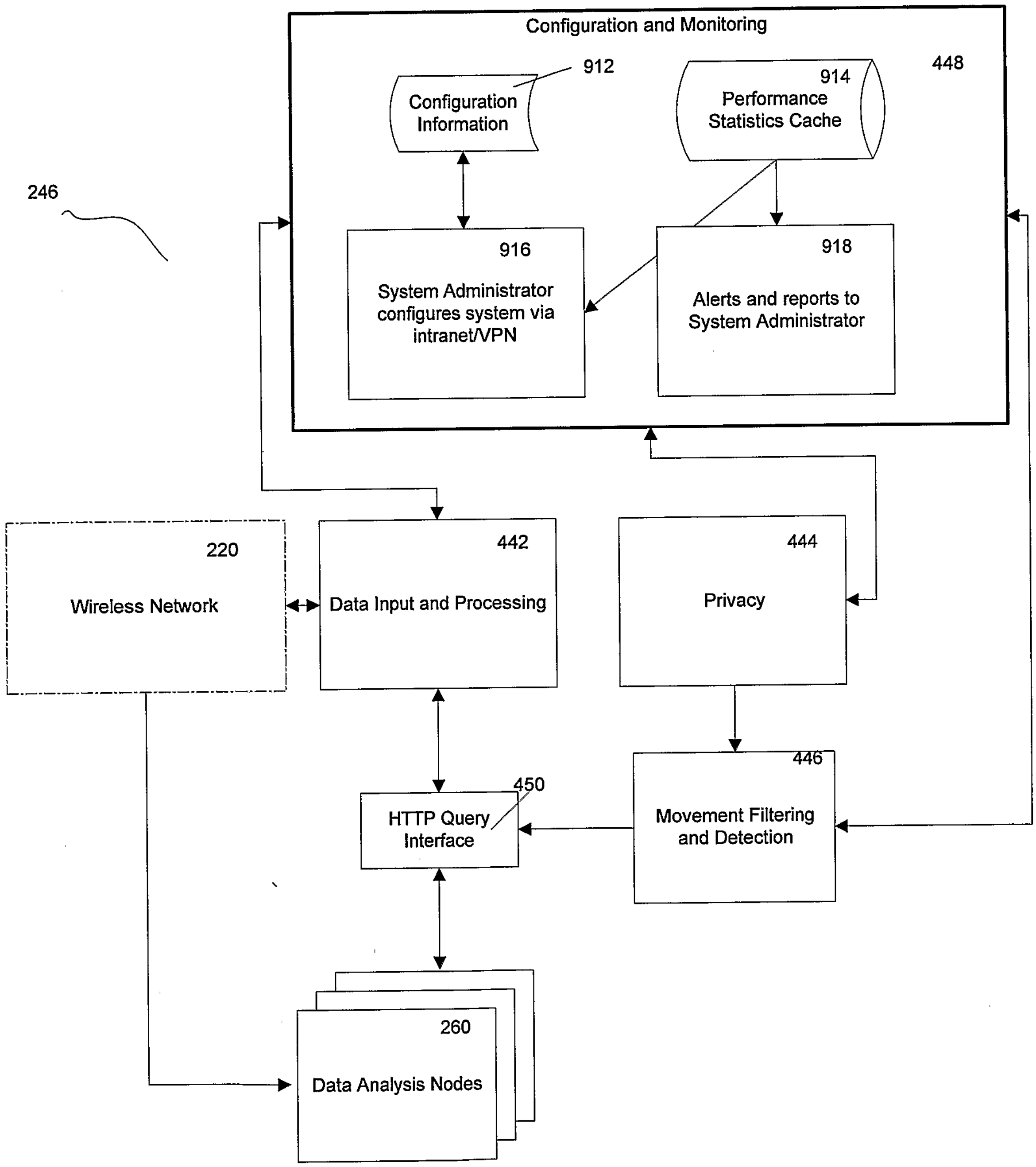


Figure 9: DEX Configuration and Monitoring

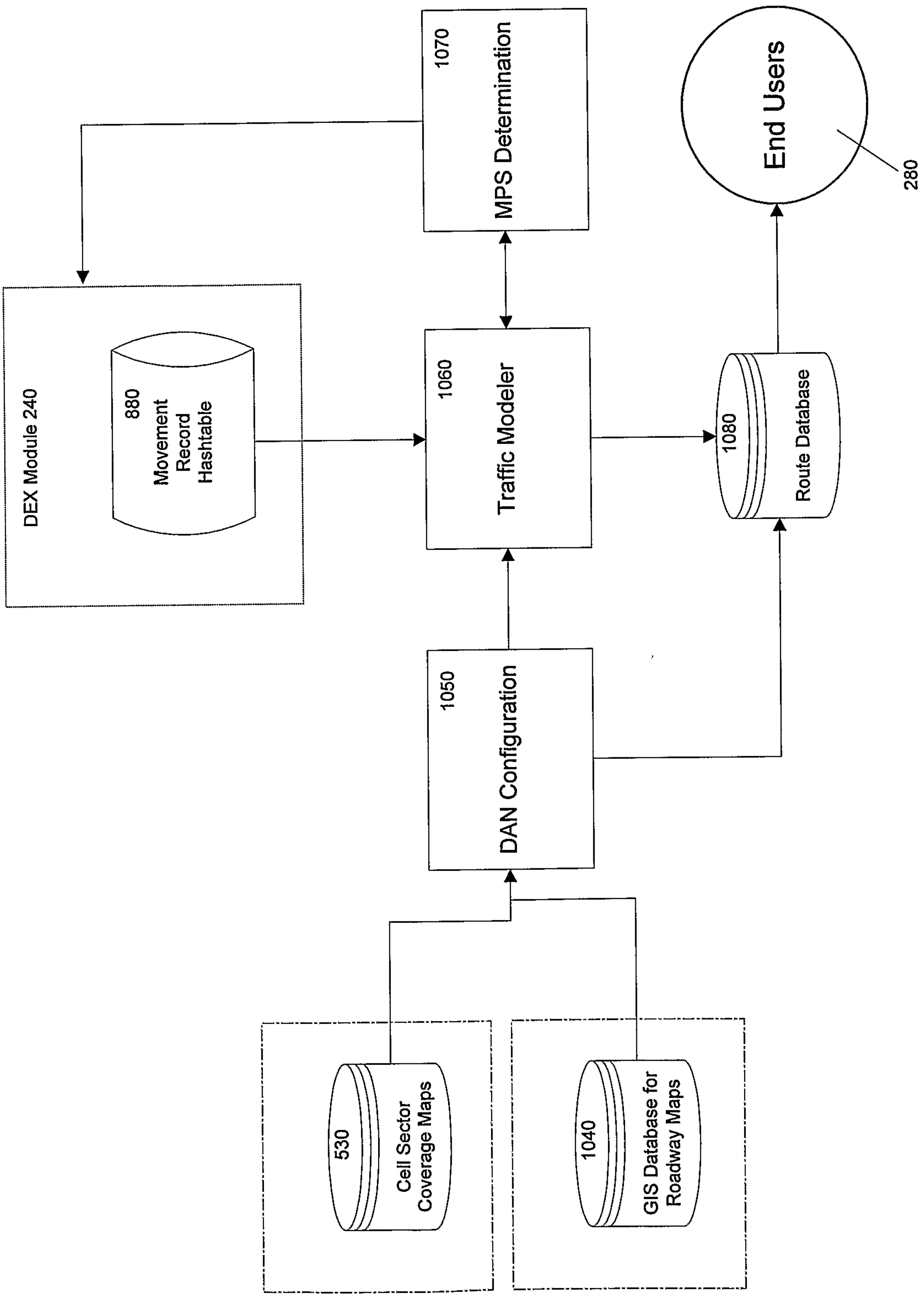


Figure 10: DAN Process-Level Block Diagram

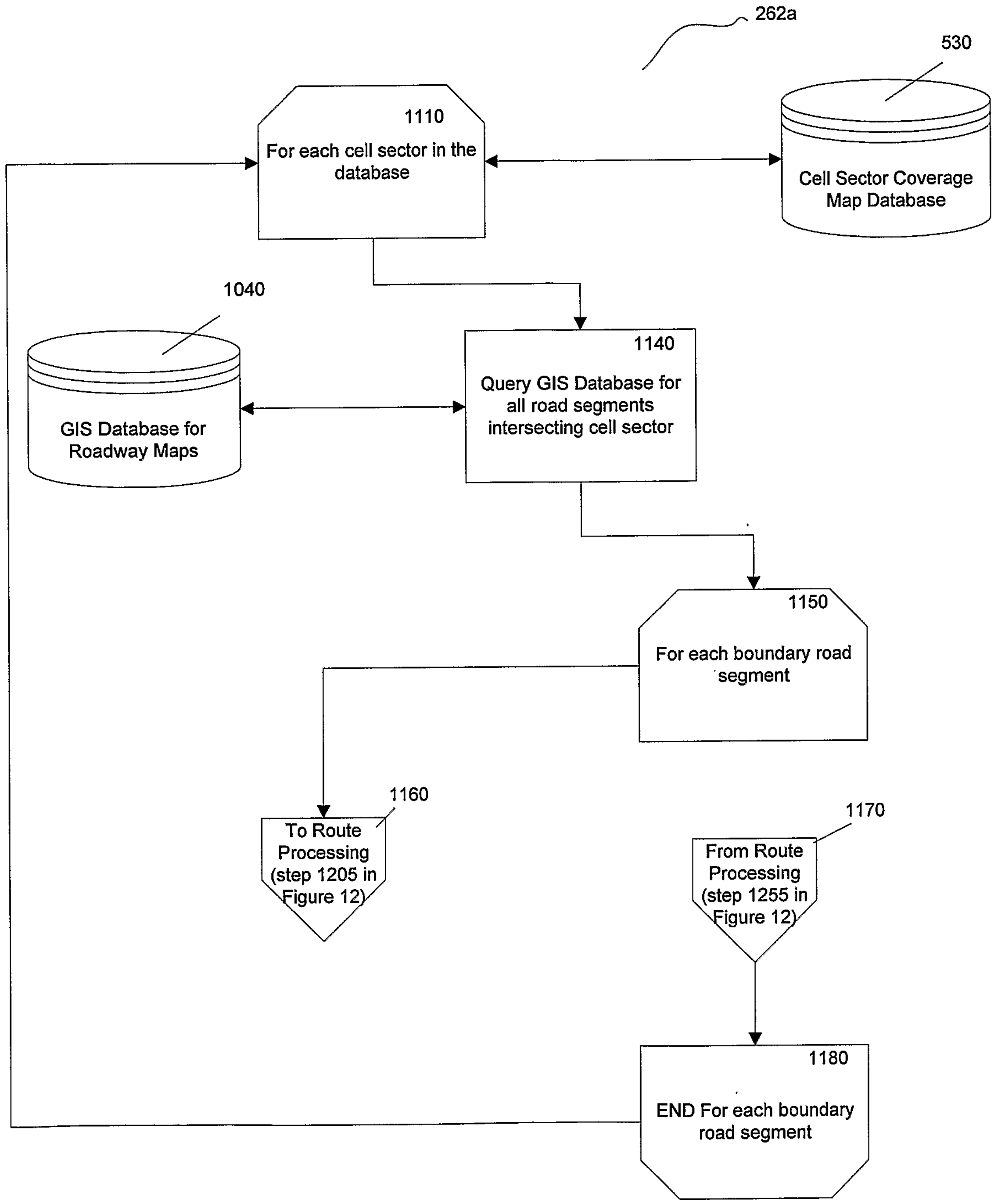


Figure 11: Route Generation

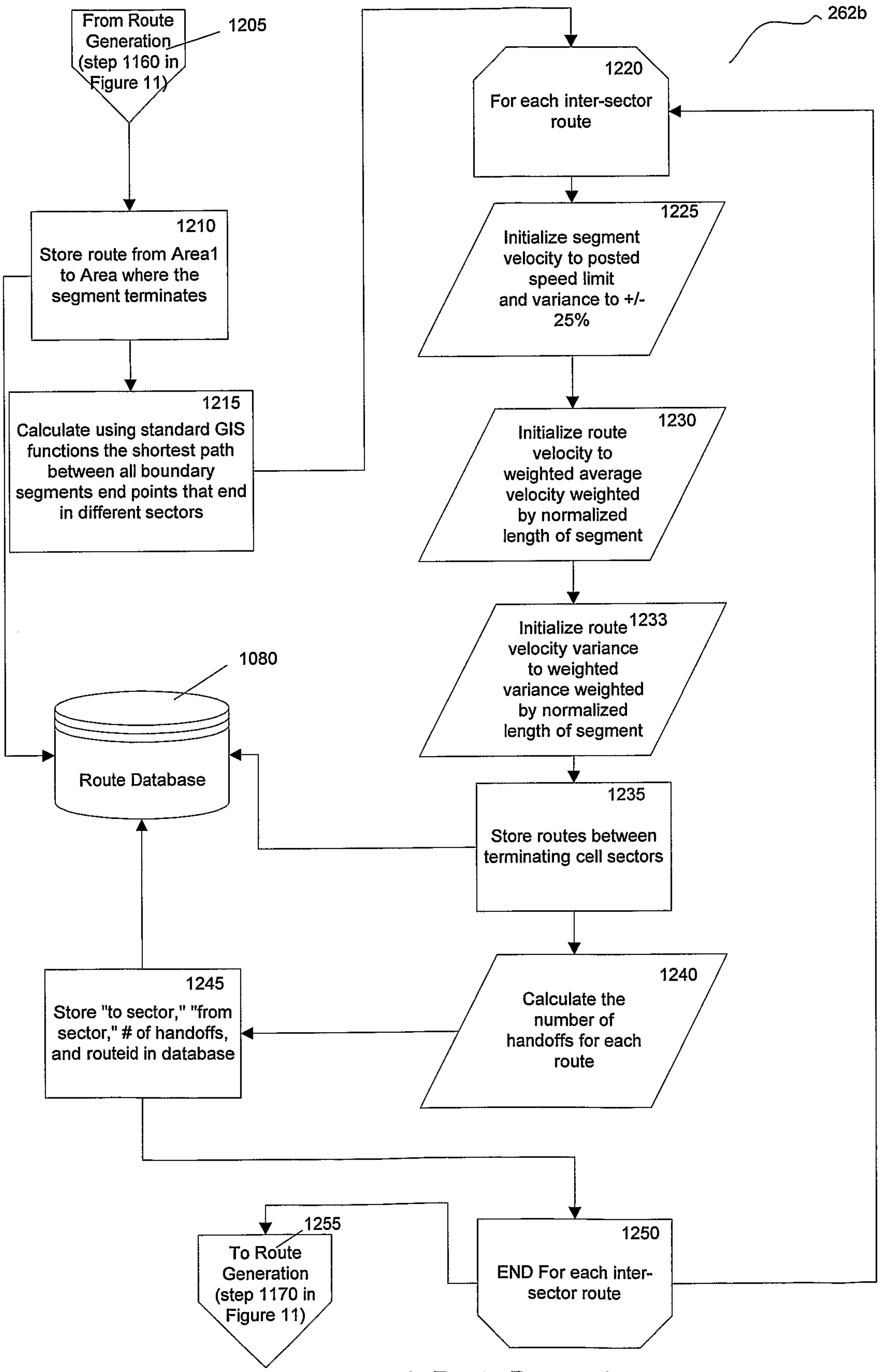


Figure 12: Route Processing

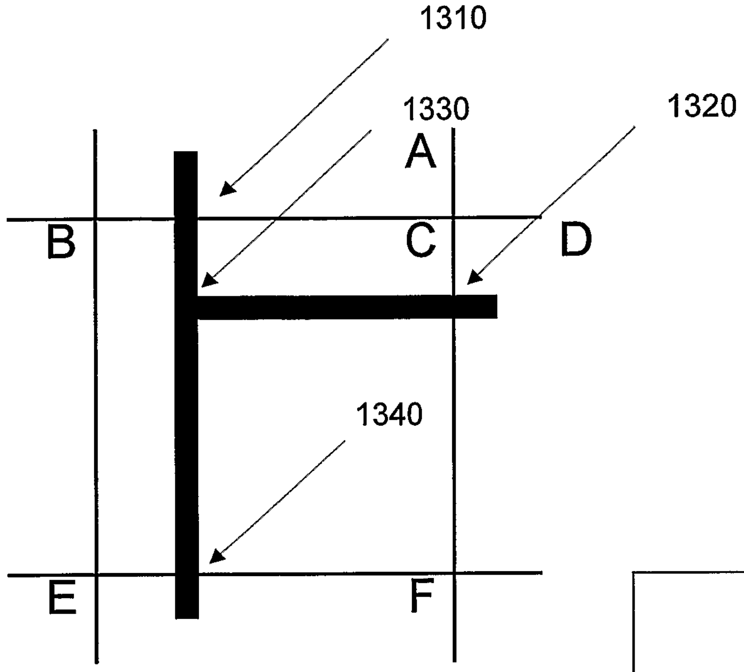


Figure 13b: Illustration of Cell Sector/Roadway overlay

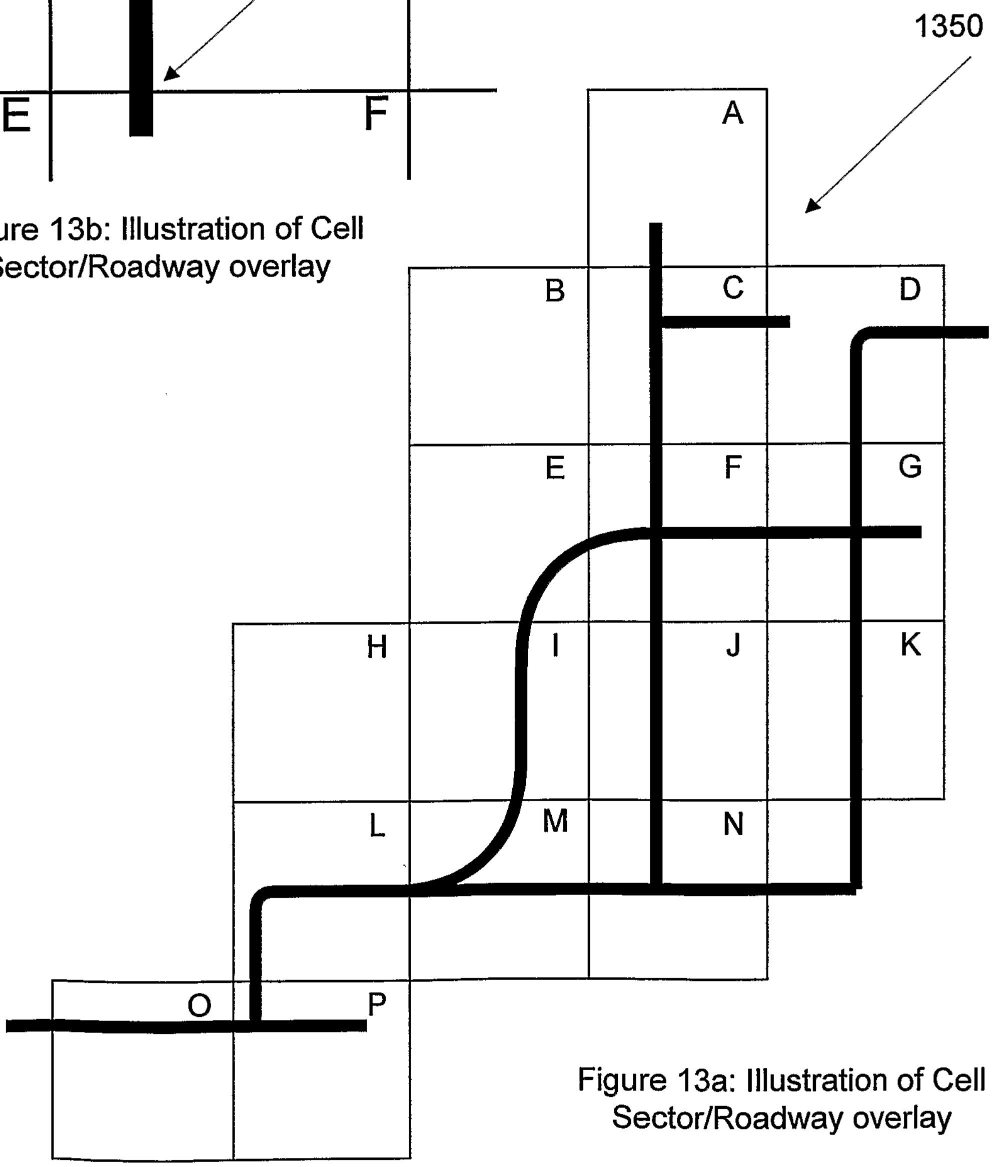


Figure 13a: Illustration of Cell Sector/Roadway overlay

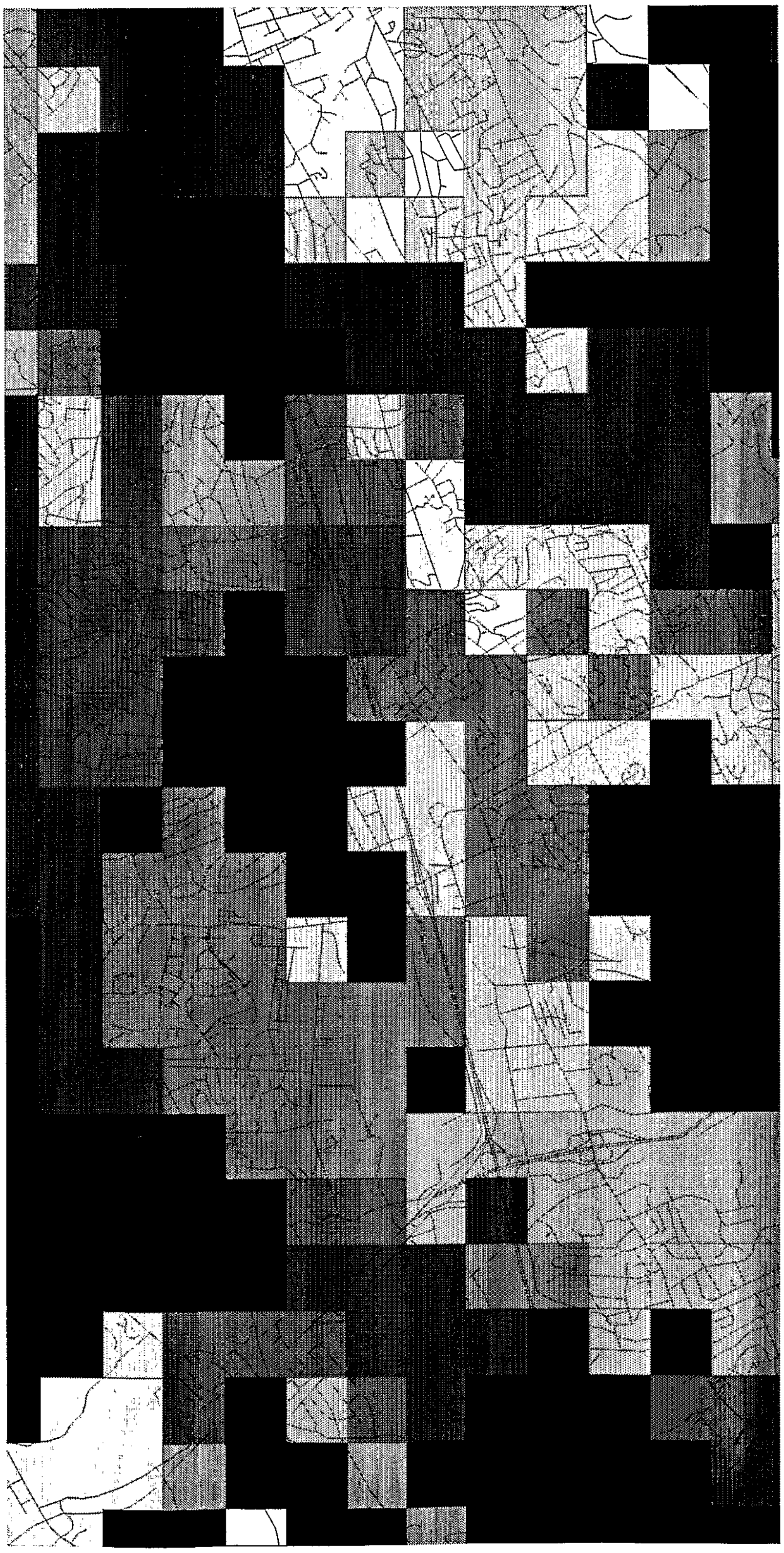


Figure 14: Realistic Cell Sector/Roadway Overlay

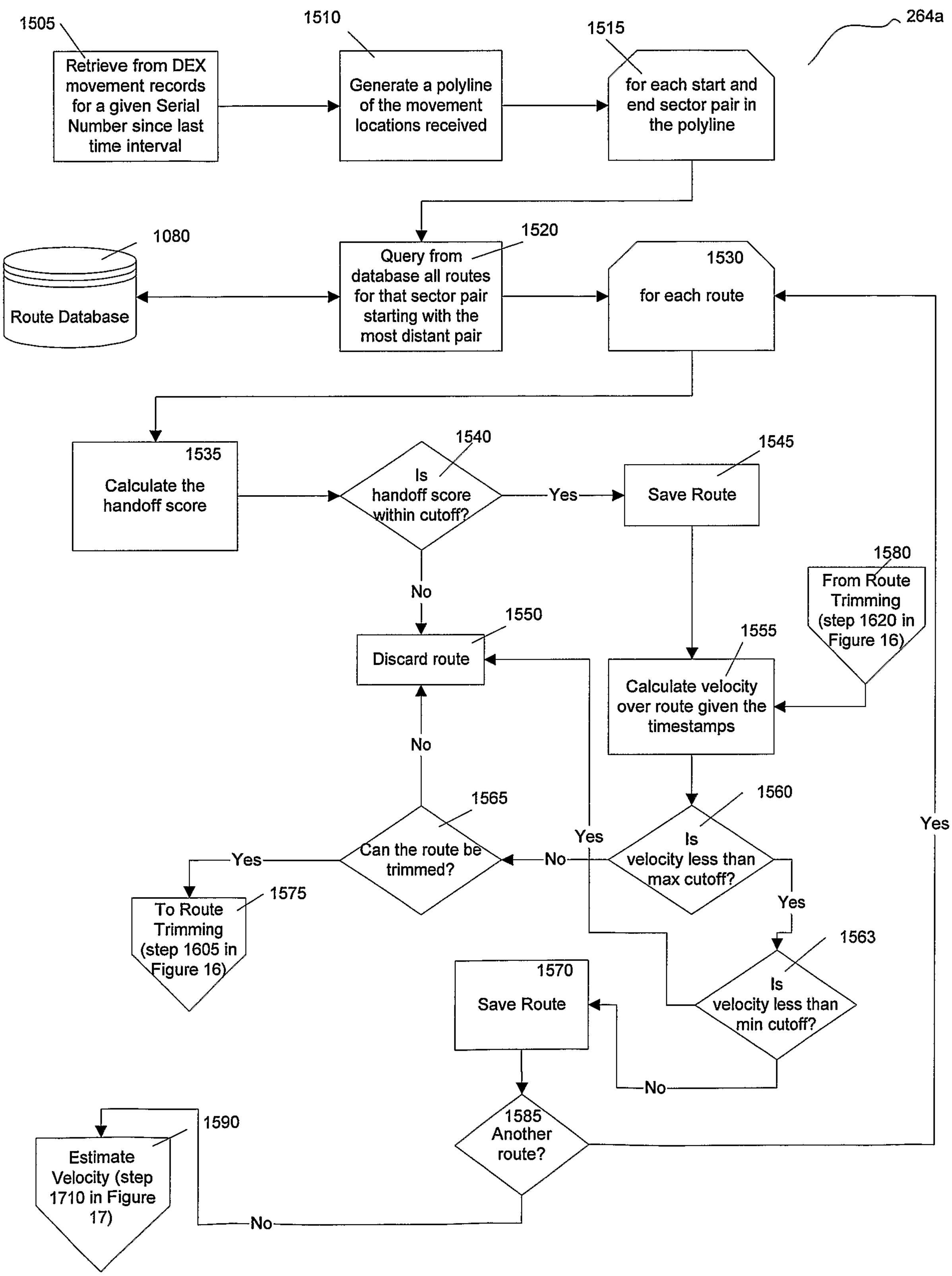


Figure 15: Route Selection

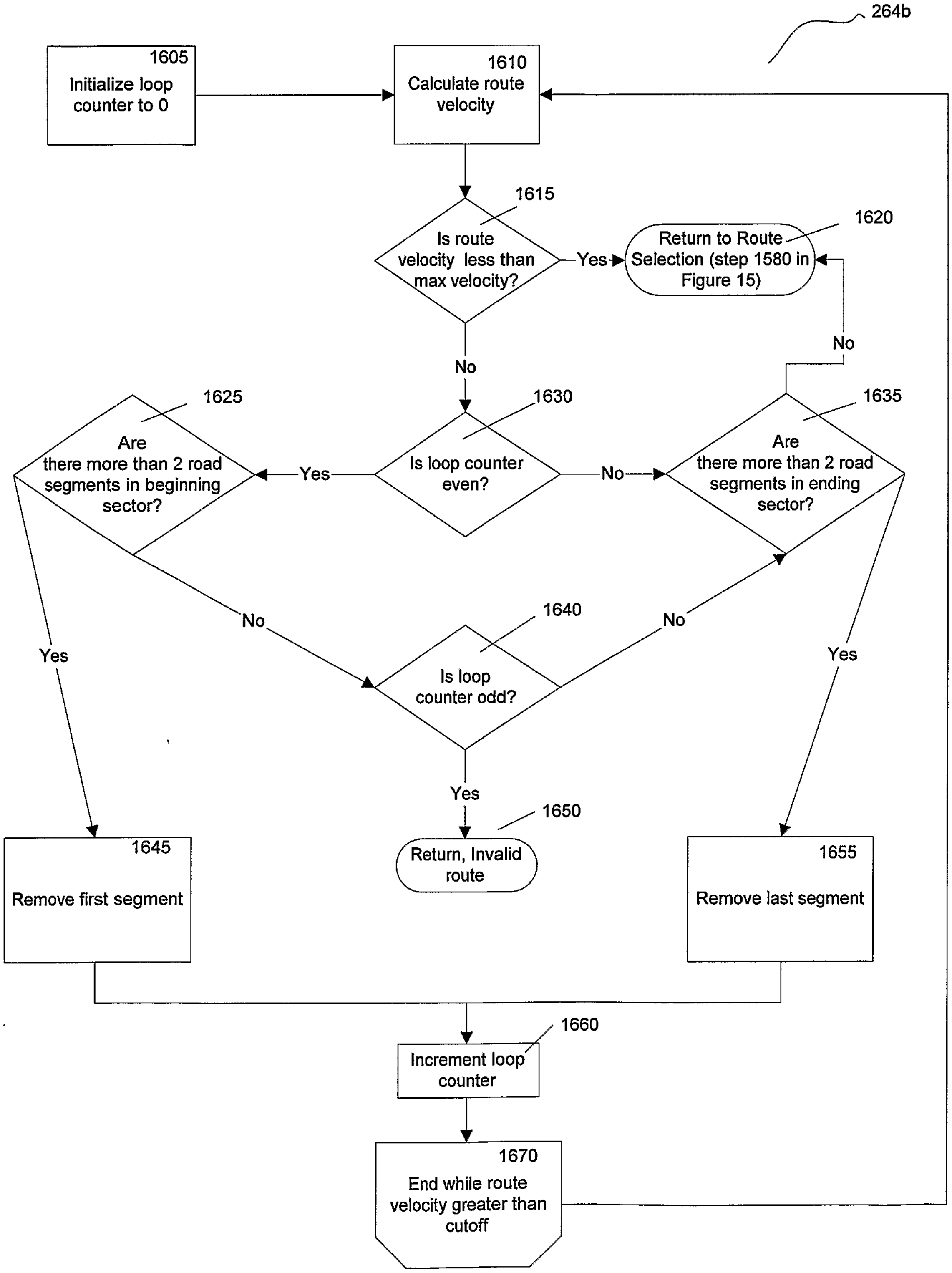


Figure 16: Route Trimming

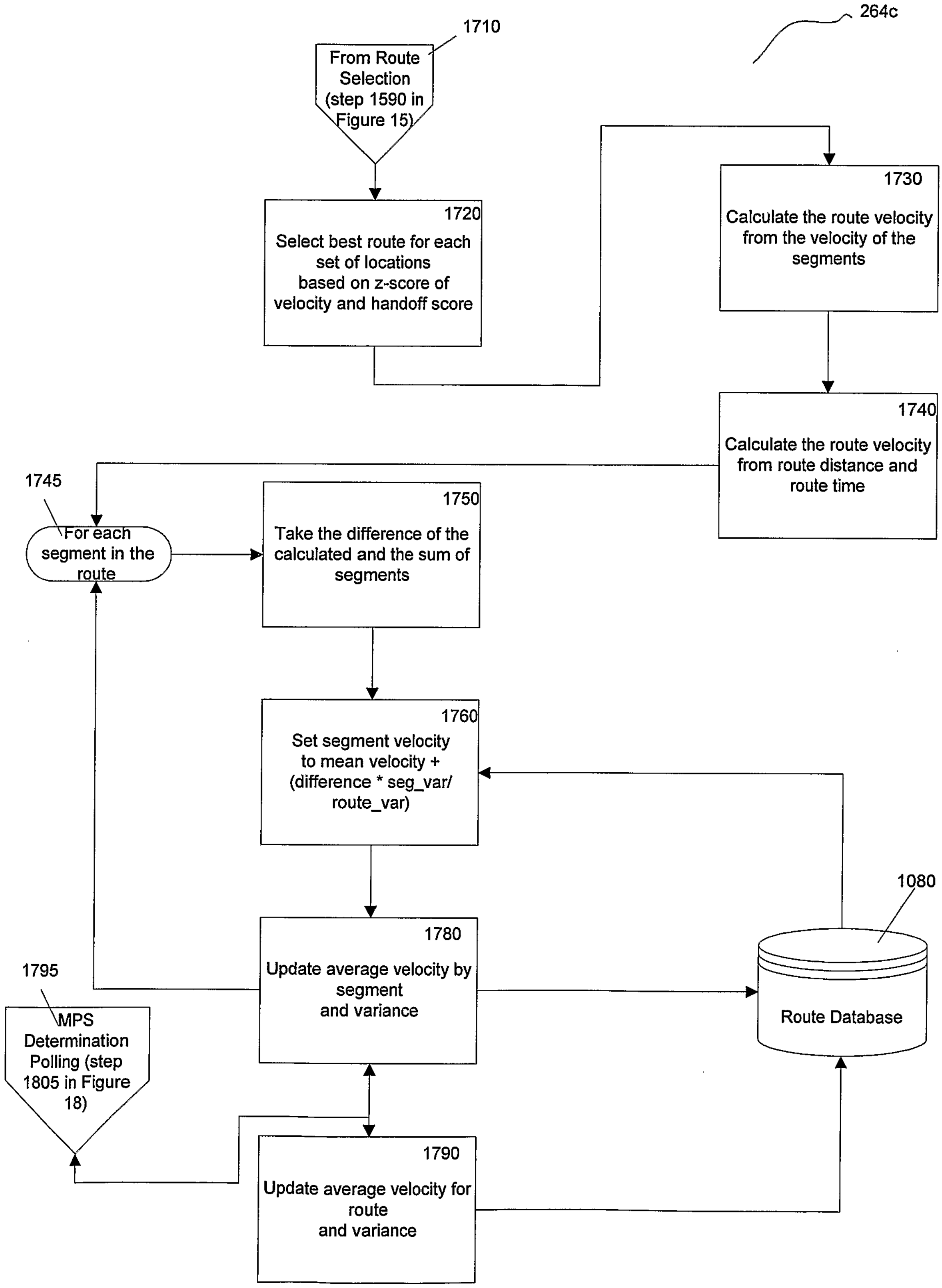


Figure 17: Velocity Estimation

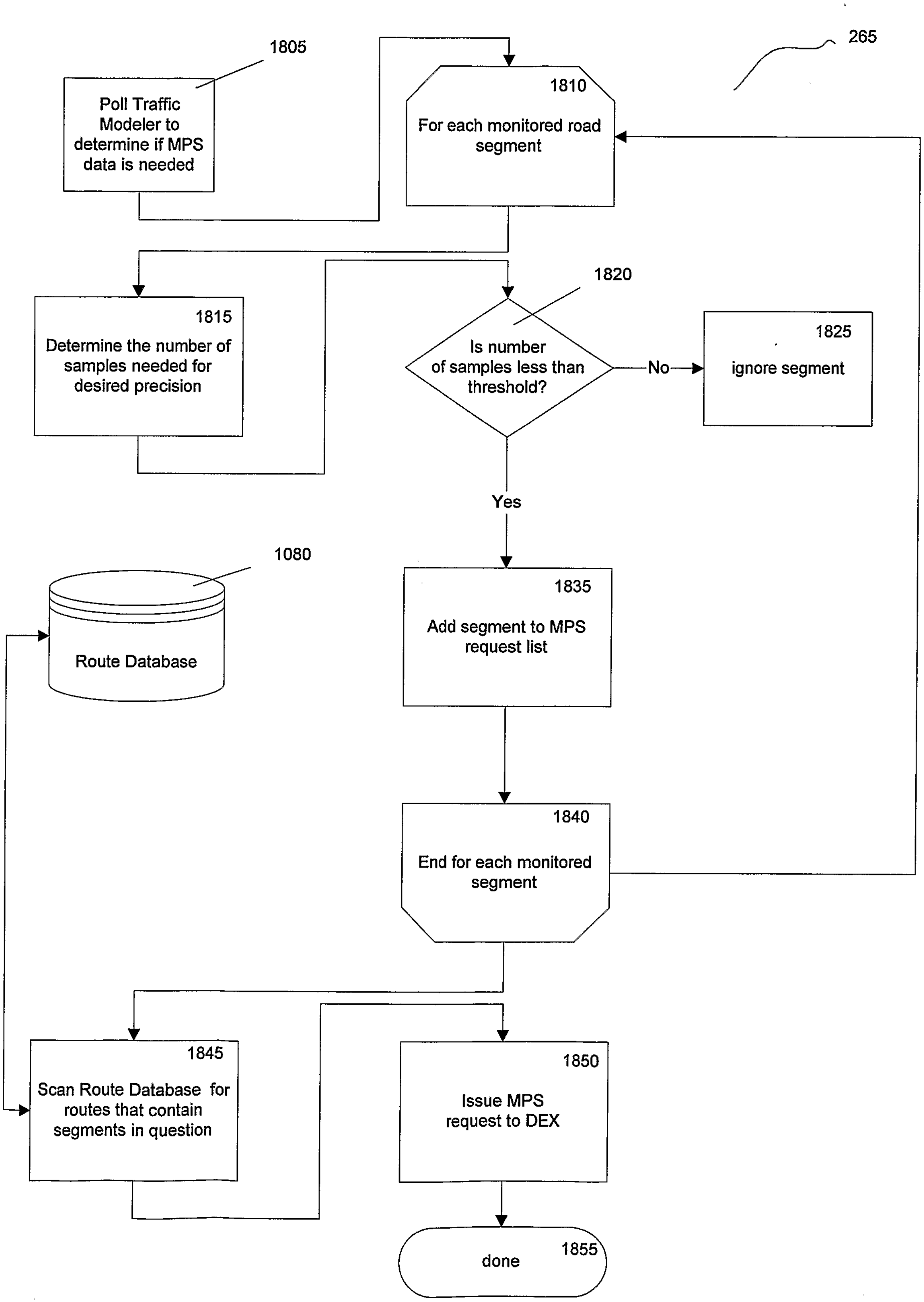


Figure 18: MPS Determination

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/29385

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04Q 7/20
US CL : 455/456,457,426; 340/870.01,870.07,539,988; 701/117,118,119,208
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 455/456,457,426; 340/870.01,870.07,539,988; 701/117,118,119,208

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,E	US 6,490,519 B1 (LAPIDOT ET AL.) 03 DECEMBER 2002 (03.12.2002), ALL	1-30
A,P	US 6,420,999 B1 (VAYANOS) 16 JULY 2002 (16.07.2002), ALL	1-30
A	US 5,023,900 (TAYLOE ET AL.) 11 JUNE 1991 (11.06.1991), ALL	6-16

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 December 2002 (04.12.2002)	19 DEC 2002

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Eugene Yun Telephone No. (703) 305-2689

Form PCT/ISA/210 (second sheet) (July 1998)