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(54) Title: CELLULAR NETWORK-BASED LOCATION SYSTEM
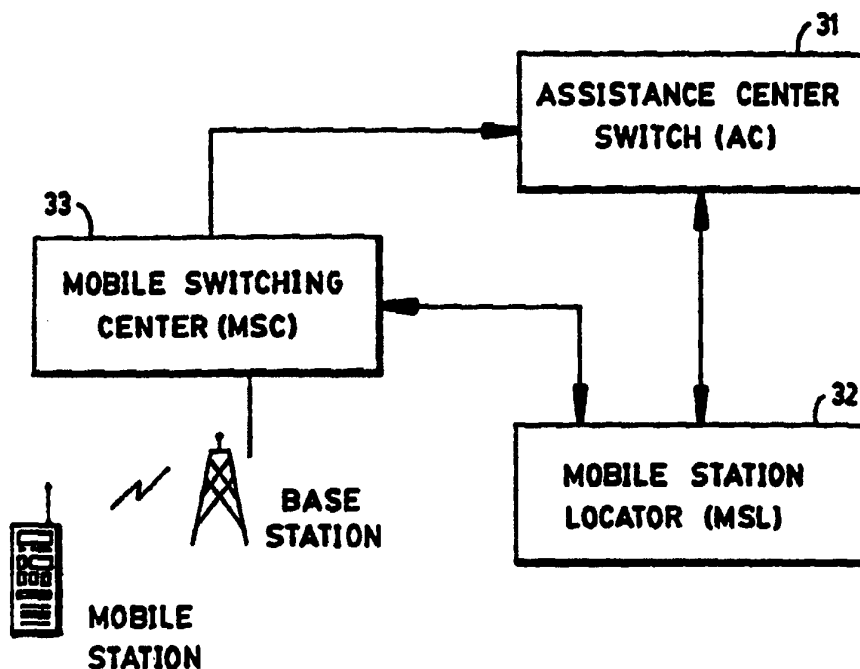
(57) Abstract

In a cellular system configuration, the location of a mobile station is determined from the acquisition of cellular network data pertaining to the mobile station, and the translation of such network data into a corresponding geographical position profile. The cellular system includes a mobile station locator (32) entity for receiving from a mobile switching center (33) the network data such as cell and/or sector ID and trunk group member number. The mobile station locator (32) translates the network data into position information such as geographic coordinates (latitude and longitude), resolution (radius), and angle values for sectorized cells.

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CELLULAR NETWORK-BASED LOCATION SYSTEM

Technical Field

       The present invention relates to cellular

5   communication systems and, more particularly, to a cellular
configuration for determining the location of a mobile
station.

Background Art

10   The increased terminal mobility offered by cellular
telephone networks as well as mobile radio data networks
has brought about an increased demand for location-based
services and applications. Fleet operators are interested
in automated vehicle tracking applications to enhance their

15   dispatch operations. Moreover, stolen vehicle recovery
systems have enjoyed a significant amount of success during
the past few years. However, most efforts to date have
been designed around specialized equipment employed at the
mobile operator site for acquiring location information.

20   For example, U.S. Patent No. 5,043,736 to Darnell et al.
discloses a cellular position locating system where the
location of a remote unit is derived from data transmitted
by a global positioning system to a specially equipped
receiver at the remote unit.

25

Disclosure of the Invention

       Accordingly, the present invention provides, in a
cellular system comprising a plurality of cell sites each
including a plurality of mobile stations in communication

30   with a base station, and comprising a plurality of
interconnected mobile switching centers each in
communication with the base stations of certain cell sites,
wherein each mobile switching center maintains network
identification data for each mobile station being served in

35   said certain cell sites, a method of determining the
location of a mobile station originating communications
within a cell site, comprising the steps of: acquiring the

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network identification data for said mobile station from
the mobile switching center serving said cell site; and
translating said acquired network identification data into
geographical location information.

5   In another aspect the present invention concerns, in a
cellular system comprising a plurality of cell sites each
including a plurality of mobile stations in communication
with a base station, and comprising a plurality of
interconnected mobile switching centers each in

10 communication with the base stations of certain cell sites,
wherein each mobile switching center maintains network
identification data for each mobile station being served in
said certain cell sites, a method of determining the
location of a mobile station originating communications

15 within a cell site, comprising the steps of:
transmitting from the mobile switching center a cellular
channel including the network identification data for said
mobile station; receiving the transmitted network
identification data; and translating the received network

20 identification data into geographical location information.

Brief Description of the Drawings
        Figure 1 is a flowchart depicting a communications
sequence in accordance with one embodiment of the present

25 invention;
        Figure 2 is a flowchart depicting a communications
sequence in accordance with another embodiment of the
present invention;
        Figure 3 is a block diagram of a mobile system

30 configuration employing the present invention; and
        Figure 4 is a detailed block diagram representation of
the mobile system configuration in Figure 3.

Best Mode for Carrying Out the Invention

35   The implementation of certain cellular services
requires that the mobile station location be made available
to the service provider. For example, in a 911 emergency

service, medical personnel need an accurate and precise
reading on the source of a distress call in order for
prompt medical attention to be made available within the
entire coverage area of single or multi-carrier cellular
5   networks. Although the location finding system disclosed
by Darnell et al., _supra_, conveys highly accurate
positional information from a modified mobile station
specially configured to interface with a GPS system, a more
desirable system from a subscriber perspective would keep
10   intact the existing mobile station configuration.

The present invention concerns an enhancement to the
existing cellular network topology permitting the
acquisition of a mobile station location using cellular
parameters from the network. The cellular parameters
15   define the placement of each mobile station within its
cellular network and its relationship to other mobile
stations. For example, the parameters may include data
identifying the communications trunk group serving the
mobile station, a member number, and cell and/or sector ID.
20   An accurate conversion of cellular data into a geographical
profile may be performed using radio plans as a
translational mechanism. The radio plans, which correspond
to geographic maps of radio coverage, furnish information
such as the latitude and longitude derived from the cell
25   base station antenna location, elevation, radius, and
angles for sectorized cells.

For purposes of discussion and clarity, the term
"mobile station locator" (MSL or "Locator") is used
hereinafter to encompass a facility, mechanism, or assembly
30   in whatever form implemented, constructed, or operable,
which interacts with and is the recipient of location-
determinative cellular data from the cellular network. The
MSL itself maintains an information resource responsive to
input cellular data for generating a corresponding
35   geographical location estimate. The resource is
constructed by accumulating position data from radio

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coverage maps, for example, where cellular data is
translatable into geographical information.

The basic configuration of a cellular network includes
a plurality of base stations defining cell sites and
5   providing wireless communication to mobile station units
within the cell site coverage area. The cellular network
is further configured with a plurality of mobile switching
centers in communication with the base stations and other
switching centers to perform processing and switching
10 functions enabling connections between mobile stations and
interfacing to external networks such as the PSTN.

In one embodiment of the present invention detailed in
the flow diagram sequence of Figure 1, a code representing
the identity of a mobile station is transmitted from the
15 mobile switching center (MSC or "Center")to the mobile
station locator. In particular, the identity code
corresponds to a mobile Identification Number (MIN) and/or
an Electronic Serial Number (ESN). The Locator then
queries the Center with the MIN, requesting network data on
20 the mobile station having the designated MIN. In response
to this query, the Center retrieves the requested
information such as trunk group and member number, and then
forwards it to the Locator. A translation operation at the
Locator converts the cellular network data into
25 corresponding geographical location information.

In another embodiment of the present invention
detailed in the flow diagram sequence of Figure 2, cellular
network data is transmitted along with the MIN from the
Center to the Locator; accordingly, in this embodiment, the
30 Locator does not prompt the Center for cellular data. In a
preferred implementation, the Center invokes the
transmission of cellular data pertaining to a mobile
station in response to a trigger command from the mobile
station represented by certain dialed mobile digits known
35 as a feature code.

Figure 3 is a system level block diagram
illustratively representing a cellular configuration for

implementing the present invention. For purposes of
investigating the location-finding capability, an
Assistance Center 31 was included to monitor the call from
the mobile station and the position information from the

5   Mobile Station Locator (MSL) 32. In particular, AC 31 is
an entity receiving a voice channel over a cellular link
connected to the Mobile Switching Center (MSC) 33, and
receiving the geographical location data from Locator 32.
The Assistance Center 31 includes a processing center with

10   dispatching and/or storage capabilities which receives user
calls and location data and provides services based upon
that information. The Assistance Center 31 specifically
contains equipment which provides the capability for a
call-taker (i.e., operator or dispatcher) to talk with the

15   cellular phone caller and display the caller's position on
a graphical display.
        The Mobile Switching Center 33 is a cellular telephone
network switch that provides processing and switching
functions to allow cellular phones to communicate with

20   other phones (cellular and wireline). The Mobile Station
Locator 32 is a facility performing the retrieval and
storage of location information pertaining to mobile
stations. In particular, Locator 32 receives, retrieves,
stores and processes location information, and then

25   furnishes it to AC 31. The Locator 32 is equipped with an
MSL-MSC Interface (MMI) that performs the retrieval of
location information from the Mobile Switching Center 33.
        Base stations, also called cell sites, are connected
to Center 33 and provide radio communication with the

30   cellular phones. Base stations can be configured with
omnidirectional or sectorized antennas. An omni cell
provides radio coverage radiating out from the cell center
in all directions; this type of a cell may be approximated
by a circle on a map. A sectorized cell has antennas which

35   provide coverage for a section of the circle; this type of
a cell may be approximated by a pie-wedge shape on a map.

The cellular configuration shown in Figure 3 was
exercised during a Location Assistance and Tracking
Information Service (LATIS) field trial demonstration to
explore the methods by which the location of a mobile
5 station (e.g., cellular phone) originating a call may be
made available to entities both internal and external to
the cellular network. The Locator 32 principally serves
the function of collecting location data from the cellular
network, translating it, and providing it to AC 31. The
10 location data comprised the geographic coordinates and size
of the serving cellular network cell site (e.g., base
station). The resolution of this location data was limited
by the size of the cell site; however, the resolution of
the data from multiple cell sites was enhanced by sector
15 information such as the cell subset/section.

The LATIS trial activated the acquisition mode to
determine a mobile station's position by engaging the
operator into initiating a call into the cellular network.
In particular, the mobile station operator dialed a
20 recognizable feature code (FC) on a standard cellular
phone. The Center 33 recognized the feature code and
connected the call to AC 31 for establishing a voice
connection between the answering personnel and the caller.

The acquisition of location information by Locator 32,
25 and its subsequent delivery to AC 31, is accomplished
during the LATIS trial by a first and second transport
scheme hereinafter designated Methods I and II. In Method
I, Center 33 transmits the caller's identity to AC 31 over
a network connection. The caller's identity is defined by
30 a Mobile Identification Number (MIN) which corresponds to
the telephone number of the station originating a call.
For the purposes of the trial, the MIN was ten (10) digits
in length.

The AC 31 responds by forwarding to Locator 32 a
35 message containing the caller's MIN in order to request
cellular data relevant to the MIN. The Locator 32 then
interacts with Center 33 to retrieve the cell-site trunk

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currently in use by that particular mobile station. The
Locator 32 converts the trunk information received from
Center 33 into a location "value" including a geographic
coordinate (latitude and longitude), a resolution parameter
5   (radius), and possibly two angle values (for sectorized
cells). This information is then formatted and transmitted
to AC 31 for graphical display. Depending upon the type of
base station currently serving the cellular phone, the
location value may be displayed by AC 31 in different ways,
10   such as with a circle described by the geographic
coordinate and the resolution, or a pie-wedge conveying
this information and supplemented with the two angle
values.

In Method II, Center 33 multiplexes the caller's
15   identity (e.g., MIN) with cellular network data and
transmits the combined signal to AC 31. For example,
Center 33 may outpulse the MIN plus a 5-digit code
representing the serving cell/sector. The AC 31 receives
this code and forwards it to Locator 32, which converts it
20   into a geographical location value that is transmitted to
AC 31 for graphical display. The following table
summarizes the features of the transport methods used
during the trial.

Location Transport Method	Mobile Dialed Digits (Feature Code)	Signaling Data Outpulsed from MSC to AC
I	*57	MIN(10)
II	211	MIN(10)+cell&sector(5)

Although the LATIS field trial included specific routes
35   for communicating cellular network data to Locator 32, these
routes are indicated for illustrative purposes only and should
not serve as a limitation of the present invention. Rather,
the cellular network data may be transmitted to Locator 32
directly or indirectly via any type of communications link.

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Furthermore, the network data may be transmitted before or contemporaneously with the voice channel. For example, the voice channel may be forwarded to AC 31 or another entity over one link, while the network data may be independently routed

5   over an alternative path to Locator 32. In addition, the MIN and/or network data (depending upon the application) may be multiplexed with the voice channel before transmission from Center 33.

Likewise, even though in Method I the Locator 32 was

10   prompted with the MIN by Assistance Center 31, and in Method II the cell/sector location data was initially transmitted to AC 31 before being coupled to Locator 32 for conversion, this supervisory/coordinating role of AC 31 should not serve as a limitation of the present invention. Rather, it should be

15   apparent to those skilled in the art that the MIN for Method I and the cellular network data for Method II could be transmitted directly to Locator 32 from Center 33, while the voice communication would be separately transmitted by Center 33 to AC 31 or any other end user.

20   Figure 4 is a further block diagram representation of the cellular configuration in Figure 3. The specific components, subsystems, and other entities mentioned in conjunction with Figure 4 should not be viewed as a limitation of the present invention, but as representative of one implementation of the

25   cellular configuration. It should be apparent to those skilled in the art that the functions demonstrated in Figure 4 may be implemented by other equivalent means.

The mobile station employed standard cellular phones such as Motorola transportable cellular phones which did not

30   require any non-standard modifications. The phones were initialized with MINs (telephone numbers) from the serving GTE Mobilnet cellular system so that the phone would be on its "home" system throughout the trial.

The Mobile Switching Center 33 was an AT&T Autoplex

35   System 1000 comprising one Executive Cellular Processor (ECP) 41 and several Digital Cellular Switches (DCS) 42. Each DCS 42 is connected to several base stations (cell sites). The

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only hardware modification made to Center 33 was the
connection of a dedicated T-1 span (trunk group) to carry the
test calls to an Assistance Center Switch 43. The link
between the DCS 42 and ACS 43 is designated interface A in
5 Figure 4.

The ECP 41 was modified to provide the necessary digit
translation, call routing, and trunk signaling. The following
discussion enumerates the modifications made to certain forms
of ECP 41.

10 (1) The Subscriber and Feature Information Form was modified
        to add Primary Dialing Class 22. The MIN of each test
        phone was part of Dialing Class 22; this class was
        created for the trial to restrict the dialing
        capabilities of the test phones and to prevent
15   interference with the live traffic.

    (2) Pattern matching was added to the Dialing Plan form
        (DPLAN). These modifications specified the feature codes
        that were used. If the dialed digits received form the
        mobile station matched *57 (Method I), or 211 (Method
20   II), a Destination Index of 911 for the DXDRTE route and
        a Dialed Number Modification (DNMOD) of 13 were assigned.
        If the digits matched *58 + 12 or more digits (which
        would be latitude/longitude), a Destination Index of 911
        and a DNMOD of 14 were assigned.

25 (3) Dialed Number Modification (DNMOD) 13 performed cell and
        sector matching. If the call originated from one of the
        cells/sectors in the table, a corresponding set of digits
        was added to the dialed digits (*57 or 211), and the
        entire set was routed to the Digit-By-Digit Call Routing
30   (DXDRTE).

    (4) Dialed Number Modification (DNMOD) 14 performed latitude
        and longitude translation. The *58 was deleted from the
        incoming digits, and the remaining lat/long digits were
        routed to the Digit-By-Digit Call Routing (DXDTRE).

35 (5) The Digit-By-Digit Call Routing (DXDTRE) assigned an
        outgoing trunk group and outpulsed the digits. The
        Feature Group D signaling method was used. The caller's

MIN was outpulsed in the ANI (Automatic Number
Identification) field, and the digits sent by the DNMOD
forms were outpulsed in the Called Address field.

5   As noted above, Assistance Center 31 in Figure 3 is
equipped with means for communicating with the mobile station
via the cellular network over a communications link such as a
voice channel, and for receiving and displaying the
geographical position information of the mobile station
10 caller.   The Assistance Center 31 is represented in Figure 4
as an Assistance Center Switch (ACS) 43 and an Assistance
Center Dispatch Station 46, discussed _infra_. The ACS 43
contains telephone switching equipment capable of receiving
and discerning identity and location information pertaining to
15 incoming calls, and routing those calls to operators as
necessary.
        The ACS 43 is configured to include a Summa Four SDS-500
switch 44 which was configured with two T1 cards, one used
during the trial and the other used for testing.   The ACS 43
20 may further include a dial tone generator, an MF (multi-
frequency) card for inband signaling-data capture, and an SLIC
card to control attached telephone sets if so desired.   A
dedicated T1 span (interface A) from Center 33 was connected
to one of the T1 cards; calls from Center 33 entered through
25 ports on this card.   The SDS switch 44 was controlled by an
SDS host 45 which was running the SDS control software.   The
switch 44 communicated switch-related information and activity
to the host 45 through reports; the host 45 issued commands to
control the switch 44; and the switch 44 responded to commands
30 with responses.   The SDS host machine 45 was an HP-9000 series
workstation.
        The control software for the switch 44 was written in the
C programming language and comprised five main modules
(discussed _infra_) to execute the functions of receive
35 messages, send messages, signal capture, analyze number, and
prepare MSL input.

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Receive Messages module

This module received messages from the SDS switch 44.
This module was designed to support different types of
applications; based upon the destination code and function ID
5   in a message, the message was forwarded to an application
module. For the trial, only one module, namely the signal
capture module, was used.

Send Messages module

10 This module received messages from host modules and
queued them for transmission to the switch. It returned
several status responses to the calling module, including
socket full/output pending and communication error.

15 **Signal Capture module**

This module reacted to changes in the T1 and telset
resources; these changes were sent to the host via Inpulse
Rule Complete reports, Incoming Port Change reports, Outgoing
Port change reports, or responses to Outgoing Port Control
20 commands. Based upon the report, a command was built and sent
to the switch via the Send Messages module. The commands
included the resource's virtual communication address, and
were formulated with the SDS Application Program Interface
(API).

25 The Inpulse Rule Complete report indicated that the
signaling information from an inbound call (on the T1 span)
was complete. The received signaling data were then sent to
the Analyze Number module for analysis and further action.

30 **Analyze Number module**

This module analyzed the digits received by the signal
capture module to determine which set of location data it
contained (e.g., latitude & longitude, cell & sector, or
none). The location data were then reformatted into a
35 location information set and sent to the Prepare MSL Input
module.

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Prepare MSL Input module

This module prepared a location record for the MSL from the given location information set. If any error in the location set was detected, an appropriate error message was

5   written to a log file. Otherwise, a data record was passed immediately to Locator 32 via the Send Messages module.

Additionally, this module sent an Outgoing Port Control command to the switch to perform an Outpulse Rule (ringing, etc.) for an ACDS telset (discussed _infra_). Since six telsets

10 were used, if the first one was busy, the second one rang; if they both were busy, the call was queued (with ringback heard by the caller), and the first available telset received the call.

As noted above, the Assistance Center may also include an

15 Assistance Center Dispatch Station (ACDS) 46 for housing telephone dispatching equipment 47 that enables an operator to talk with a caller and process the caller's location. This phone equipment would be interfaced to the SDS switch 44 through the SLIC card.

20   The ACDS comprised six standard telephones 47 and one HP-9000 series workstation 48. The telephones 47, connected to the ACS 43, allowed the operator to communicate with the callers/testers. Two software applications ran on the workstation: a Geographic Information System (GIS) for

25 electronic mapping of callers' locations and a Graphical User Interface (GUI) which allowed the operator to quickly collect test scenario data.

The Geographic Information System is an X Window application which displays geographic data. In addition, GIS

30 contains highly powerful algorithms for determining the shortest route/path between any two or more points. The following features were specifically added for use in the trial.

*   A feature was added to display incoming location data

35   with a car icon; this corresponded with "exact" locations
         where latitude and longitude data were present.

*   A feature was added to display incoming location data
    with a circle; this corresponded with locations from
    omni-directional base stations.

*   A feature was added to display incoming location data as
5   a pie-wedge (section of a circle); this corresponded with
    locations from sectorized base stations.

*   Capabilities were added to retrieve and delete the
    information related to a call. While any icon was
    illuminated, the operator could click on the icon and
10 retrieve the specific information related to that call:
    MIN, latitude & longitude (if applicable), and
    cell/sector values (if applicable). The operator could
    also delete the entry, at which point the icon would be
    removed.

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The GUI assists the operator in the gathering of
necessary information. The GUI was built using X
Windows/Motif 1.1 widget family, and includes a menu bar with
twelve fields which the operator can fill with test
20 information. The fields are delineated below.

    (a) Dialing MIN: The tester's MIN.
    (b) Date: The date and times were obtained from the
            workstation's operating system.
25 (c) Dial Type: The dialing types (Method I or II) are listed.
    (d) Cell: The name and number of the test cells were listed.
    (e) Cell_id: The number of the cell used.
    (f) Sector: The sector used by the tester in that cell.
    (g) Caller: Caller's name.
30 (h) Call_taker: The operator's name.
    (i) Weather: Four conditions were listed: sunny, partly
            cloudy, rainy, and foggy.
    (j) Location: Thirty-two pre-assigned test locations were
            listed.
35 (k) Result: Pass or fail result was given to each test_index.

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(1) Duration: Three call-duration times were listed: less
    than ten seconds, less than one minute, and greater than
    one minute.

5   A comment field was also provided to function as a server
for location information. The Mobile Station Locator 32 was
implemented with an HP-9000 series workstation.

        The Locator 32 included an MSL Host & Server unit 49
10 containing software written in C and comprising the following
six modules: main control, request, query-one, query-all,
database-retrieval, GIS-interface. The MSL server 49 was
designed to handle multiple simultaneous calls and operated as
follows. The main control module waited for an incoming
15 request from the ACS 43 (via interface B). For each incoming
call, if the location data were present, the MSL server 49
translated it (if necessary) and formatted a data message
which was sent to the ACDS 46. If the incoming call did not
contain location data, the MSL server 49 checked if
20 information from a Mobile Switching Center was included; if
the Center was known, Locator 32 interacted with that
particular Center using the query-one module. If the Center
was not known, Locator 32 had the capability to interact with
all connected Mobile Switching Centers using the query-all
25 module. Both types of query modules were designed to use an
MSL-MSC interface module 50, discussed below.
        To ascertain the performance of the Mobile Station
Locator 32, the main control module recorded the following
events, with time-stamps, in log files:
30 *   incoming mobile station call message received;
    *   query sent to MSC interface process by the MSC query
        process;
    *   query response received from the MSC interface process;
        and
35 *   mobile station location record sent to ACDS.

MSL-MSC Interface

The purpose of the MSL-MSC Interface (MMI) module 50 is
to perform MSC-specific processing to retrieve location
information. The MMI 50 was written as an Expect script using
5   TCL (Tool Command Language). The MMI 50 login routine
established a connection with the Autoplex ECP 41 Recent
Change port through the workstation's serial port. During the
trial, this connection involved dialing a modem and logging
into the ECP 41, all of which were handled automatically by
10   the MMI 50. Once a connection was established, the MMI 50
main program continuously scanned an input file for query
requests from the MSL server 49.

When a query request was found, the MMI 50 would issue an
OP:DN command to the ECP 41; this command would contain the
15   MIN received from Locator 32 in the query request message.
Under normal operating circumstances, ECP 41 would return an
MCR (Mobile Call Register) value. The MMI 50 would then issue
an OP:MCR command with the MCR value. Under similar operating
circumstances, ECP 41 would return, among other data, the cell
20   site trunk information corresponding with the trunk currently
serving the mobile station. The MMI 50 returned this
information (trunk group and member number) to the MSL server
49 by writing it into an output file. If any errors were
encountered, the MMI 50 would write an appropriate error
25   message into the output file.

MSL Data Message Formats and Translations

The Locator 32 receives location data and performs
conversions to provide a uniform output message format to
30   applications (API). An illustrative output message format is
as follows:

cell and sector	4	characters
longitude	8	
latitude	8	
elevation	5	
radius	5	
starting angle	5	

      real coverage angle 5

      message/comments   125

A space was used to delimit each field.

5   The MSL host 49 executes certain conversion operations to properly translate the cellular network identification data for a specified mobile station into geographical position information. For example, transport Method I provides trunk group and member number data from the MSL-MSC Interface 50 to

10 the MSL host 49. This data is translated in a first conversion operation into cell ID and sector ID information. In a second conversion operation, employed as a principal operation for transport Method II or as a secondary operation for transport Method I, the input data comprising cell/sector

15 ID is converted into latitude and longitude, resolution (radius), angle 1, and angle 2.

      The conversion operations are preferably performed using indexable tables previously generated and stored at Locator 32. The data for the first conversion operation was obtained,

20 for example, from lists of trunk groups and member numbers used by each cell site (categorized by cell ID and/or sector ID). The data for the second conversion operation was gathered from radio plans (geographic maps of radio coverage) for the cells chosen for the trial, and organized into a

25 tabular format. The latitude and longitude of each cell were taken directly from these radio plans using the base station antenna location as an index. The angles for sectorized cells were also extracted from the radio plans and other tables. The resolution of each cell/sector was determined from the

30 radio plans as the distance from its center to the furthest point that provided at least -75dB radio signal coverage. The -75dB figure was preferably used as a measure of the signal strength necessary to qualify as a threshold for handoff.

      The following describes the interfaces among the units

35 represented in Figure 4.

      (1) MSC-ACS Interface (link "A")

This is a T1 span with Feature Group D (FG-D) signaling.
The MSC 33 outpulsed ANI (the mobile's MIN) and,
depending upon the location-transport method, a string of
dialed digit which contained information pertaining to
the location of the caller.

(2) ACS-MSL interface (link "B")
This is a file-transfer interface between the SDS host 45
and the MSL Server 49 processes. For all mobile-
originated calls, a request message including the
mobile's MIN and optional location information was
written by the SDS Host 45 into a file. The MSL server
49 read the data from the file. The SDS Host 45 and MSL
processes were executed on separate machines connected
through an ethernet link.

(3) MSL-MSC interface (link "C")
This is a serial connection between the MSL interface
unit 50 and the MSC's recent change port. Since Locator
32 is located remotely from Center 33, modems are used on
a dial-up telephone line. The MSL's MMI 50 interacted
with the MSC 33 to retrieve serving trunk group and
member number data for a given MIN when transport Method
I is operational.

(4) MSL-ACDS interface (link "D")
This is a file-transfer interface between the MSL Server
49 and the ACDS 46 application processes. The MSL writes
its output messages containing the geographic location
information into a file which is read by the ACDS
application (GIS). Since the MSL and ACDS processes are
executed on separate machines, an ethernet connection was
used to transport the file read-write messages.

As an alternative to the location-finding schemes
discussed above, the geographical location data may be
obtained at the mobile station site using an enhanced mobile

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unit interfaced to an external position location system such
as a GPS satellite. Location data for this service consisted
of the latitude and longitude information uploaded by the
enhanced mobile station. The resolution of this data was
5 dependent upon the capabilities of the positioning equipment
used at the mobile station.

For this service (designated transport Method III), an
"enhanced" cellular phone employed an attached positioning
device capable of determining the current location of the
10 mobile unit. At the mobile operator's command, the enhanced
phone read the current location information from the
positioning device and automatically initiated a call. The
dialed digits comprised a feature code plus the latitude and
longitude location information. The Mobile Switching Center
15 recognized this feature code and connected the call to the
Assistance Center. In particular, the Switching Center
outpulsed the MIN plus the latitude ('lat') and longitude
('lon') which were included in the digits dialed by the
cellular phone; the 'lat' required eight digits, and the 'lon'
20 required seven digits. The Switching Center transmitted this
information to the Station Locator, which reformatted it and
sent it to the Assistance Center for graphical display.
Transport Method III is summarized in the following table.

25 Location Transport Method	Mobile Dialed Digits	Signaling Data Outpulsed to AC from MSC
III	*58+lon(8)+lat(7)	MIN(10)+lon(8)+lat(7)

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The implementation of transport Method III required
certain modifications to the mobile system configuration
described above. The following discussion recites the
enhancements made for the GPS-based implementation.

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Enhanced Cellular Phones

Five GTE CCP-2000 Cellular Credit Card Phones (CCP) were
modified for use in the aforementioned LATIS trial to

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implement Transport Method III. The modifications included
the software and hardware revisions noted below.

Hardware modifications included the following.
5   *   The RJ-11 data jack on the side of the CCP was modified
          to connect directly to the serial port of the CCP's
          microprocessor. This allowed the CCP to communicate with
          an attached positioning device via a serial link.

10   Several modifications were made to the CCP's operating
     software.
          *   The software polled the serial port once every second
               looking for location data from the connected positioning
               device. If data was found and valid position information
15   was included, the data was flagged as valid and stored in
               a buffer. If no data was found, or if invalid position
               information was included, the data was flagged as
               invalid.
          *   The software displayed a location status on the CCP's
20   display. If location data flag indicated valid data in
               the buffer, the display would be updated with latitude
               and longitude information alternating every five seconds.
               If the data was flagged as invalid, an "Invalid Loc Data"
               message was displayed every five seconds.
25   *   The function of the "Data" key was changed to provide the
          following functionality. When the Data key was pressed
          by a user/tester, the CCP would automatically initiate a
          call. The dialed digits included a 3-digit programmable
          feature code (FC) followed by 15 digits of position
30   information (8 longitude digits followed by 7 latitude
          digits). Once the call was successfully initiated,
          control of the CCP was returned to the tester.
          *   The "Lock" key functionality was modified such that it
               would act as a toggle for a Tracking Mode. If the
35   Tracking Mode was currently off when the Lock key was
               pressed, the CCP software would enable the mode; if the
               mode was on when the key was pressed, the software turned

off the mode. While in the Tracking Mode, the CCP
software maintained complete control of the phone; the
tester could only press the Lock key, which would lead to
the mode being disabled and control returned to the
5   tester. While in the Tracking Mode, the CCP would
initiate calls automatically in a pre-programmed
interval. The call initiation was identical to that
corresponding to the Data key press, but the duration of
the call and the time between calls were determined by a
10   set of programmable parameters.
*   The CCP's service utility was modified to allow the
feature code for the Data key to be programmed.
Modifications were made also to allow programming of the
feature code, call duration, and between-call interval
15   for Tracking Mode.

The positioning devices were Lowrance OEM GPS receivers,
although any such geographical positioning system may be
employed. These receivers were capable of receiving signals
20 from location acquisition systems such as GPS satellites,
processing the signals, and computing a location estimate
based on those signals. One GPS receiver was connected to
each CCP-2000 phone through a serial data cable. The GPS
receivers automatically forwarded location information
25 messages once every second. These messages contained the
receiver status, position status, and position information.
The resolution of GPS receivers is highly dependent upon
environmental factors and varies continuously. Under typical
conditions, a GPS receiver that is receiving data from three
30 or more satellites will have an accuracy of 50 to 100 meters.
While there has been shown and described herein what are
presently considered the preferred embodiments of the
invention, it will be apparent to those skilled in the art
that various changes and modifications can be made therein
35 without departing from the scope of the invention as defined
by the appended claims.

CLAIMS:

1.   In a cellular system comprising a plurality of cell sites
      each including a plurality of mobile stations in
      communication with a base station, and comprising a
5   plurality of interconnected mobile switching centers each
      in communication with the base stations of certain cell
      sites, wherein each mobile switching center maintains
      network identification data for each mobile station being
      served in said certain cell sites, a method of
10   determining the location of a mobile station originating
      communications within a cell site, comprising the steps
      of:
      acquiring the network identification data for said mobile
            station from the mobile switching center serving
15   said cell site; and
      translating said acquired network identification data
            into geographical location information.

2.   The method as recited in claim 1 wherein the acquiring
20   step includes the steps of:
      transmitting from the mobile switching center a cellular
            channel including an identity code assigned to the
            communicating mobile station;
      prompting the mobile switching center with said identity
25   code to request network identification data for said
            communicating mobile station;
      at the mobile switching center, responsively retrieving
            the requested network identification data using the
            identity code; and
30   transmitting the network identification data from said
            mobile switching center.

3.   The method as recited in claim 2 includes the step of:
      developing an information array at the mobile switching
35   center including entries for each mobile station in
            said cell site indexed by a respective identity
            code.

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4.   The method as recited in claim 2 wherein:
     said cellular channel further includes the mobile station
          communication.

5.   The method as recited in claim 1 wherein the translating
     step includes the steps of:
     generating a database correlating network identification
          data for each mobile station with respective
          geographical location information; and
     retrieving geographical location information from said
          database for said communicating mobile station using
          said acquired network identification data as an
          index into said database.

6.   In a cellular system comprising a plurality of cell sites
     each including a plurality of mobile stations in
     communication with a base station, and comprising a
     plurality of interconnected mobile switching centers each
     in communication with the base stations of certain cell
     sites, wherein each mobile switching center maintains
     network identification data for each mobile station being
     served in said certain cell sites, a method of
     determining the location of a mobile station originating
     communications within a cell site, comprising the steps
     of:
     transmitting from the mobile switching center a cellular
          channel including the network identification data
          for said mobile station;
     receiving the transmitted network identification data;
     and
     translating the received network identification data into
          geographical location information.

7.   The method as recited in claim 6 wherein the translating
     step includes the steps of:

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generating a database correlating network identification
data for each mobile station with respective
geographical location information; and
retrieving geographical location information from said
5   database for said communicating mobile station using
said acquired network identification data as an
index into said database.

8.   A location-finding assembly in a cellular system, said
10   system servicing a plurality of mobile stations through a
base station connected to a mobile switching center,
comprising:
server means responsive to a location request for
prompting the mobile switching center for network
15   data on a base station;
said server means including means for receiving network
data from the mobile switching center, and means for
converting said network data into a corresponding
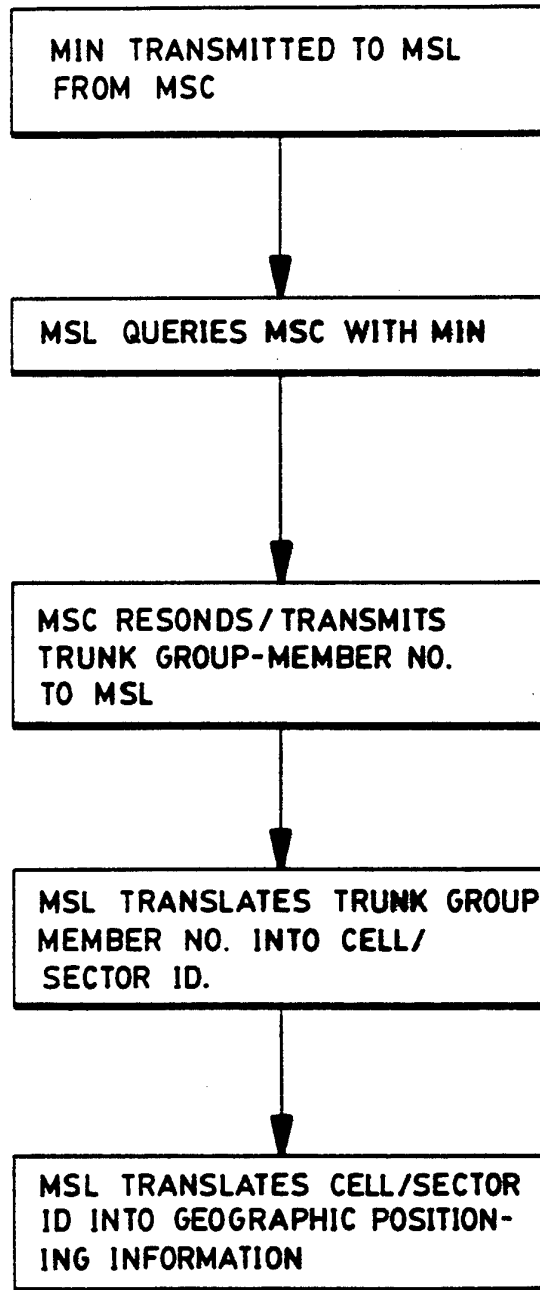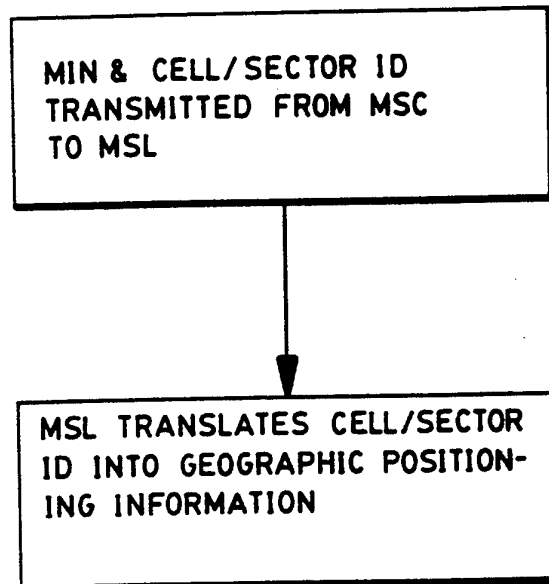geographical position profile.

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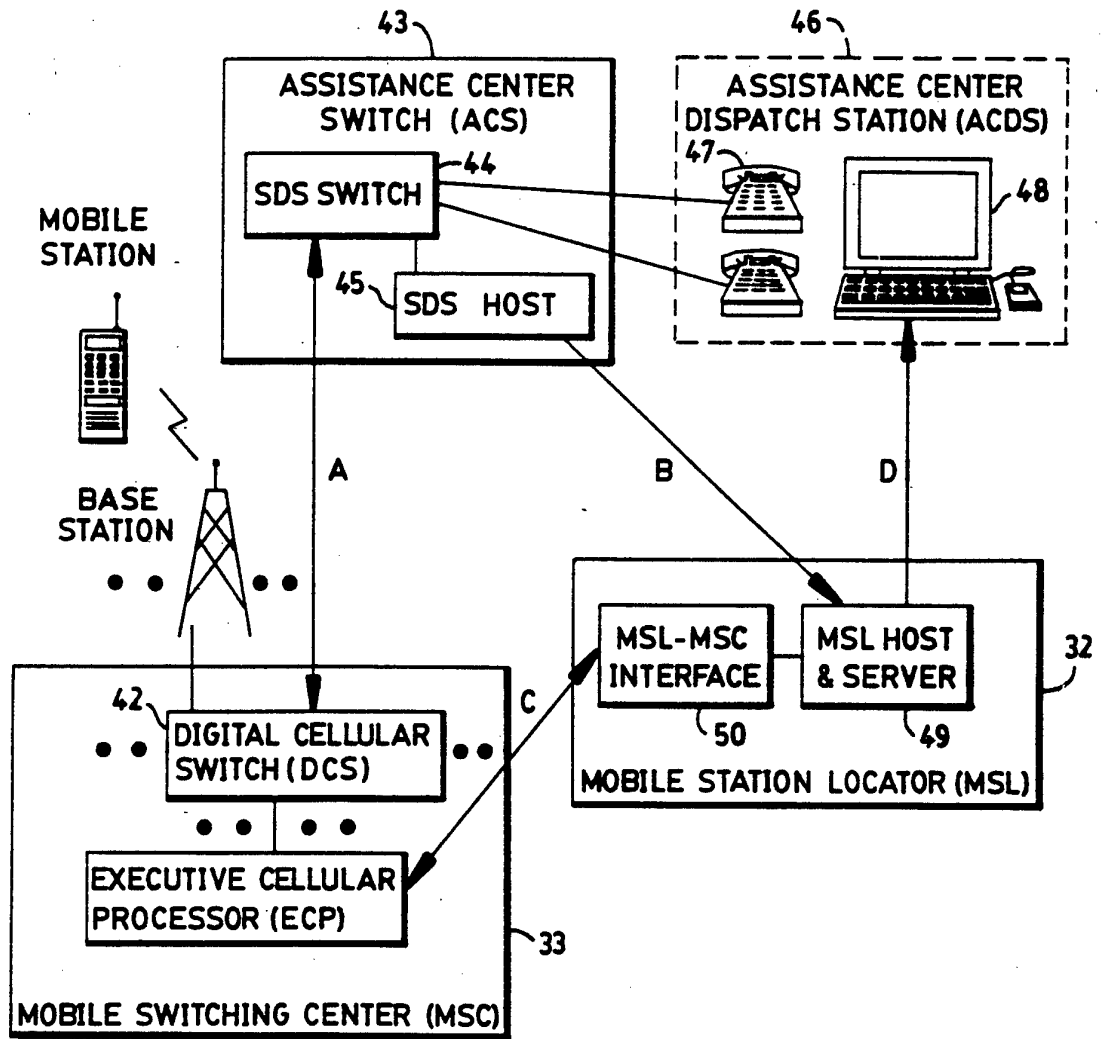
MIN TRANSMITTED TO MSL
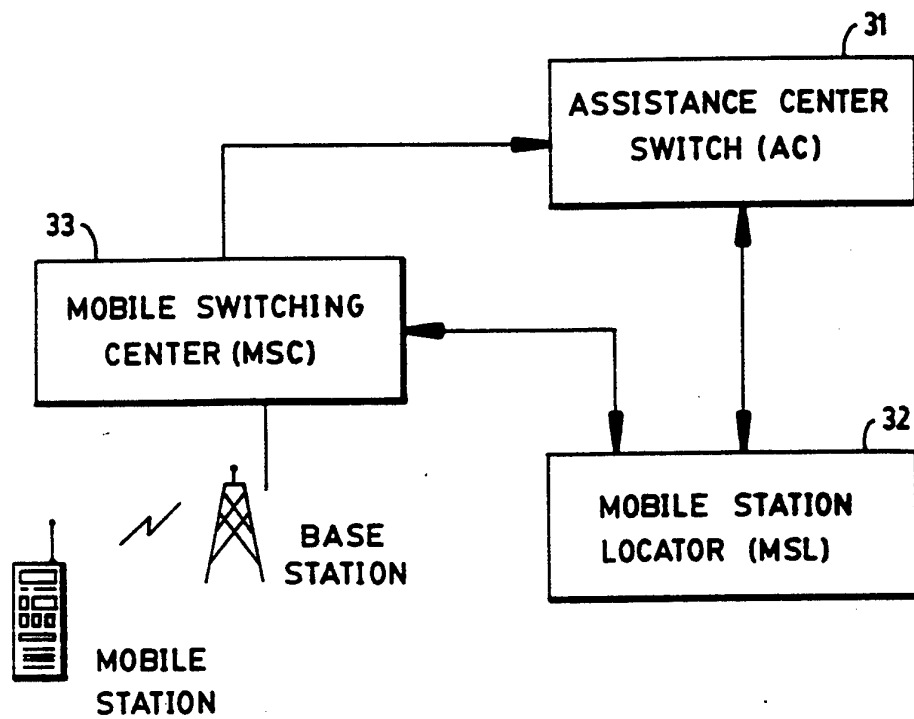FROM MSC

MSL QUERIES MSC WITH MIN

MSC RESONDS / TRANSMITS
TRUNK GROUP-MEMBER NO.
TO MSL

MSL TRANSLATES TRUNK GROUP
MEMBER NO. INTO CELL/
SECTOR ID.

MSL TRANSLATES CELL/SECTOR
ID INTO GEOGRAPHIC POSITION-
ING INFORMATION

FIG. I

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┌─────────────────────────────┐
│                             │
│  MIN &  CELL/SECTOR ID      │
│  TRANSMITTED FROM MSC       │
│  TO MSL                     │
│                             │
└─────────────┬───────────────┘
              │
              │
              ▼
┌─────────────────────────────┐
│                             │
│  MSL TRANSLATES CELL/SECTOR │
│  ID INTO GEOGRAPHIC POSITION-│
│  ING INFORMATION            │
│                             │
└─────────────────────────────┘
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FIG. 2

FIG. 3

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FIG. 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04Q 7/22, 7/28, 7/34
US CL :379/59
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. : 379/59, 60; 455/33.1, 33.2; 340/998, 989, 990, 993, 995; 342/454, 457

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

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
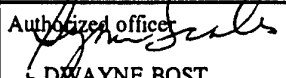
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,055,851 (SHEFFER) 08 October 1991; see Abstract, column 4, line 58 through column 5, line 30.	1-8
A	US, A, 5,235,633 (DENNISON et al.) 10 August 1993; see Abstract.	1-8
A, P	US, A, 5,327,144 (STILP et al.) 05 July 1994; see Abstract.	1-8
A, P	US, A, 5,398,190 (WORTHAM) 14 March 1995; see Abstract.	1-8

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

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be part of particular relevance		
"E"	earlier document published on or after the international filing date	"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
"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)	"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
"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	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 JULY 1995	21 AUG 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer DWAYNE BOST
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