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(54) **MULTI-MODE INTEROPERABLE MOBILE STATION COMMUNICATIONS ARCHITECTURES AND METHODS**

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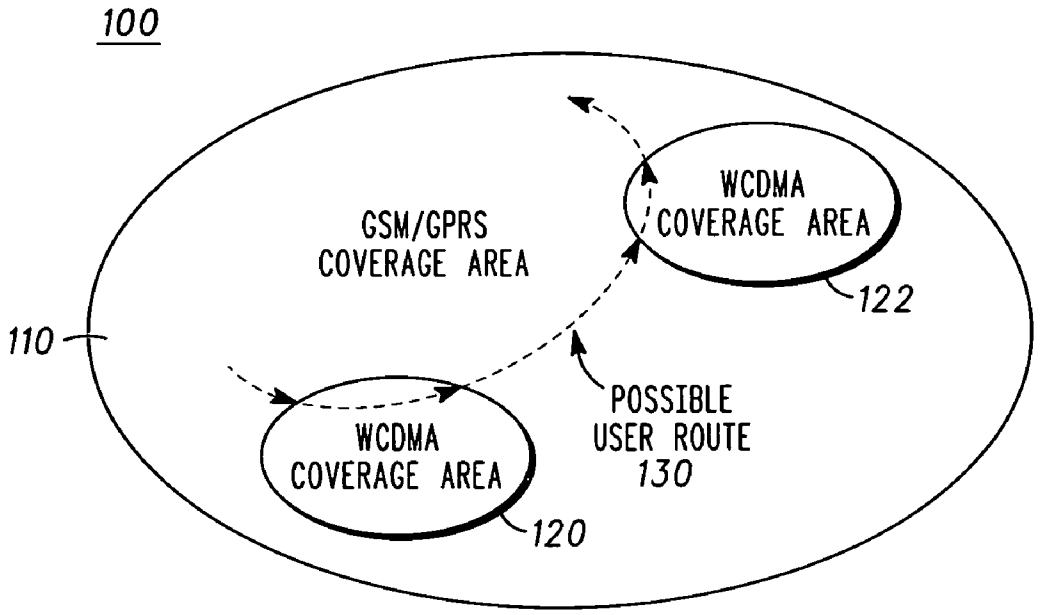
(57) **ABSTRACT**

A multi-mode mobile wireless communications device architecture **(200)** including an application layer **(210)**, a services layer **(220)** interfacing the applications layer, a multi-mode layer **(230)** interfacing the service layer, and a hardware layer **(240)** interfacing the multi-mode layer. The multi-mode layer includes first and second interoperable radio access technologies, for example W-CDMA UMTS and GSM/GPRS technologies.



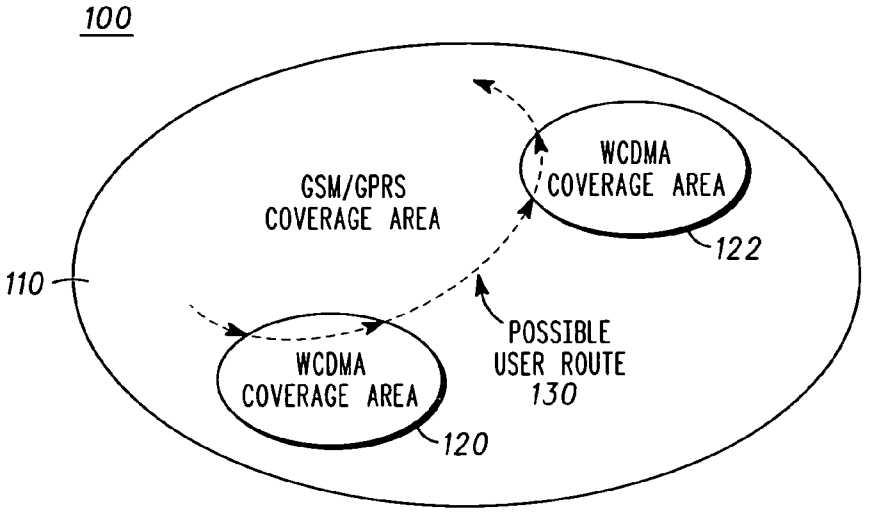

100
GSM/GPRS
COVERAGE AREA
WCDMA
COVERAGE AREA
122
110
POSSIBLE
USER ROUTE
130
WCDMA
COVERAGE AREA
120

FIG. 1

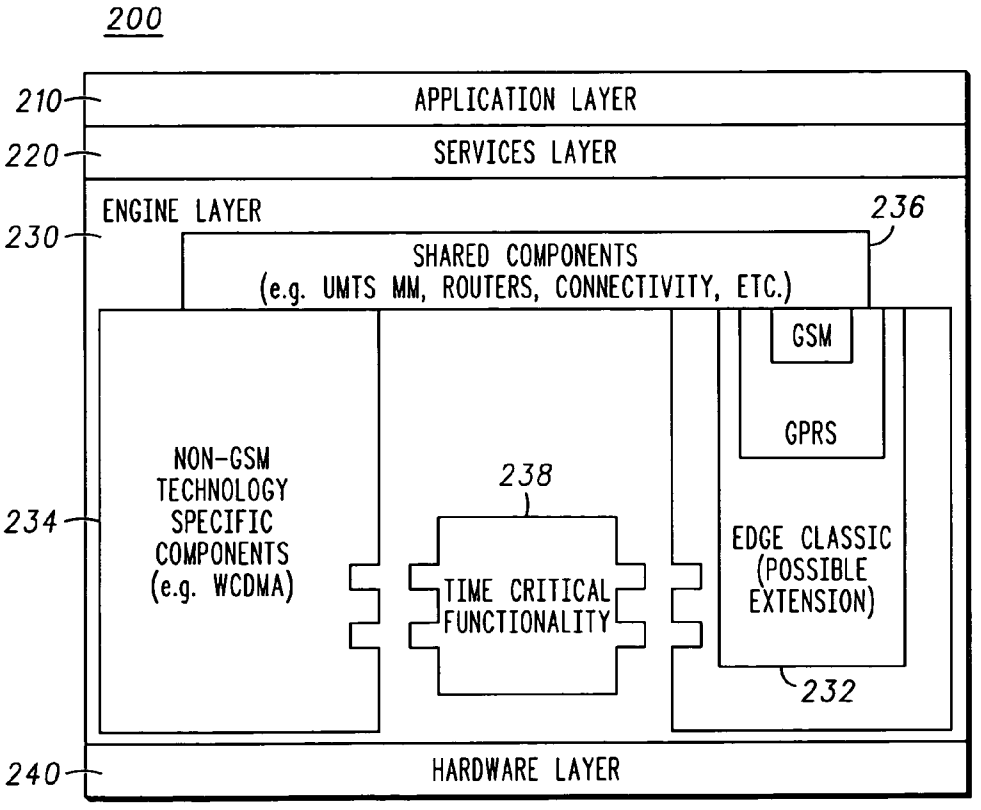

200
210
APPLICATION LAYER
220
SERVICES LAYER
ENGINE LAYER
230
236
SHARED COMPONENTS
(e.g. UMTS MM, ROUTERS, CONNECTIVITY, ETC.)
GSM
GPRS
NON-GSM
TECHNOLOGY
SPECIFIC
COMPONENTS
(e.g. WCDMA)
234
238
TIME CRITICAL
FUNCTIONALITY
EDGE CLASSIC
(POSSIBLE
EXTENSION)
232
240
HARDWARE LAYER

FIG. 2

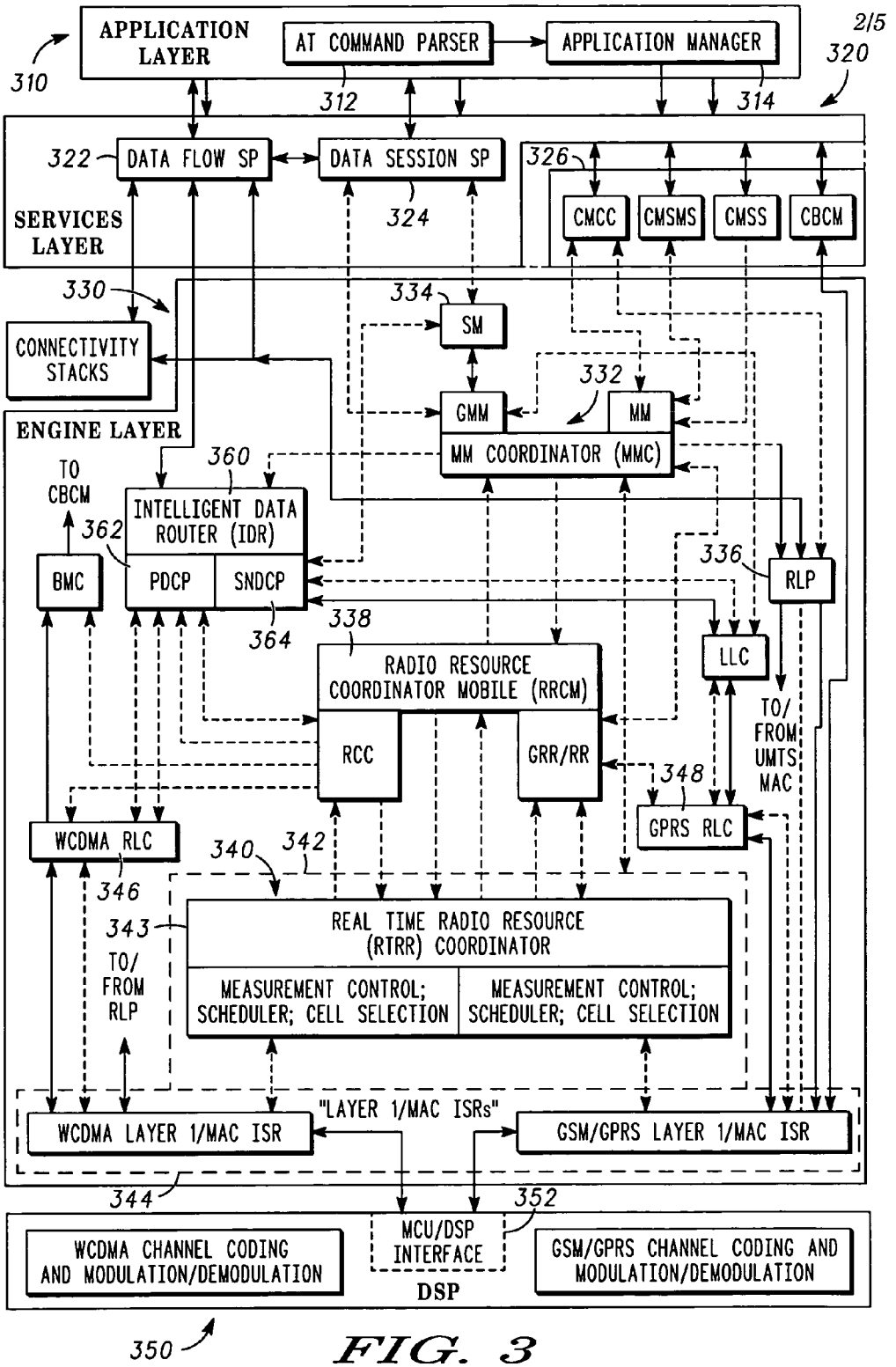

APPLICATION LAYER
AT COMMAND PARSER
APPLICATION MANAGER
2/5
320
310
312
314
322
DATA FLOW SP
DATA SESSION SP
326
SERVICES LAYER
324
CMCC
CMSMS
CMSS
CBCM
330
334
SM
CONNECTIVITY STACKS
332
GMM
MM
MM COORDINATOR (MMC)
ENGINE LAYER
360
TO CBCM
INTELLIGENT DATA ROUTER (IDR)
362
BMC
PDCP
SNDCP
336
RLP
364
338
LLC
RADIO RESOURCE COORDINATOR MOBILE (RRCM)
TO/ FROM UMTS MAC
RCC
GRR/RR
348
GPRS RLC
WCDMA RLC
340
342
346
343
REAL TIME RADIO RESOURCE (RTRR) COORDINATOR
TO/ FROM RLP
MEASUREMENT CONTROL; SCHEDULER; CELL SELECTION
MEASUREMENT CONTROL; SCHEDULER; CELL SELECTION
"LAYER 1/MAC ISRs"
WCDMA LAYER 1/MAC ISR
GSM/GPRS LAYER 1/MAC ISR
344
352
WCDMA CHANNEL CODING AND MODULATION/DEMODULATION
MCU/DSP INTERFACE
DSP
GSM/GPRS CHANNEL CODING AND MODULATION/DEMODULATION
350

FIG. 3

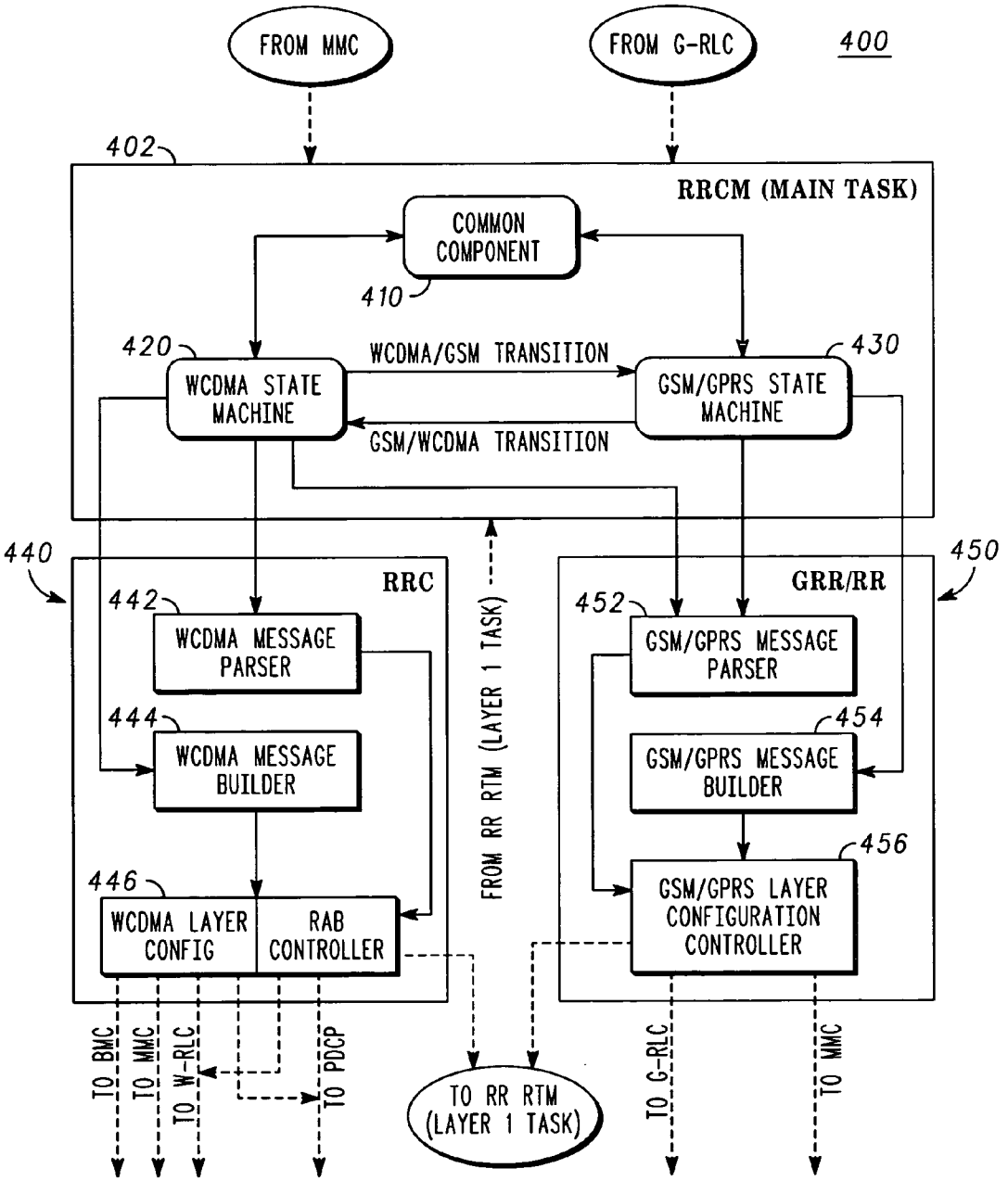

FROM MMC
FROM G-RLC
400
402
RRCM (MAIN TASK)
COMMON COMPONENT
410
420
WCDMA/GSM TRANSITION
430
WCDMA STATE MACHINE
GSM/GPRS STATE MACHINE
GSM/WCDMA TRANSITION
440
RRC
450
GRR/RR
442
WCDMA MESSAGE PARSER
452
GSM/GPRS MESSAGE PARSER
444
WCDMA MESSAGE BUILDER
454
GSM/GPRS MESSAGE BUILDER
456
446
WCDMA LAYER CONFIG
RAB CONTROLLER
GSM/GPRS LAYER CONFIGURATION CONTROLLER
FROM RR RTM (LAYER 1 TASK)
TO BMC
TO MMC
TO W-RLC
TO PDCP
TO RR RTM (LAYER 1 TASK)
TO G-RLC
TO MMC

FIG. 4

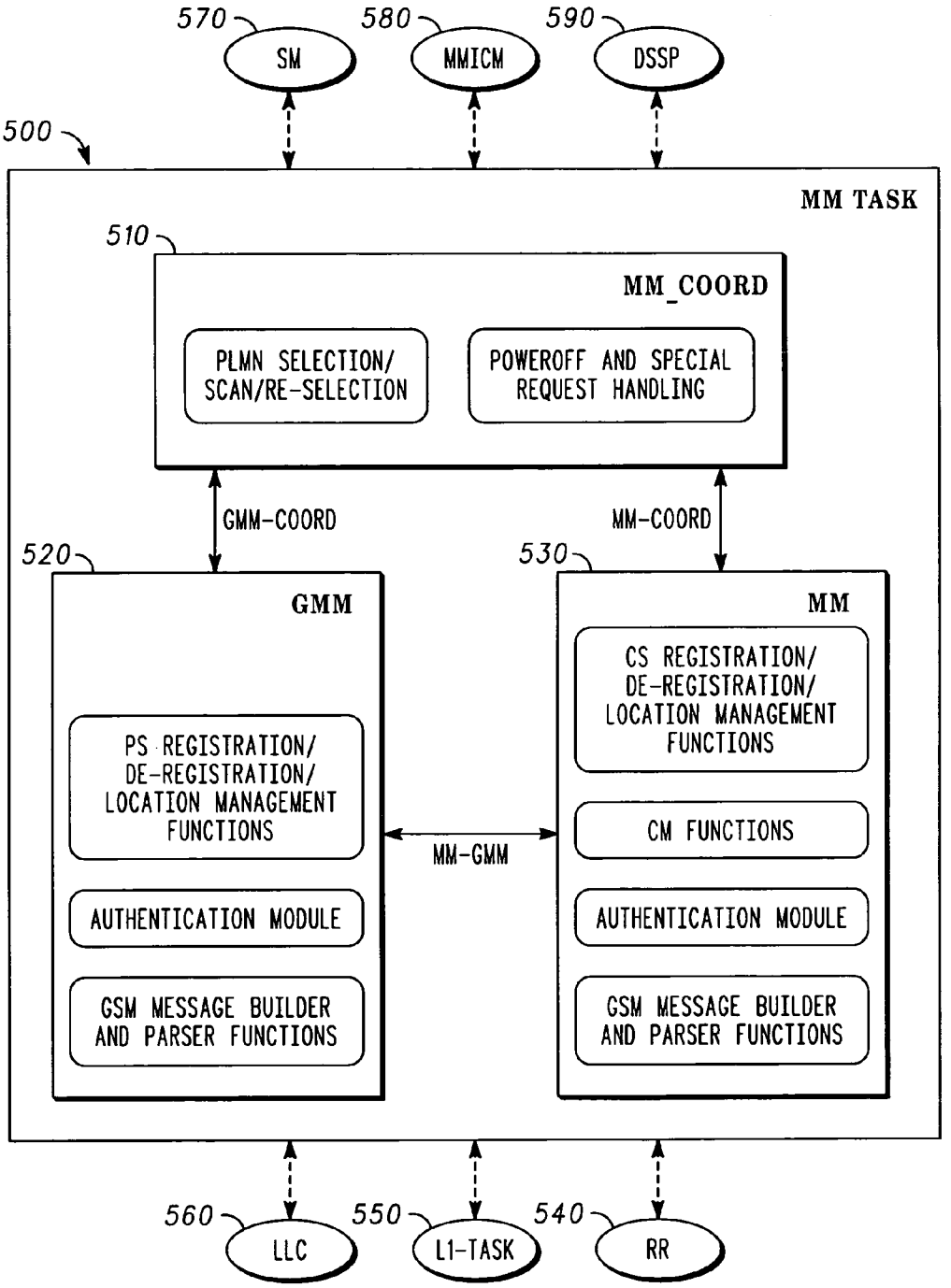

570
SM
580
MMICM
590
DSSP
500
MM TASK
510
MM_COORD
PLMN SELECTION/ SCAN/RE-SELECTION
POWEROFF AND SPECIAL REQUEST HANDLING
GMM-COORD
MM-COORD
520
GMM
PS REGISTRATION/ DE-REGISTRATION/ LOCATION MANAGEMENT FUNCTIONS
AUTHENTICATION MODULE
GSM MESSAGE BUILDER AND PARSER FUNCTIONS
MM-GMM
530
MM
CS REGISTRATION/ DE-REGISTRATION/ LOCATION MANAGEMENT FUNCTIONS
CM FUNCTIONS
AUTHENTICATION MODULE
GSM MESSAGE BUILDER AND PARSER FUNCTIONS
560
LLC
550
L1-TASK
540
RR

FIG. 5

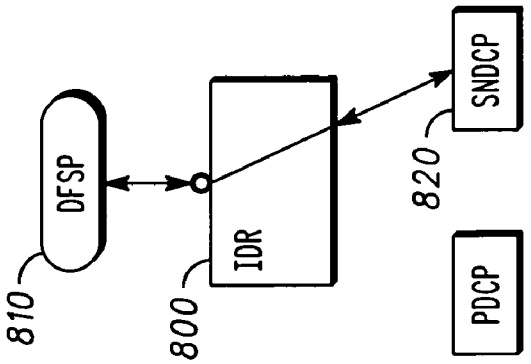


FIG. 6

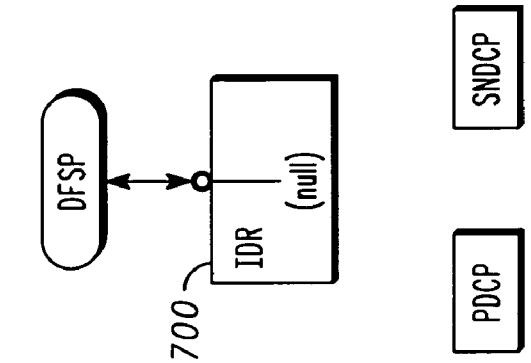


FIG. 7

FIG. 8

MULTI-MODE INTEROPERABLE MOBILE STATION COMMUNICATIONS ARCHITECTURES AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation of commonly assigned U.S. patent application Ser. No. 10/228,484 filed on 27 Aug. 2002 with like title, from which the benefits under 35 U.S.C. 120 are claimed, the contents of which are hereby incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates generally to wireless mobile station communications, and more particularly to wireless mobile station communication architectures with multi-mode interoperability, for example, communications supporting time division multiple access (TDMA) based and spread spectrum based modes of operation, wireless devices having multi-mode architectures and methods therefor.

BACKGROUND

[0003] Wireless cellular communication mobile stations with multi-service interoperability will enable communications in areas served by different communications protocols, otherwise referred to herein as a heterogeneous communications environments.

[0004] The initial deployment of new communications technologies is characterized typically by limited areas of new technology service in contiguous regions served by legacy technologies. In many countries, for example, the W-CDMA implementation of Universal Mobile Telecommunications Services (UMTS) will be deployed initially on isolated islands of service in a sea served by existing Groupe Special Mobile services (GSM)/Generalized Packet Radio Services (GPRS) network infrastructure.

[0005] UMTS services will not be offered over substantial contiguous areas until new technology infrastructure is installed or until existing infrastructure is upgraded, but this will require substantial capital outlays by telecommunications services providers and may not be complete for some time, resulting in a heterogeneous communications environment in many geographic regions for the foreseeable future.

[0006] Multi-mode cellular handsets capable of operating in areas served by emerging and legacy communications infrastructures will provide users earlier access to the emerging communications technology and hasten its deployment. Multi-mode wireless communications devices are also desirable for communications in other heterogeneous environments.

[0007] Mobile wireless communications devices will require architectures with multi-mode interoperability for seamless operation in heterogeneous communications environments.

[0008] The various aspects, features and advantages of the present disclosure will become more fully apparent to those having ordinary skill in the art upon careful consideration of the following Detailed Description with the accompanying drawings described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is an exemplary communications coverage area served by two different communications protocols.

[0010] **FIG. 2** is an exemplary multi-mode mobile station communications architecture.

[0011] **FIG. 3** is a more detailed schematic of an exemplary multi-mode mobile station architecture for GSM and W-CDMA communications.

[0012] **FIG. 4** is an exemplary radio resource coordinator module for multi-mode communication architectures.

[0013] **FIG. 5** is an exemplary mobility management component for multi-mode communication architectures.

[0014] **FIG. 6** is an exemplary data router configuration.

[0015] **FIG. 7** is another exemplary data router configuration.

[0016] **FIG. 8** is another exemplary data router configuration.

DETAILED DESCRIPTION

[0017] **FIG. 1** is an exemplary heterogeneous communications environment **100** comprising a relatively contiguous GSM/GPRS coverage area **110** and several isolated W-CDMA coverage areas **120** and **122**. The heterogeneous environment of **FIG. 1** is typical of the early stages of deployment of advanced communications network infrastructure, e.g., a W-CDMA network, in area where an existing infrastructure, e.g., GSM/GPRS, is already well established. The exemplary environment **100** is not limited to one served by the exemplary radio access networks, but may be served more generally by a heterogeneous network comprising any radio access technologies, for example, one comprising 3rd and 4th generation communications service and beyond.

[0018] For multi-mode wireless communications devices operating in heterogeneous networks, for example a mobile terminal following user route **130** in **FIG. 1**, it is desirable for the communications devices to simultaneously monitor cells of the different radio access networks in idle and active modes to perform cell selection and handover procedures, including the bi-directional handoff of radio access bearer services, for example in networks comprising GSM Base Station Subsystems (BSS) and Universal Terrestrial Radio Access Network (UTRAN) access networks.

[0019] **FIG. 2** is an exemplary multi-mode mobile wireless communications device architecture **200** comprising generally an application layer **210** interfaced with a services layer **220** interfaced with a multi-mode layer **230**, comprising at least two interoperable radio access technologies, interfaced with a hardware layer **240**.

[0020] In **FIG. 2**, the application layer **200**, at the top of the model, comprises generally one or more application subsystems. In the exemplary architecture **300** of **FIG. 3**, the application layer **310** includes a single application subsystem comprising an AT command parser **312**, an application manager **314**, and, for example, Synergy applications. The application layer may also include generally other application subsystems, for example a Java Virtual Machine and its corresponding applications, among other application subsystems.

[0021] In **FIG. 3**, the exemplary services layer **320** comprises a Data Flow Service Provider (DFSP) **322**, a Data Session Service Provider (DSSP) **324**, and Connection Management (CM) components **326**. The application layer interfaces with the services layers and communications therebetween are performed by function calls, for example

Application Utility Functions (AUF). Communications also occur within the application and services layers, for example, between the DFSP **324** and the DSSP **324**.

[**0022**] The multi-mode layer comprises generally an interoperability entity that interconnects the radio access technologies. In **FIG. 2**, the first radio access technology **232** is a GSM/GPRS radio access technology, which may include an extension, for example EDGE or EDGE Classic. The second radio access technology **234** is a non-GSM technology, for example Wideband Code Division Multiple Access (W-CDMA) Universal Mobile Telecommunications Services (UMTS) radio access technology.

[**0023**] In **FIG. 2**, the multi-mode layer, or engine layer, comprises generally a common subsystem **236** comprising components shared among the different radio access technologies, for example mobility management layer, data router, connectivity components, etc. The engine layer also includes a time critical functionality control component **238**, which is shared among the radio access technologies, for example for measurement control, scheduling, cell selection, etc. as discussed more fully below.

[**0024**] In the exemplary architecture of **FIG. 3**, the components shared by the first and second radio access technologies include the application layer **310** and the services layer **320**. In one embodiment, several components of the multi-mode layer **330** are also shared by the radio access technologies, including the mobility management component **332**, the Session Management (SM) component **334**, the Radio Link Protocol (RLP) component **336**, and other components discussed further below. In **FIG. 3**, a Digital Signal Processing (DSP) component **350** includes generally modulation and demodulation functionality for the corresponding radio access technologies, WCDMA and GSM/GPRS in the exemplary embodiment.

[**0025**] In the exemplary embodiment of **FIG. 3**, the architecture includes a radio resource layer **338** for transitioning between the first and second radio access technologies. In this exemplary embodiment, the radio resource layer is shared by the radio access technologies.

[**0026**] **FIG. 4** is a more detailed illustration of the radio resource layer **400** comprising a radio resource component **402** including a state transition component **410** and first and second state machines **420** and **430** for the corresponding radio access technologies. Other state machines may be included for embodiments that include additional radio access technologies. The state transition component **410** generally allocates resources among the first and second radio access technologies. The state transition component also maintains current state information while transitioning from one state machine to the other to enable returning to the current state if the transition is unsuccessful.

[**0027**] In the exemplary embodiment of **FIG. 4**, the first state machine **420** is coupled generally to a W-CDMA radio resource entity (RRC) **440**, which includes a W-CDMA message parser **442**, a message builder **444**, and a layer configuration controller **446**, among other known functionality elements. The second state machine **430** is coupled to the GPRS radio resource (GRR)/GSM radio resource (RR) entity **450**, which includes a GSM/GPRS message parser **452**, a message builder **454**, and a configuration controller **456**, among other known elements. The radio resource entities **440** and **450** and corresponding elements are specific to the radio access technologies in the device.

[**0028**] In **FIG. 3**, the radio resource layer **338** communicates radio resource status and other control information, for example registration area and NAS system information, PLMN availability, etc., to a mobility management layer, and in the exemplary embodiment to a mobility management component **332** thereof, the functionality of which is discussed more fully below.

[**0029**] In **FIG. 3**, a timing component **340** is coupled to the radio resource layer **338**. The exemplary timing component **340** is divided into a real-time task processing portion **342**, and an interrupt-processing portion **344**. The real-time task portion is coupled to corresponding portions of the radio access technologies for performing real-time processing, and the interrupt-processing portion is coupled to the radio access technologies for performing interrupt processing.

[**0030**] Time critical radio access technology functionality, for example, Public Land Mobile Network (PLMN) selection, cell selection and reselection, signal measurement, handover, etc., is coordinated by a real-time coordinator **343** in the real-time portion of the timing component. The real-time coordinator reports status and other information to the radio resource layer **338**, and the real-time coordinator controls switching between radio access technologies under control from the radio resource component **337**.

[**0031**] For example, during initial cell selection the radio resource component **337** controls cell selection on the appropriate radio access technology, for example GSM or W-CDMA in the exemplary embodiment, commands power measurement and channel synchronization, commands to read system information scheduled by Radio Resource (RR) component, and follows cell selection procedure to camp on the most suitable cell. After finding a cell to camp on, the radio resource component sends an indication to RR/RRC. If no cells are found suitable on the desired radio access technology, cell selection procedure on the other radio access technology is selected. If no suitable cells are found, an available PLMN list is sent to radio resource component.

[**0032**] The timing component also controls interrupt processing, for example medium access control (MAC) functionality of the first and second radio access technologies. The W-CDMA Layer 1/MAC interruption service routine (ISR) functionality includes, for example, DSP timing, transport to logical and vice verse channel mapping, etc. The timing component also controls interrupt processing for the GSM/GPRS Layer 1 MAC ISR, for example Adaptive Gain Control (AGC), Adaptive Frequency Control (AFC), waveform generation, MAC procedures, etc.

[**0033**] Interrupt processing information is communicated from each Layer 1 MAC ISR to the corresponding radio link control (RLC) components **346** and **348** of the first and second radio access technologies and to a DSP **350** via an Micro Controller Unit (MCU)/DSP interface **352** common to both radio access technologies.

[**0034**] **FIG. 5** is an exemplary mobility management task layer **500** comprising a mobility management component **510** coupled a GPRS Mobility Management (GMM), element **520** and to a Mobility Management (MM) element **530**. The GMM and MM components include functionality blocks specific to the integrated radio access technology, for example registration, de-registration and location management, authentication, message building and parsing, etc.

[**0035**] The mobility management layer interfaces with the radio resource layer **540**, the radio access technology L1-task layer **550**, the GSM Logical Link Control (LLC) entity **560**, the Session Management (SM) entity **570**, the

MMICM **580**, and the DSSP **590**. These interfaces are also illustrated generally in **FIG. 3**. The mobility management layer also interfaces with and provides radio access technology status information to the data router as discussed below.

[**0036**] In the exemplary embodiment of **FIG. 3**, a data router **360** is coupled to the services layer **320**, and particularly to the data flow service provider (DFSP) **322** thereof by a bi-direction data bus. The data router **360** is also coupled to the first and second radio access technologies, and in the exemplary embodiment to a W-CDMA Packet Data Communications Protocol (PDCP) **362** and to a GSM Sub Network Dependent Communications Protocol (SNDCP) **364**.

[**0037**] The data router **360** generally routes data between the services layer **320** and one of the radio access technologies. In **FIG. 3**, the radio resource component **338** is coupled to the data router **360** by the mobility management module **332**, which provides control information to the data router for selecting one of the radio access technologies. In **FIG. 6**, the data router **600** is configured for routing data from the DFSP **610** to the PDCP **620** for W-CDMA radio access technology (RAT). In **FIG. 7**, the data router **700** is configured for null mode, as occurs when the radio access technology is undefined, and **FIG. 8** illustrates the data router **800** configured for routing data from the DFSP **810** to the SNDCP **820** for GSM radio access technology.

[**0038**] While the present disclosure and what is considered presently to be the best mode thereof have been described in a manner that establishes possession thereof by the inventors and that enables those of ordinary skill in the art to make and use the same, it will be understood and appreciated that there are many equivalents to the exemplary embodiments disclosed herein and that myriad modifications and variations may be made thereto without departing from the scope and spirit thereof, which are to be limited not by the exemplary embodiments but by the appended claims.

1. A multi-mode mobile wireless communications device architecture, comprising:

a services layer;

an interoperability entity interconnecting first and second radio access technologies;

a packet router coupled to the services layer and to the first and second radio access technologies, the packet router routing packet data to one of the first and second radio access technologies.

2. The multi-mode mobile wireless communications device architecture of claim 1, the packet router including first and second packet protocol entities corresponding to the first and second radio access technologies.

3. The multi-mode mobile wireless communications device architecture of claim 1, a radio resource entity coupled to the first and second radio access technologies, a timing entity coupled to the first and second radio access technologies.

4. A multi-mode mobile wireless communications device architecture, comprising:

a services entity;

a multi-mode entity interconnecting first and second radio access technologies and the service entity,

the multi-mode entity including an interoperability entity for transitioning between the first and second radio access technologies during active calls, the interoperability entity for reselecting among the first and second radio access technologies.

5. The multi-mode mobile wireless communications device architecture of claim 4, a packet router coupled to the services entity and to the first and second radio access technologies, a packet router routing packet data to one of the first and second radio access technologies.

6. A method in a multi-mode mobile wireless communications device including first and second radio access technologies, comprising:

conducting a communications session with on one of the first and second radio access technologies;

switching between the first and second radio access technologies during the communications session without interrupting the communications session under control of a radio resource component;

conducting the communications session with on the other one of the first and second radio access technologies after switching.

7. The method of claim 6, controlling switching between the first and second radio resource technologies using a real-time coordinator and the radio resource component.

8. The method of claim 6, controlling interrupt processing of the first and second radio access technologies using an interrupt processing portion of a timing component.

9. The method of claim 6,

conducting the communications session includes conducting a packet session,

switching between the first and second radio access technologies includes routing packet data from one of the first and second radio access technologies to the other of the first and second radio access technologies with a packet router.

10. The method of claim 9, routing packet data includes converting the packet data to a protocol corresponding to the radio access technology to which the packet data is routed.

11. The method of claim 6,

conducting the communications session includes conducting a voice call,

switching between the first and second radio access technologies using the radio resource component without interrupting the voice call.

12. A multi-mode mobile wireless communications device architecture, comprising:

a services entity;

a multi-mode entity interconnecting first and second radio access technologies and the service entity,

the multi-mode entity including a radio resource for transitioning between the first and second radio access technologies;

a time critical functionality component coupled to the first and second radio access technologies.

13. The multi-mode mobile wireless communications device architecture of claim 12, a packet router coupled to the services layer and to the first and second radio access technologies, the packet router routing packet data to one of the first and second radio access technologies.

* * * * *