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(54) **Title**: LINK REPORT RELAY IN ACCESS DIVISION MULTIPLEXING SYSTEMS RELATED APPLICATIONS

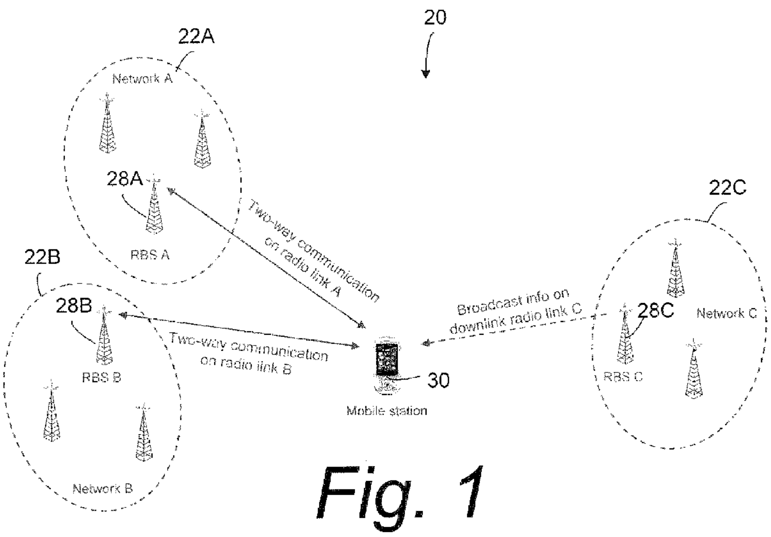

Fig. 1

(57) **Abstract**: Relevant radio-link related information is transferred through a wireless terminal (30) from one type of network (network 22B) to another type of network (network 22A) and vice versa. The wireless terminal 30 acts as a mediator or relay for the link report message of one type network (network 22B) so that link indications thereof can be utilized in a handover determination by the other type network (network 22A).

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LINK REPORT RELAY IN ACCESS DIVISION MULTIPLEXING SYSTEMS

RELATED APPLICATIONS

This application claims the priority and is related to the following United States Provisional Patent Applications, all of which are incorporated herein by reference in their entireties:

United States Provisional Patent Application 61/287,575 to Magnus Olsson et al., entitled “GSM and LTE Multiplexing Systems”, filed on December 17, 2009.

United States Provisional Patent Application 61/287,623 to Magnus Olsson et al., entitled “Link report Relay in Access Division Multiplexing Systems”, filed on December 17, 2009.

United States Provisional Patent Application 61/287,438 to Magnus Olsson et al., entitled “WCDMA and LTE Multiplexing”, filed on December 17, 2009.

United States Provisional Patent Application 61/287,627 to Magnus Olsson et al., entitled “Telecommunications Multiplexing”, filed on December 17, 2009.

United States Provisional Patent Application 61/287,630 to Magnus Olsson et al., entitled “Access Division Multiplexing – Call Setup Performance Improvement”, filed on December 17, 2009.

United States Provisional Patent Application 61/287,954 to Magnus Olsson et al., entitled “Scheduled Optimized for GSM and LTD Multiplexing”, filed on December 17, 2009.

This application is related to the following United States Patent Applications, all of which are filed on same date herewith and incorporated herein by reference in their entireties:

United States Patent Application 12/943,801 to Magnus Olsson et al., entitled “GSM and LTE Multiplexing”.

United States Patent Application 12/943,612 to Magnus Olsson et al., entitled "Keeping Packet Switched Session in LTE While Circuit Switched Registered in WCDMA".

United States Patent Application 12/943,685 to Magnus Olsson et al., entitled "Maintaining Packet Switched Session in LTE When Establishing GSM Circuit Switched Call".

United States Patent Application 12/943,736 to Magnus Olsson et al., entitled "Call Setup For Access Division Multiplexing".

United States Patent Application 12/943,504 to Magnus Olsson et al., entitled "Scheduling For Access Division Multiplexing".

United States Patent Application 12/943,770 to Magnus Olsson et al., entitled "Link Report Relay in Access Division Multiplexing Systems".

TECHNICAL FIELD

This technology pertains to wireless communications networks, and particularly to the reporting and/or use of measurements for such purposes as handover.

BACKGROUND

In a typical cellular radio system, wireless terminals (also known as mobile stations and/or user equipment units (UEs)) communicate via a radio access network (RAN) to one or more core networks. The radio access network (RAN) covers a geographical area which is divided into cell areas, with each cell area being served by a base station, e.g., a radio base station (RBS), which in some networks may also be called, for example, a "NodeB" (UMTS) or "eNodeB" (LTE). A cell is a geographical area where radio coverage is provided by the radio base station equipment at a base station site. Each cell is identified by an identity within the local radio area, which is broadcast in the cell. The base stations communicate over the air interface operating on radio frequencies with the user equipment units (UE) within range of the base stations.

In some versions of the radio access network, several base stations are typically connected (e.g., by landlines or microwave) to a controller node (such as a radio network controller (RNC) or a base station controller (BSC)) which supervises and coordinates various activities of the plural base stations connected thereto. The radio network controllers are typically connected to one or more core networks.

The Universal Mobile Telecommunications System (UMTS) is a third generation mobile communication system, which evolved from the second generation (2G) Global System for Mobile Communications (GSM). UTRAN is essentially a radio access network using wideband code division multiple access for user equipment units (UEs). In a forum known as the Third Generation Partnership Project (3GPP), telecommunications suppliers propose and agree upon standards for third generation networks and UTRAN specifically, and investigate enhanced data rate and radio capacity. Specifications for the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) are ongoing within the 3rd Generation Partnership Project (3GPP). The Evolved Universal Terrestrial Radio Access Network (E-UTRAN) comprises the Long Term Evolution (LTE) and System Architecture Evolution (SAE). Long Term Evolution (LTE) is a variant of a 3GPP radio access technology wherein the radio base station nodes are connected to a core network (via Serving Gateways, or SGWs) rather than to radio network controller (RNC) nodes. In general, in LTE the functions of a radio network controller (RNC) node are distributed between the radio base stations nodes (eNodeB's in LTE) and SGWs. As such, the radio access network (RAN) of an LTE system has an essentially "flat" architecture comprising radio base station nodes without reporting to radio network controller (RNC) nodes.

Cellular Circuit-Switched (CS) telephony was introduced in the first generation of mobile networks. Since then CS telephony has become the largest service in the world with approximately 4 billion subscriptions sold. Even today, the main part of the mobile operator's revenue comes from the CS telephony service (including Short Message Services (SMS)), and the 2G GSM networks still dominate the world in terms of subscriptions. 3G subscriptions are increasing in volume, but that increase is less in part because of users with handheld mobile terminals migrating from 2G to 3G and more as a result of mobile broadband implemented via dongles or embedded chipsets in laptops.

The long-term evolution (LTE) project within 3GPP aims to further improve the 3G standard to, among other things, provide even better mobile broadband to the end-users (higher throughput, lower round-trip-times, etc.).

A common view in the telecommunication industry is that the future networks will be all-IP networks. Based on this assumption, the CS domain in was removed in the LTE work. As a result, the telephony service cannot be used by a 3GPP Release 8 compliant LTE terminal, unless one of the following four things is done:

(1) Implement CS fallback, (CSFB), so that an LTE terminal falls back to 2G GSM when telephony service is used.

(2) Implement 3GPP Internet Protocol (IP) Multimedia Subsystem (IMS)/ Multimedia Telephony (MMTel), which is a simulated CS telephony service provided over IP and IMS that inter-works with the Public Switched Telephone Network (PSTN)/ Public Land Mobile Network (PLMN).

(3) Implement a tunneling solution with Unlicensed Mobile Access (UMA)/ Generic Access Network (GAN) over LTE where the CS service is encapsulated into an IP tunnel.

(4) Implement a proprietary Voice over IP (VoIP) solution with PSTN/PLMN interworking.

All of these four possibilities have drawbacks. In deployed GSM networks that do not have Dual Transfer Mode (DTM) capabilities; CS and Packet Switched (PS) services cannot be used in parallel. Hence, all PS services running prior to a call to or from a terminal using Circuit Switched Fallback (CSFB) are put on hold or are terminated. If the GSM network has DTM, the PS performance will be greatly reduced (from 10's of Mbps to 10's to 100's of kbps). One drawback with the CS fallback approach is that when calling or being called and the terminal is falling back to GSM and the CS service from LTE. Circuit Switched Fallback (CSFB) also prolongs call set-up time.

The IMS/MMTel approach uses a completely new core/service layer that is IMS based. This provides new possibilities to enhance the service but also comes with the drawback of a financial hurdle for the operator to overcome. A new core network drives capital expenditures (CAPEX), and integration of that core network drives an initial operating expenditures (OPEX) increase. Further, the IMS/MMTel approach needs features implemented in the terminals and the legacy CS network in order to handle voice handover to/from the 2G/3G CS telephony service.

Using UMA/GAN over LTE is not a standardized solution so a drawback is that it is a proprietary solution which may make terminal availability a problem. It also adds additional functions to the core/service layer in both the network and terminal, e.g., a GAN controller in the network and GAN protocols in the UE terminal.

The proprietary VoIP approach, if operator controlled, comes with the same drawbacks as for the IMS/MMTel (new core/service layer) approach along with the difficulties associated with it being proprietary and handover to 2G/3G CS may not be supported.

There is yet a further solution for using a legacy CS telephony service with a wireless terminal such as a 3GPP release 8-compliant LTE terminal. In that further solution, also known as a type of Access Division Multiplexing (ADM), transmissions of GSM CS voice are interleaved in between LTE transmissions. See, e.g., PCT/SE2007/000358, which is incorporated herein by reference. In one example implementation of such an ADM solution a wireless terminal simultaneously communicates with two TDMA-based radio systems, e.g., the wireless terminal can maintain communications paths to both systems by means of alternating in time its communication between the two systems. The toggling between the two systems is on a time scale small enough to effectively yield a simultaneous communication between the two systems.

In an example ADM implementation such as that disclosed in PCT/SE2007/000358, the first system can be a GSM system and the second system can be an LTE system. The communication path to the GSM system is used to maintain a radio channel for a CS voice service; the LTE radio channel is used for data services.

In an example interleaved ADM solution shown in PCT/SE2007/000358 the mobile station (wireless terminal) is capable of transmission and reception of at most one radio system at any one time (single receiver and single transmitter technology). In a slightly different embodiment and mode the mobile station is capable of maintaining two receiving radio channels in parallel while still only capable of transmitting on one radio channel (dual receiver and single transmitter technology). The dual receiver and single transmitter implementation improves the performance by simultaneous reception of data from the two systems while still using interleaving (e.g., of PCT/SE2007/000358) for its uplink transmission. The dual receiver single transmitter solution has a higher cost of the mobile station since it requires double receiver radio chains of radio parts.

SUMMARY

In one of its aspects the technology disclosed herein provides mechanism(s) for transferring relevant radio-link related information from type of network to another type of network (and vice versa) by means of a wireless terminal (e.g., mobile station) acting as a mediator for the corresponding measurement messages. In an example preferred implementation the radio resource control function is placed in a first network A (e.g., a GSM network). The radio resource control function could equally well be placed in a second network B (e.g., a LTE network), or any other radio network constituting one of the networks A or B described herein.

In one of its aspects the technology disclosed herein concerns a method of operating a communications system. The communications system comprises a first radio access technology network and a second radio access technology network. In an example mode the method comprises a base station node of the second radio access technology network performing a quality determination with respect to an uplink transmission from a wireless terminal. The base station node of the second radio access technology network includes an indication of the quality determination with respect to the uplink transmission from the wireless terminal in a link report message transmitted to the wireless terminal. The wireless terminal includes the indication of the quality determination with respect to the uplink transmission from the wireless terminal based on the indication received in the link report message in a proxy link report message and transmits the proxy link report message to a node of the first radio access technology network. A control node of the first radio access technology network uses the quality determination with respect to the uplink transmission from the wireless terminal (as included in the proxy link report message) to determine whether to perform a radio access technology handover procedure.

In an example mode and embodiment, the wireless terminal includes essentially the entire link report message (including the indication of the quality determination with respect to the uplink transmission from the wireless terminal) in a proxy link report message and transmits the proxy link report message to a node of the first radio access technology network. In another example mode and embodiment, the wireless terminal obtains the indication of the quality determination with respect to the uplink transmission and inserts or otherwise includes the quality determination in the proxy link report message. In yet another example mode and embodiment, the wireless terminal obtains the indication of the quality determination with respect to the uplink transmission and processes or operates upon (e.g., filters or averages) the indication of the quality determination and then inserts or otherwise includes (as the indication of the quality determination) a processed or derived indication of the quality determination in the proxy link report message.

In an example mode and embodiment the method further comprises the wireless terminal also providing, to the node of the first radio access technology network, an indication of a quality determination regarding a transmission between the wireless terminal and the first radio access technology network. The node of the first radio access technology network also uses the indication of the signal quality between the wireless terminal and the first radio access technology network to determine whether to perform the radio access technology handover procedure. In an example implementation, the wireless terminal also includes, in the proxy link report message, the indication of the quality determination regarding a transmission between the wireless terminal and the first radio access technology network. In another example mode and embodiment, the method further comprises the wireless terminal including the indication of the quality determination regarding the transmission between the wireless terminal and the first radio access technology network in a wireless terminal separate link report message.

In an example mode and embodiment the method further comprises the wireless terminal making a determination regarding signal quality of a third radio access technology network. The node of the first radio access technology network also uses the indication of the signal quality of the third radio access technology network to determine whether to perform the radio access technology handover procedure. In an example implementation the wireless terminal includes the indication of the signal quality of the third radio access technology network in the proxy link report message. In another example implementation the wireless terminal includes the indication of the signal quality of the third radio access technology network in a wireless terminal separate link report message.

In another of its aspects the technology disclosed herein concerns a wireless terminal which serves as a multi-network measurement communicator. The wireless terminal comprises a communications interface and a link report processor. The communications interface is configured to enable the wireless terminal to communicate with a first radio access technology network and a second radio access technology. The link report processor is configured to receive a link report message from the second radio access technology network and to prepare a proxy link report message for transmission to a node of the first radio access technology network. The link report message comprises an indication of an uplink quality from the wireless terminal to the second radio access technology network. The link report processor is configured to include an indication of the quality determination in the proxy link report message.

In an example embodiment, the communications interface is configured to perform interleaved communications with the first radio access technology network and the second radio access technology network. In an example implementation the first radio access technology network and the second radio access technology network comprise a GSM network and a Long Term Evolution (LTE) network.

In an example embodiment the wireless terminal further comprises a wireless terminal measurement unit. The wireless terminal measurement unit is configured to perform a downlink quality measurement with respect to the first radio access technology network and a downlink quality measurement with respect to the second radio access technology network. The link report processor and the communications interface are configured to transmit an indication of at least one of the downlink quality measurements to the node of the first radio access technology network.

In an example embodiment the link report processor is configured to include the indication of at least one of the downlink quality measurements in the proxy link report message which is sent to the node of the first radio access technology network.

In another example embodiment the link report processor is configured to include the indication of at least one of the downlink quality measurements in a wireless terminal separate link report message which is sent to the node of the first radio access technology network separately from the proxy link report message.

In an example embodiment the measurement unit is further configured to make a signal quality determination for a third radio access technology network. The link report processor and the communications interface are configured to transmit an indication of the signal quality of the third radio access technology network to the node of the first radio access technology network. In an example implementation, the link report processor is configured to include the indication of the signal quality of the third radio access technology network in the proxy link report message.

In another of its aspects the technology disclosed herein concerns a method of operating a wireless terminal capable of communicating with a first radio access technology network and a second radio access technology. The wireless terminal method comprises the wireless terminal receiving a link report message from the second radio access technology network. The link report message comprises an indication of an uplink quality from the wireless terminal to the second radio access technology network. The wireless terminal method further comprises the wireless terminal including an indication of the quality determination in a proxy link report message and transmitting the proxy link report message to a node of the first radio access technology network.

In an example mode and embodiment the wireless terminal method further comprises the wireless terminal performing interleaved communications with the first radio access technology network and the second radio access technology network. In an example implementation the first radio access technology network and the second radio access technology network comprise a GSM network and a Long Term Evolution (LTE) network.

In an example mode and embodiment the wireless terminal method further comprises the wireless terminal making a downlink quality determination with respect to the first radio access technology network and a downlink quality determination with respect to the second radio access technology network, and the wireless terminal transmitting an indication of at least one of the downlink quality determinations to the node of the first radio access technology network. In an example implementation the wireless terminal method further comprises the wireless terminal including the indication of the at least one of the downlink quality determinations in the proxy link report message. In another example implementation, the wireless terminal method further comprises the wireless terminal including the indication of the at least one of the downlink quality determinations in a wireless terminal separate link report message which is sent to the node of the first radio access technology network separately from the proxy link report message.

In an example mode and embodiment the wireless terminal method further comprises the wireless terminal making a determination of downlink quality with respect to a third radio access technology network and the wireless terminal transmitting an indication of the signal quality of the third radio access technology network to the node of the first radio access technology network. In an example implementation the wireless terminal method further comprises the wireless terminal including the indication of the signal quality of the third radio access technology network in the proxy link report message.

In another of its aspects the technology disclosed herein concerns a radio base station node. The radio base station node comprises a communications interface; a base station measurement unit; and a base station link report processor. The communications interface is configured to handle uplink and downlink transmissions with respect to a wireless terminal. The base station measurement unit is configured to perform a quality measurement with respect to the uplink transmissions from the wireless terminal. The base station link report processor is configured to include an indication of the quality measurement in a downlink message to the wireless terminal.

In another of its aspects the technology disclosed herein concerns a radio access network handover control node. The radio access network handover control node comprises a control node link report processor and a handover unit. The control node link report processor is configured to receive a link report message and a proxy link report message. The handover unit is configured to use both the link report message and the proxy link report message to determine whether to perform handover from the first radio access technology network to the second radio access technology network. The link report message includes an indication of a quality measurement regarding a transmission between a wireless terminal and a node of the first network. The handover unit is configured to receive the proxy link report message from the wireless terminal through the first radio access technology network, the proxy link report including an indication of a quality determination regarding an uplink transmission from the wireless terminal to a node of the second radio access technology network.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of preferred embodiments as illustrated in the accompanying drawings in which reference characters refer to the same parts throughout the various views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

Fig. 1 is a diagrammatic view of a system in which a wireless terminal (e.g., mobile station) is simultaneously active in a radio communication with two radio networks A and B while also being in the coverage area of a third network C.

Fig. 2 is a schematic view of a communications system comprising two radio access technology networks and a wireless terminal which serves as a multi-network measurement communicator.

Fig. 3 is a schematic view of a communications network comprising three radio access technology networks and a wireless terminal which serves as a multi-network measurement communicator.

Fig. 4A is a diagrammatic view of an example embodiment of a multi-network measurement communicating wireless terminal.

Fig. 4B is a diagrammatic view of another example embodiment of a multi-network measurement communicating wireless terminal, and particularly an example embodiment of a multi-network measurement communicating wireless terminal which processes or operates upon (e.g., filters or averages) an indication of the quality determination and then inserts or otherwise includes (as the indication of the quality determination) a processed or derived indication of the quality determination in the proxy link report message.

Fig. 5 is a more detailed diagrammatic view of an example embodiment of a multi-network measurement communicating wireless terminal.

Fig. 6 is a yet more detailed diagrammatic view of an example embodiment of a multi-network measurement communicating wireless terminal.

Fig. 7 is a diagrammatic view of an example embodiment of a base station node configured to prepare a link report message for transmission to a multi-network measurement wireless terminal.

Fig. 8 is a more detailed diagrammatic view of an example embodiment of a base station node configured to prepare a link report message for transmission to a multi-network measurement wireless terminal.

Fig. 9 is a diagrammatic view of an example embodiment of a base station control node.

Fig. 10 is a more detailed diagrammatic view of an example embodiment of a base station control node.

Fig. 11 is a flowchart showing example, representative acts or steps comprising a basic method of operating a wireless terminal as a multi-network measurement communicator.

Fig. 11A is a flowchart showing example, representative acts or steps comprising another method of operating a wireless terminal as a multi-network measurement communicator.

Fig. 11B is a flowchart showing example, representative acts or steps comprising yet another method of operating a wireless terminal as a multi-network measurement communicator.

Fig. 12 is a flowchart showing the basic method of Fig. 11 wherein the wireless terminal is suitable for performing multiplexing or interleaving with respect to plural radio access technology networks.

Fig. 13 is a diagrammatic view showing the basic method of Fig. 11 as augmented by the wireless terminal making one or more downlink quality measurements and including an indication of at least one of the downlink quality measurements in a proxy link report message.

Fig. 14 is a diagrammatic view showing the basic method of Fig. 11 as augmented by the wireless terminal making one or more downlink quality measurements and including an indication of at least one of the downlink quality measurements in a separate link report message which precedes the proxy link report message.

Fig. 15 is a diagrammatic view showing the basic method of Fig. 11 as augmented by the wireless terminal making one or more downlink quality measurements and including an indication of at least one of the downlink quality measurements in a separate link report message which is subsequent to the proxy link report message.

Fig. 16 is a diagrammatic view showing the basic method of Fig. 13 as augmented by the wireless terminal making and reporting measurements with respect to yet another network and including the measurements with respect to the yet other network in a proxy link report message.

Fig. 17 is a diagrammatic view showing the basic method of Fig. 13 as augmented by the wireless terminal making and reporting measurements with respect to yet another network and including the measurements with respect to the yet other network in a separate link report message which precedes the proxy link report message.

Fig. 18 is a diagrammatic view showing the basic method of Fig. 13 as augmented by the wireless terminal making and reporting measurements with respect to yet another network and including the measurements with respect to the yet other network in a separate link report message which is subsequent to the proxy link report message.

Fig. 19 is a flowchart showing example, representative acts or steps comprising a basic method of operating a communication system which includes a multi-network measurement capability.

Fig. 20 is a diagrammatic view showing the basic method of Fig. 19 as augmented by the wireless terminal making one or more downlink quality measurements and including an indication of at least one of the downlink quality measurements in a proxy link report message.

Fig. 21 is a diagrammatic view showing the basic method of Fig. 19 as augmented by the wireless terminal making one or more downlink quality measurements and including an indication of at least one of the downlink quality measurements in a separate link report message which precedes the proxy link report message.

Fig. 22 is a diagrammatic view showing the basic method of Fig. 19 as augmented by the wireless terminal making and reporting measurements with respect to yet another network and including the measurements in the proxy link report message.

Fig. 23 is a diagrammatic view showing the basic method of Fig. 19 as augmented by the wireless terminal making and reporting measurements with respect to yet another network and including the measurements with respect to the yet other network in a separate link report message which is subsequent to the proxy link report message.

DETAILED DESCRIPTION

In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. That is, those skilled in the art will be able to devise various arrangements which, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. In some instances, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail. All statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

Thus, for example, it will be appreciated by those skilled in the art that block diagrams herein can represent conceptual views of illustrative circuitry or other functional units embodying the principles of the technology. Similarly, it will be appreciated that any flow charts, state transition diagrams, pseudocode, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

The functions of the various elements including functional blocks, including but not limited to those labeled or described as “computer”, “processor” or “controller”, may be provided through the use of hardware such as circuit hardware and/or hardware capable of executing software in the form of coded instructions stored on computer readable medium. Thus, such functions and illustrated functional blocks are to be understood as being either hardware-implemented and/or computer-implemented, and thus machine-implemented.

In terms of hardware implementation, the functional blocks may include or encompass, without limitation, digital signal processor (DSP) hardware, reduced instruction set processor, hardware (e.g., digital or analog) circuitry including but not limited to application specific integrated circuit(s) [ASIC], and (where appropriate) state machines capable of performing such functions.

In terms of computer implementation, a computer is generally understood to comprise one or more processors or one or more controllers, and the terms computer and processor and controller may be employed interchangeably herein. When provided by a computer or processor or controller, the functions may be provided by a single dedicated computer or processor or controller, by a single shared computer or processor or controller, or by a plurality of individual computers or processors or controllers, some of which may be shared or distributed. Moreover, use of the term “processor” or “controller” shall also be construed to refer to other hardware capable of performing such functions and/or executing software, such as the example hardware recited above.

There are still network functions yet to be solved for the above-described radio behavior and transmitter/receiver implementations of the transmitter and receiver technology for an Access Division Multiplexing system such as disclosed in PCT/SE2007/000358, for example. Among the network functions yet to be solved are those related to paging, registration, handoff, and mobility that are required by a mobile that is simultaneously engaged in a circuit switched (CS) voice service in one network and a packet data service in a second network.

The technology disclosed herein concerns, e.g., the problem of having a network-controlled handoff (e.g., a network-controlled handoff algorithm) in a situation where a mobile station is simultaneously connected to two different radio networks.

In cellular radio systems such as Global System for Mobile communication (GSM), Wideband Code Division Multiple Access (WCDMA), cdma1x, Evolution Data Optimized (EVDO), Long Term Evolution (LTE) and others the network is responsible for evaluating different cell alternatives for a mobile station in active mode. As used herein, “active mode” means that that the mobile station is actively engaged in a data transfer, a voice call, or both. In GSM this is equivalent to the mobile station being in dedicated mode while in WCDMA and LTE the wireless terminal (e.g., mobile station) has an established radio bearer and radio resource context respectively. In each of the systems noted above, when the mobile station is active in its communication, the network does radio-link quality measurements on the uplink transmissions from the mobile station to the radio-base station. Similarly the mobile station does quality measurement on the downlink radio transmission. The measurements in both the uplink and the downlink can contain combinations of signal strength measurements, bit-error measurements, estimated bit-error probabilities, frame erasure rates, block error rates or any other relevant indicators for the quality of the radio link. The measurements in the downlink are specified, e.g., by the 3GPP Technical Specifications. The mobile station also performs quality measurements on candidate non-serving radio cells in addition to the quality measurements on the active radio channels. These quality measurements typically involve measuring signal strengths only, but can also contain other measures either directly or indirectly.

In order for the network to evaluate the serving and neighboring cells with respect to radio performance for a mobile station, a network radio resource control entity which performs the evaluation needs quality information (e.g., measurements) both from the network itself (relating to the uplink radio quality) and from the mobile station (relating to the downlink radio quality and the quality of radio links to neighboring cells). In state of the art technology this is done by instructing the mobile station to send its measurements (or a representation of its measurements) to the network in a set of well defined link reports. The link reports are either sent continuously as in GSM and WCDMA or conditionally relative a set of radio and traffic conditions as in LTE. A resource management control unit in the network then combines the quality information in the link reports sent by the mobile station with network maintained information from the network measurements. The combined information about uplink-, downlink- and neighboring cell radio-link quality is used by the network in a set of locating algorithms to determine the best cell for the mobile to be connected. The locating algorithms are typically not standardized but may differ from system to system. In the preferred implementation the network then uses the results from the locating algorithm to determine whether the serving cell is the preferred cell (in which case no handoff command is sent to the mobile station) or if one of the neighboring cells is preferred (in which case a handoff is prepared and an appropriate handoff command is sent to the mobile station).

The technology disclosed herein addresses, e.g., a problem illustrated in the context of Fig. 1. Fig. 1 shows a communication system 20 comprising three networks 22, e.g., network 22A, network 22B, and network 22C. Although unillustrated in Fig. 1, some networks 22 comprise base station control nodes 26 (e.g., base station controller nodes or radio network controller nodes). Each network 22 has one or more base stations 28, such base station 28A for network 22A, base station 28B for network 22B, and base station 28C for network 22C.

In the situation shown in Fig. 1, mobile station or wireless terminal 30 is simultaneously active in a radio communication with two radio networks, e.g., network 22A and network 22B. In an example situation, network 22A can be, e.g., a GSM radio network and network 22B can be a LTE radio network. In the Fig. 1 situation, a radio resource control unit (located, e.g., at base station control node 26) would need measurement information from the mobile station, the network 22 A, and the network 22B.

Thus, in an example situation shown in Fig. 1 wireless terminal 30 is actively communicating in a GSM network (system/network 22A) and actively communicating in an LTE network (system/network 22B) while also being in the coverage area of a WCDMA network (system/network 22C). The quality (e.g., measurement) information from the wireless terminal 30 is needed to evaluate the downlink performance of the radio communication with network 22A and with network 22B. The quality information from the wireless terminal 30 is further needed by the radio resource control function to evaluate the expected radio performance should the mobile station be handed off to a neighboring cell in network 22C. The quality information from network 22A is needed to evaluate the quality of the uplink radio communication with network 22A and potentially also other relevant information kept by network 22A such as load situation and network level interference levels. Similarly quality information from network 22B is needed to evaluate the quality of the uplink radio communication with network 22B and potentially also other relevant information kept by network 22B such as load situation and network level interference levels. Any effective radio resource control function would need all the information above to be able to evaluate the total radio-link performance (communication with both system 22A and system 22B) and compare with the estimated performance after a potential handoff to system 22C.

A problem is that with present state of the art the radio resource control function cannot have the desired quality information from wireless terminal 30, network 22A, and network 22B. This is because there is no mechanism available to transfer the quality information from network 22A to network 22B, or vice versa. This means that if the radio resource control function is placed in network 22A (e.g., in the GSM network), with present state of the art technology the radio resource control function would not have any information relating to uplink performance of the communication with network 22B (e.g., the LTE network) or indeed any other relevant information kept by network 22B such as load situation. Similarly, if the radio resource control function were placed in network 22B (e.g., the LTE network), with present state of the art technology the radio resource control function would not have any information relating to uplink performance of the communication with network 22A (e.g., GSM network) or indeed any other relevant information kept by network 22A such as load situation.

The problem implies severe restrictions to the performance of the communication service in a multi-radio technology network scenario such as depicted in Fig. 1. As one example, if the radio resource control unit is placed in the system 22B (e.g., the LTE system) the radio resource control function would be ignorant about the uplink GSM voice performance (GSM here being the network 22A). If the mobile station finds itself in a location with high enough uplink (UL) path loss, e.g., deep inside a building, the GSM voice call would be dropped by the GSM network without the radio resource control function even being aware of the poor quality in the GSM uplink communication. But had the radio resource control function had the relevant quality information from network 22A, the dropped call could have been prevented by a handoff to network 22C before the uplink radio link in network 22A was lost.

In one of its aspects the technology disclosed herein provides mechanism(s) for transferring relevant radio-link related information from one network to another network, e.g., from network 22B to network 22A (and vice versa) by means of a wireless terminal 30 (e.g., mobile station) acting as a mediator or relay or multi-network communicator for the corresponding quality messages.

In an example implementation (such as illustrated in Fig. 2), the radio resource control function is placed in network A (e.g., the GSM network). However, it should be understood that the radio resource control function could equally well be placed in network B (e.g., the LTE network), or any other radio network constituting one of the networks A or B or any other network described herein.

In one example communications system 20(2) illustrated in Fig. 2, the radio resource control function (RRCU) 34A is implemented in the GSM base station controller (BSC) 26A as part of network 22A. In this example scenario, network 22A comprises at least one GSM base station (RBS 28A) connected to at least on base station controller (BSC) 26A. The base station controller 26A contains or comprises radio resource control function (RRCU) 34A and memory unit (MU1) 36A.

Another example communications system 20(3), shown in Fig. 3, resembles that of Fig. 2 but further includes network 22C. The network 22C comprises at least one radio base station (RBS) 28C which is connected to at least one radio network controller (RNC) 26C. In the example of Fig. 3, the network 22C is a WCDMA radio access technology network. It should be understood, however, that network 22C is intended to be representative of a third network, and need not be a WCDMA radio access technology network but could be, for example, another GSM or LTE network, or even another of the networks mentioned above.

As shown in Fig. 2 at least one wireless terminal 30 moves in the coverage area of the radio base station 28A (of network 22A) and the radio base station 28B (of network 22B). Fig. 3 shows the wireless terminal (UE) 30 moving in the coverage area of the radio base station 28A (of network 22A), the radio base station 28B (of network 22B), and the radio base station 28C (of network 22C). The wireless terminal 30 comprises memory unit (MU2) 38.

In the scenario depicted in Fig. 2, the network 22A performs GSM uplink radio measurements of the uplink communication link to network 22A in the RBS 28A according to 3GPP Technical Specifications. Using known technology the measurement results are transported from the RBS 28A over the Abis interface to the BSC 26A which stores the measurement/link report in memory unit (MU1) 36A accessible to the radio resource control unit (RRCU) 34A.

In parallel the LTE RBS 28B – being part of network 22B – performs quality measurement of the uplink radio radio-link communication channel from the wireless terminal 30 to the Long Term Evolution (LTE) RBS 28B. Using the technology disclosed herein, the RBS 28B periodically writes the measurement results in a link report message (MRM1) that is sent on the downlink radio channel to the wireless terminal 30. Alternatively the link report can comprise processed measurement results such as the filtered signal strength or average values of the performance indications measured by the Long Term Evolution (LTE) radio base station RBS 28B. As used herein a "link report" can include any information germane to a handover decision, and thus includes but is not limited to link-related information such as measurements such as those just mentioned.

The wireless terminal 30 receives the link report message MRM1 and stores the information therein in local memory unit (MU2) 38 implemented in wireless terminal 30. In parallel to this process the wireless terminal 30 uses prior art technology to measure the performance quality of the downlink communication channels relating to network 22A and network 22B respectively. In the Fig. 3 embodiment, wireless terminal 30 also uses known technology to measure the signal strength and/or acquire other quality information (e.g,. measurement) relating to the expected radio channel quality the wireless terminal 30 would get were it to connect to any neighboring cell belonging to the network 22C (network 22C being a WCDMA network in the Fig. 3 example implementation).

Using the technology disclosed herein wireless terminal 30 subsequently constructs a link report message MRM2. In the link report message MRM2 the wireless terminal 30 writes the information stored in the memory unit MU2 that was received in the link report message MRM1 previously received from the LTE RBS 28B. The wireless terminal 30 optionally further writes into the link report message MRM2 the quality (e.g., measurement) results obtained by the mobile station on the downlink radio channels and on neighboring cells. Further using the technology disclosed herein the wireless terminal 30 sends the link report message MRM2 to the radio resource control function 34A in network 22A. The link report message MRM2 can be sent over the radio link to the GSM RBS 28A which in turn forwards this message across the Abis interface to the GSM BSC 26A where the radio resource function 34A is implemented.

In a further act the BSC 26A stores the link report in the memory unit (MU1) 36A accessible to the radio resource control unit 34A. The radio resource control unit 34A then has essentially all necessary information available in the memory unit MU1 36A located in the GSM BSC 26A.

It should be understood to the person skilled in the art that there exist alternative implementations that differ in design to the preferred example embodiment described above but which still use the acts described herein. In one alternative embodiment the roles of the networks 22A and 22B are reversed so that the radio resource control unit resides in network 22B. In this modification the roles of networks 22A and 22B are reversed and the link report message is created in network 22A and sent to the mobile station for further transmission to the network 22B. In yet an alternative implementation the information contained in the link report message MRM1 is sent in a first message from the wireless terminal to the network 22A while the mobile station messages are sent in a second message from the wireless terminal to network 22A. In still other implementations the content of either of the link report messages MRM1 and MRM2 comprise other sets of quality measurements, load measurements, or any other information kept by either network 22B or the mobile station that can be of relevance to the radio resource control function in network 22A.

Fig. 4A illustrates in more detail an example embodiment of a wireless terminal 30(A) which serves as a multi-network relay/communicator. The wireless terminal 30(A) comprises communications interface 40 and link report processor 42. The communications interface 40 is configured to enable the wireless terminal 30(A) to communicate over a radio interface with a first radio access technology network (e.g., network 22A) and a second radio access technology (e.g., network 22B). The link report processor 42 is configured to receive a second network link report message MRM1 from the second radio access technology network (e.g., 22B) and to prepare a proxy link report message MRM2 for transmission to a node of the first radio access technology network 22A (e.g., the base station control node 26A).

As understood from the foregoing, the link report message MRM1 comprises an indication of an uplink quality measurement from the wireless terminal 30 to the second radio access technology network 22B (e.g., to base station 28B). The link report processor 42 of wireless terminal 30 is configured to include an indication of the quality determination MRM1 in the proxy link report MRM2 for transmission to the node (e.g., base station control node 26A) of the first radio access technology network 22A.

In some example modes and embodiments, the wireless terminal includes essentially the entire link report message (including the indication of the quality determination with respect to the uplink transmission from the wireless terminal) in the proxy link report message MRM2 and transmits the proxy link report message MRM2 to the node of (e.g., base station control node 26A) the first radio access technology network.

In other example modes and embodiments, the wireless terminal obtains the indication of the quality determination with respect to the uplink transmission and inserts or otherwise includes the quality determination (but not necessarily the entire link report message) in the proxy link report message MRM2 before transmitting the proxy link report message MRM2 to the node of the first radio access technology network.

In yet other example modes and embodiments represented by Fig. 4, the wireless terminal obtains the indication of the quality determination with respect to the uplink transmission and processes or operates upon (e.g., filters or averages) the indication of the quality determination and then inserts or otherwise includes (as the indication of the quality determination) a processed or derived indication of the quality determination in the proxy link report message.

In any of the example modes and embodiments described herein, the wireless terminal may obtain the indication of the quality determination with respect to the uplink transmission; then process or operates upon the information received in a link report message (e.g., the indication of the quality determination); and then include a result or output of such processed or operated-upon information in the proxy link report message as the "quality determination". The processing or operating upon the information received in a link report message may involve or include the information received in a link report message from any network, including the second radio access technology network (received in e.g., the link report message MRM1) and the third radio access technology network (received in, e.g., the link report message MRM3). The result or output of any such processed or operated-upon information is still considered an "indication" of the quality determination of the uplink quality for the particular link for which quality is assessed. It should therefore be understood that, with reference to any embodiment or mode described herein, usage of the "indication" or "quality indication" may be an output or result of a processing or operation upon the indication of quality determination as received in the link report message, and is indeed based upon the link report message.

The operation or processing performed on or with respect to the information received in a link report message may be performed by the link report processor 42 of any of the preceding embodiments or other embodiments encompassed hereby. In one example implementation illustrated in Fig. 4B, such operation or processing may include filtering or averaging. For example, Fig. 4B shows a filter F which performs simple filtering such as maintaining a running average, with the filtered or averaged result being reporting as the indication of the quality determination (rather than the raw data which was actually included in the link report message and upon which the filtered or averaged result or output is based).

In an example embodiment, the communications interface 40 is configured to perform interleaved communications with the first radio access technology network 22A and the second radio access technology network 22B in accordance with techniques such as, for example, those disclosed in PCT/SE2007/000358. In a non-limiting example implementation the first radio access technology network 22A and the second radio access technology network 22B comprise a GSM network and a Long Term Evolution (LTE) network, respectively.

In the example embodiment of Fig. 4A the wireless terminal 30 further comprises wireless terminal measurement unit 44. The wireless terminal measurement unit 44 is configured to perform a downlink quality measurement with respect to the first radio access technology network 22A and a downlink quality measurement with respect to the second radio access technology network 22B. The link report processor 42 and the communications interface 40 are configured to transmit an indication of at least one of the downlink quality measurements to the node of the first radio access technology network (e.g., to base station control node 26A of network 22A).

In an example embodiment the link report processor 42 is configured to include the indication of at least one of the downlink quality measurements in the proxy link report message MRM2 which is sent to the node 26A of the first radio access technology network 22A. In another example embodiment the link report processor 42 is configured to include the indication of at least one of the downlink quality measurements in a wireless terminal separate link report message MRM3 which is sent to the node 26A of the first radio access technology network 22A separately from the proxy link report message MRM2.

In an example embodiment such as that understood with reference to Fig. 3, the measurement unit 44 is further configured to measure signal quality of a cell of a third radio access technology network 22C. The link report processor 42 and the communications interface 40 are configured to transmit an indication of the signal quality of a cell of the third radio access technology network 22C to the node 26A of the first radio access technology network 22C. In an example implementation, the link report processor 42 is configured to include the indication of the signal quality of a cell of the third radio access technology network 22C in the proxy link report message MRM2.

Fig. 5 shows yet more details of an example wireless terminal, such as wireless terminal 30(5). In addition to wireless terminal elements and functionalities already discussed, wireless terminal 30(5) comprises multi-radio access technology/network scheduler 50 which schedules the interleaved or multiplexed transmissions to/from plural networks, e.g., network 22A and network 22B. Fig. 5 further shows that the link report processor 42 can comprise, in an example embodiment, analysis unit 52 and report preparation unit 54. The analysis unit 52 serves to analyze the link report message MRM1 received from the base station 28B. The report preparation unit 54 serves to prepare the link report message MRM2 (and optionally the wireless terminal separate link report message MRM3) which is sent to base station control node 26A.

Broken line 60 depicts, in Fig. 5 as well as other figures, a platform by which functionalities and units illustrated within line 60 can be realized in example embodiments. The terminology "platform" is a way of describing how the functional units of wireless terminal 30 can be implemented or realized by machine. One example platform is a computer implementation wherein one or more of the elements framed by line 60, including link report processor 42 and wireless terminal measurement unit 44 are realized by one or more processors which execute coded instructions stored in memory (e.g., non-transitory signals) in order to perform the various acts described herein. In such a computer implementation the wireless terminal 30 can comprise, in addition to a processor(s), a memory section 62 (which in turn can comprise random access memory 64; read only memory 66; application memory 68 (which stores, e.g., coded instructions which can be executed by the processor to perform acts described herein); and any other memory such as cache memory, for example).

Whether or not specifically illustrated, typically the wireless terminal 30 of each of the embodiments discussed herein can also comprise certain input/output units or functionalities, the representative input/output units for wireless terminal 30 being illustrated in Fig. 5 as keypad 70; audio input device (e.g. microphone) 72; visual input device (e.g., camera) 74; visual output device (e.g., display 76); and audio output device (e.g., speaker) 78. Other types of input/output devices can also be connected to or comprise wireless terminal 30.

In the example of Fig. 5 and other drawings the platform depicted by line 60 has been illustrated as computer-implemented or computer-based platform. Another example platform for wireless terminal 30 can be that of a hardware circuit, e.g., an application specific integrated circuit (ASIC) wherein circuit elements are structured and operated to perform the various acts described herein.

Fig. 6 illustrates in more detail how wireless terminal 30(6) can comprise first controller 80A configured to handle administration and transmissions of network 22A and second controller 80B configured to handle administration and transmissions of network 22B. First controller 80A and second controller 80B can be realized or implemented by a same processor or controller (or processor system), and in such case may constitute separate sets of non-transitory executable signals (e.g., programs or routines stored on tangible media). Fig. 6 specifically shows how various ones of the aforementioned units, such as link report processor 42 and wireless terminal measurement unit 44, can have separate subsections thereof (e.g., link report processor 42A and link report processor 42B) associated with the respective networks 22A and 22B.

As used herein, "wireless terminal(s)" or "UE" can be mobile stations or user equipment units (UE) such as but not limited to mobile telephones ("cellular" telephones) and laptops with wireless capability), e.g., mobile termination), and thus can be, for example, portable, pocket, hand-held, computer-included, or car-mounted mobile devices which communicate voice and/or data with radio access network.

Fig. 7 illustrates, in simplified manner, an example embodiment of a radio base station node 28. The base station 28 of Fig. 7 is intended to be a representative base station node for any suitable radio access technology network and is configured to prepare a link report message MRM1 for transmission to the wireless terminal 30. To this end the radio base station node 28 comprises communications interface 100; base station measurement unit 104; and base station link report processor 106. The communications interface 100 is configured to handle uplink and downlink transmissions over a radio or air interface with respect to wireless terminal 30. The base station measurement unit 104 is configured to perform a quality measurement with respect to the uplink transmissions from wireless terminal 30. The base station link report processor 106 is configured to include an indication of the quality measurement in a downlink message (e.g., MRM1 (e.g., link report message MRM1) to wireless terminal 30.

Fig. 8 shows an example embodiment radio base station node 28 in somewhat more detail. In addition to communications interface 100, base station measurement unit 104, and base station link report processor 106, the base station 28 of Fig. 8 further comprises interface 108 (an interface to core network(s)); scheduler 110; and memory 112 (including application(s) memory 118). Fig. 8 illustrates also base station measurement unit 104 as comprising analysis unit 120 and report preparation unit 122.

In similar manner as illustrated elsewhere herein, in an example embodiment the base station 28 comprises a platform simply depicted as broken line 124. Units and functionalities shown within platform line 124, including base station measurement unit 104 and base station link report processor 106, are in this example embodiment realized by machine implementation such as by computer implementation and/or at least partially by hardware implementation (e.g., a circuit or ASIC, for example). Comments herein concerning computer and/or processor and/or controller implementation in general thus also apply to base station 28, which can also have numerous input and output units such as those previously described for wireless terminal 30.

Fig. 9 shows an example embodiment of a base station control node 26, also known herein as a radio access network handover control node. As shown in Fig. 9, radio access network handover control node 26 comprises control node link report processor 130 and handover unit 132. The control node link report processor 130 is configured to receive a home network quality link report (from a home network to which base station control node 26 belongs) and a foreign network quality link report (concerning a foreign network to which base station control node 26 does not belong). The handover unit 132 is configured to use both the home network quality link report and the foreign network quality link report to determine whether to perform a radio access technology handover to the foreign network. The home network quality link report includes an indication of a quality measurement regarding a transmission between wireless terminal 30 and a node of the home network (e.g., base station node 28A for base station control node 26A). The foreign network quality link report is included in a proxy link report message (e.g., proxy link report message MRM2) received from wireless terminal 30 through the home network. The foreign network quality link report comprises handover-germane information such as, for example, an indication of a quality measurement regarding an uplink transmission from wireless terminal 30 to a node of the foreign network (e.g., base station 28B of network 22B in Fig. 2, for example).

Fig. 10 shows an example embodiment base station control node 26 in a more specific implementation. In addition to control node link report processor 130 and handover unit 132, Fig. 10 illustrates base station control node 26 as comprising interface 134 to home network base stations (such as base station 28A when the base station control node is base station control node 26A); interface 136 to a suitable core network; resource allocation and traffic handling unit 138; and memory 142 (including application(s) memory 148).

In similar manner as illustrated elsewhere herein, in an example embodiment the base station control node 26 comprises a platform simply depicted as broken line 150. Units and functionalities shown within platform line 150, including handover unit 132 and handover unit 134, are in this example embodiment realized by machine implementation such as by computer implementation and/or at least partially by hardware implementation (e.g., a circuit or ASIC, for example). Comments herein concerning computer and/or processor and/or controller implementation in general thus also apply to base station control node 26, which can also have numerous input and output units such as those previously described for wireless terminal 30.

Fig. 11 illustrates example, representative acts or steps comprising a basic method of operating a wireless terminal (such as wireless terminal 30 of Fig. 2) capable of communication over a radio interface with at least a first radio access technology network (e.g., network 22A) and a second radio access technology (e.g., network 22B). Act 11-1 comprises the wireless terminal receiving a link report message (e.g., link report message MRM1) from the second radio access technology network. The link report message MRM1 comprises handover-germane link information as assessed by the second network, e.g., an indication of an uplink quality (e.g., an uplink quality measurement) from the wireless terminal 30 to the second radio access technology network. The uplink quality measurement from the wireless terminal 30 to the second radio access technology network can be made by base station measurement unit 104, and the link report message prepared by base station link report processor 106 (see Fig. 8). Act 11-2 of the wireless terminal method further comprises the wireless terminal including the indication of an uplink quality in a proxy link report message (e.g., proxy link report message MRM2) and transmitting the proxy link report message to a node of the first radio access technology network (e.g., to base station control node 26A of network 22A in the example embodiment of Fig. 2).

Fig. 11A shows an example mode and embodiment similar to that of Fig. 11, but wherein as act 11A-2 the wireless terminal includes essentially the entire link report message (including the indication of the quality determination with respect to the uplink transmission from the wireless terminal) in the proxy link report message MRM2 and transmits the proxy link report message MRM2 to the node of (e.g., base station control node 26A) the first radio access technology network.

Fig. 11B shows another example mode and embodiment also similar to that of Fig. 11 but further described with reference to Fig. 24. In the mode and embodiment of Fig. 11B as act 11-1 the wireless terminal receives or obtains the indication of the quality determination with respect to the uplink transmission (e.g., in the link report message). As act 11B-1 the wireless terminal processes or operates upon (e.g., filters or averages) the indication of the quality determination (as received in the link report message) to obtain a processed or operated-upon output or result which is also considered as an "indication of the quality determination". As act 11B-2 the wireless terminal inserts or otherwise includes (as the indication of the quality determination) a processed or derived indication of the quality determination in the proxy link report message.

Fig. 12 resembles Fig. 11, but further illustrates the fact that, in an example mode and embodiment, as act 11-3 the wireless terminal method further comprises the wireless terminal performing interleaved or multiplexed communications with the first radio access technology network and the second radio access technology network. In an example implementation the first radio access technology network and the second radio access technology network comprise a GSM network and a Long Term Evolution (LTE) network. The interleaved or multiplexed communications can be in accordance with the techniques described in PCT/SE2007/000358, for example, which is incorporated herein by reference.

Fig. 13 illustrates that, in another example mode and embodiment, the acts of Fig. 11 can be augmented with one or more downlink quality determinations made by wireless terminal 30. Act 13-0 of Fig. 13 comprises the wireless terminal 30 performing a downlink quality determination (e.g., measurement) with respect to the first radio access technology network (e.g., network 22A of Fig. 2) and a downlink quality determination with respect to the second radio access technology network (e.g., network 22B of Fig. 2). In an example embodiment of Fig. 4A, for example, the downlink quality determinations can be made by wireless terminal measurement unit 44. As a further act 13-1, the wireless terminal transmits an indication of at least one of the downlink quality determinations to the node of the first radio access technology network (e.g., to base station control node 26A of Fig. 2). In the particular embodiment and mode shown in Fig. 13, the indication of at least one of the downlink quality determinations is included in the proxy link report message (e.g., proxy link report message MRM2) which is sent to the node of the first radio access technology network.

In another example embodiment and mode shown in Fig. 14, as act 14-0 the wireless terminal includes the indication of at least one of the downlink quality determinations in a wireless terminal separate link report message (e.g., wireless terminal separate link report message MRMS) which is sent to the node of the first radio access technology network separately from the proxy link report message. In the mode of Fig. 14 the wireless terminal separate link report message MRMS precedes the proxy link report message MRM2, but as illustrated in Fig. 15 the wireless terminal separate link report message MRMS can (as act 15-2) succeed (follow in time) the proxy link report message MRM2 (act 15-1).

Fig. 16 shows the method of Fig. 13 being augmented by the wireless terminal 30 making or obtaining determinations with respect to quality of yet another network (e.g., network 22C of Fig. 3). Act 16-0 comprises the wireless terminal making (e.g., measuring) or obtaining a determination of signal quality of a cell of a third radio access technology network 22C (shown in Fig. 16 as being in addition to the downlink determinations for network 22A and network 22B). As a further act the wireless terminal transmits an indication of the signal quality of a cell of the third radio access technology network to the node of the first radio access technology network (act 16-1).

In the particular embodiment and mode shown in Fig. 16, as act 16-1 the indication of the signal quality of a cell of the third radio access technology network is also included in the proxy link report message (e.g., proxy link report message MRM2) which is sent to the node of the first radio access technology network. In another example embodiment and mode shown in Fig. 17, as act 17-0 the wireless terminal includes the indication of the signal quality of a cell of the third radio access technology network in a wireless terminal separate link report message (MRMS) which is sent to the node of the first radio access technology network separately from the proxy link report message. In the mode of Fig. 17 the wireless terminal separate link report message of act precedes the proxy link report message MRM2 (act 17-1), but as illustrated in Fig. 18 the wireless terminal separate link report message MRMS can (as act 18-2) succeed (follow in time) the proxy link report message MRM2 (act 18-1).

Fig. 19 illustrates example, representative acts or steps comprising a basic method of operating a communication system such as communication system 20 of Fig. 2. Act 19-1 comprises a base station node of the second radio access technology network (e.g., base station 28B of Fig 2) performing a quality determination with respect to an uplink transmission from a wireless terminal (e.g., wireless terminal 30). Act 19-2 comprises the base station node of the second radio access technology network including an indication of the quality determination in a link report message (e.g., link report message MRM1) transmitted on a downlink from to the wireless terminal. Act 19-3 comprises the wireless terminal then including an indication of the quality determination in a proxy link report message (e.g., proxy link report message MRM2). Act 19-4 comprises the wireless terminal transmitting (relaying) the proxy link report message to a node of the first radio access technology network (e.g., to base station control node 26A of network 22A of Fig. 2). Act 19-5 comprises the node of the first radio access technology network using the quality determination with respect to the uplink transmission from the wireless terminal (as included in the proxy link report message) to determine whether to perform a radio access technology handover procedure.

Act 19-4 comprises the wireless terminal also providing, as a home network quality link report to the node of the first radio access technology network, an indication of a quality determination regarding a transmission between a wireless terminal and the first radio access technology network.

In an example embodiment and mode illustrated in Fig. 20, and in addition to acts 19-1 and 19-2, as act 20-1 the wireless terminal makes a determination (e.g., measurement) of a quality determination regarding a transmission between the wireless terminal and the first radio access technology network. As act 20-2 the wireless terminal also includes, in the proxy link report message, the indication of the quality determination regarding a transmission between the wireless terminal and the first radio access technology network. As act 20-3 the control node of the first radio access technology network also uses (in addition to the indications utilized in act 19-5) the indication of the signal quality between the wireless terminal and the first radio access technology network to determine whether to perform the radio access technology handover procedure.

In yet another example embodiment and mode illustrated in Fig. 21, and in addition to acts 19-1 and 19-2, as act 21-1 the wireless terminal includes the indication of at least one of the downlink quality determinations in a wireless terminal separate link report message which is sent to the node of the first radio access technology network separately from the proxy link report message. As understood from previous discussions and figures, the proxy link report message can either precede or follow the separate link report message. Moreover, the downlink (DL) determinations performed by wireless terminal 30 can occur either before or after receipt of the second network measurement report message MRM1.

In an example embodiment and mode illustrated in Fig. 22, and in addition to acts 19-1 and 19-2, the method further comprises as act 22-1 the wireless terminal determining (e.g., measuring) or obtaining signal quality of a cell of a third radio access technology network 22C (shown in Fig. 22 as being in addition to the downlink determinations for network 22A and network 22B). As a further act 22-2 the wireless terminal transmits an indication of the signal quality of the third radio access technology network (e.g., of a cell of the third radio access technology network) to the node of the first radio access technology network. As act 22-3 the node of the first radio access technology network also uses the indication of the signal quality of the third radio access technology network to determine whether to perform the radio access technology handover procedure. The determination of act 22-3 can use other indications such as those of act 19-5 and act 20-3.

In the particular embodiment and mode shown in Fig. 22, as act 22-2 the indication of the signal quality of the third radio access technology network is also included in the proxy link report message (e.g., proxy link report message MRM2) which is sent to the node of the first radio access technology network. In another example embodiment and mode shown in Fig. 23, as act 23-3 the wireless terminal includes the indication of the signal quality of a cell of the third radio access technology network in a wireless terminal separate link report message which is sent to the node of the first radio access technology network separately from the proxy link report message of act 23-2. In the mode of Fig. 23 the wireless terminal separate link report message of act 23-3 succeeds the proxy link report message MRM2 (act 23-2), but it should also be appreciated that the wireless terminal separate link report message can 23-3 precede (be earlier in time) the proxy link report message MRM2 of act 23-2. As act 23-4 the node of the first radio access technology network also uses the indication of the signal quality of the third radio access technology network to determine whether to perform the radio access technology handover procedure. The determination of act 23-4 can use other indications such as those of act 19-5 and act 20-3.

It should also be understood by the person skilled in the art that, although herein described in the context of the 3GPP radio technologies GSA, WCDMA, and LTE, the technology disclosed herein may equally well be used in any other combination of radio technologies including IEEE 802.11 technologies (WiFi), IEEE 802.16 systems (WiMAX), cdma systems described in 3GPP" or any other radio technology using cellular structures and handoff technology.

An advantage of the technology disclosed herein is a better quality of the voice and data services for mobile stations moving around in a multitude of radio networks. In particular the technology disclosed herein leads to more accurate decisions for handoffs to better cells when a mobile station enters a region of poor radio quality in the service cells. In an example preferred embodiment with a combined GSM, WCDMA and LTE network the technology disclosed herein will lead to inclusion of uplink quality measurements for the LTE data service in the evaluation algorithm for when to handoff from the combined GSM/LTE networks to the WCDMA network.

Another advantage of the technology disclosed herein is a reduction in number of dropped voice calls in a combined GSM/WCDMA/LTE system.

Yet another advantage is a better mobile data service in a multi-technology radio network.

One additional advantage of the technology disclosed herein is that it reduces the number of unnecessary handoffs between different radio technology networks.

The functions, events, steps, or acts described above may be implemented by units including those aforementioned, which can be computer-implement or preformed by a processor or controller as those terms are herein expansively defined.

Although the description above contains many specificities, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of this invention. Therefore, it will be appreciated that the scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the present invention is accordingly to be unduly limited. Reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural, chemical, and functional equivalents to the elements of the above-described preferred embodiments that are known to those of ordinary skill in the art are expressly incorporated and are intended to be encompassed hereby. Moreover, it is not necessary for a device or method to address each and every problem sought to be solved by the present invention, for it to be encompassed hereby.

WHAT IS CLAIMED IS:

1. A method of operating a wireless terminal (30) capable of communicating with a first radio access technology network and a second radio access technology, the method characterized by:

the wireless terminal (30) receiving a link report message from the second radio access technology network, the link report message comprising an indication of an uplink quality from the wireless terminal (30) to the second radio access technology network;

the wireless terminal (30) including an indication of the quality determination in a proxy link report message and transmitting the proxy link report message to a node of the first radio access technology network.

2. The method of claim 1, further comprising the wireless terminal (30) including essentially the entire link report message in the proxy link report message.

3. The method of claim 1, further comprising the wireless terminal (30) processing the indication of the uplink quality and including a processed result as the indication of the quality determination in the proxy link report message.

4. The method of claim 1, further comprising the wireless terminal (30) performing interleaved communications with the first radio access technology network and the second radio access technology network, and wherein the first radio access technology network and the second radio access technology network each comprise one of a Global System for Mobile communication (GSM) network and a Long Term Evolution (LTE) network.

5. The method of claim 1, further comprising:

the wireless terminal (30) performing a downlink quality determination with respect to the first radio access technology network and a downlink quality determination with respect to the second radio access technology network;

the wireless terminal (30) transmitting an indication of at least one of the downlink quality determinations to the node of the first radio access technology network.

6. The method of claim 5, further comprising the wireless terminal (30) including the indication of at least one of the downlink quality determinations in the proxy link report message.

7. The method of claim 5, further comprising the wireless terminal (30) including the indication of at least one of the downlink quality determinations in a wireless terminal (30) separate link report message.

8. The method of claim 1, further comprising:

the wireless making a determination of signal quality with respect to a third radio access technology network; and

the wireless terminal (30) transmitting an indication of the signal quality of the third radio access technology network to the node of the first radio access technology network.

9. The method of claim 8, further comprising the wireless terminal (30) including the indication of the signal quality of the third radio access technology network in the proxy link report message.

10. A wireless terminal (30) comprising:

a communications interface (40) configured to enable the wireless terminal (30) to communicate with a first radio access technology network and a second radio access technology network;

characterized by:

a link report processor (42) configured to receive a link report message from the second radio access technology network and to prepare a proxy link report message for transmission to a node of the first radio access technology network;

the link report message comprising an indication of an uplink quality from the wireless terminal (30) to the second radio access technology network; and

the link report processor (42) being configured to include an indication of the quality determination in the proxy link report message.

11. The apparatus of claim 10, wherein the link report processor (42) is configured to include essentially the entire link report message in the proxy link report message.

12. The method of claim 10, wherein the link report processor (42) is configured to process the indication of the uplink quality and to include a processed result as the indication of the quality determination in the proxy link report message.

13. The apparatus of claim 10, wherein the communications interface (40) is configured to perform interleaved communications with the first radio access technology

network and the second radio access technology network, and wherein the first radio access technology network and the second radio access technology network each comprise one of a Global System for Mobile communication (GSM) network and a Long Term Evolution (LTE) network.

14. The apparatus of claim 10, further comprising:

a wireless terminal (30) measurement unit configured to perform a downlink quality measurement with respect to the first radio access technology network and a downlink quality measurement with respect to the second radio access technology network; and

wherein the link report processor (42) and the communications interface (40) are configured to transmit an indication of at least one of the downlink quality measurements to the node of the first radio access technology network.

15. The apparatus of claim 14, wherein the link report processor (42) is configured to include the indication of at least one of the downlink quality measurements in the proxy link report message.

16. The apparatus of claim 14, wherein the link report processor (42) is configured to include the indication of at least one of the downlink quality measurements in a wireless terminal (30) separate link report message which is sent to the node of the first radio access technology network separately from the proxy link report message.

17. The apparatus of claim 10, wherein the measurement unit is further configured to make a signal quality determination with respect to a third radio access technology network; and wherein the link report processor (42) and the communications interface (40) are configured to transmit an indication of the signal quality of the third radio access technology network to the node of the first radio access technology network.

18. The apparatus of claim 17, wherein the link report processor (42) is configured to include the indication of the signal quality of the third radio access technology network in the proxy link report message.

19. A radio base station node (28) comprising:

a communications interface (100) configured to transmit uplink transmissions to and receive downlink transmissions from a wireless terminal (30);

a base station measurement unit (104) configured to perform a quality determination with respect to an uplink transmission from the wireless terminal (30);

characterized by:

a base station link report processor (106) configured to include an indication of the quality determination in a link report message to the wireless terminal (30).

20. A radio access network handover control node (26) characterized as comprising:

a control node link report processor (130) configured to receive a link report message and a proxy link report message;

a handover unit (132) configured to use both the link report message and the link report message to determine whether to perform handover from the first radio access technology to the second radio access technology network;

wherein the link report message includes an indication of a quality measurement regarding a transmission between a wireless terminal (30) and a node of the first network; and

wherein the handover unit is configured to receive the proxy link report message from the wireless terminal (30) through the first radio access technology network, the proxy link report message including an indication of a quality determination regarding an uplink transmission from the wireless terminal (30) to a node of the second radio access technology network.

21. A method of operating a communications system comprising a first radio access technology network and a second radio access technology network, the method characterized by:

a base station node of the second radio access technology network performing a quality determination with respect to an uplink transmission from a wireless terminal (30);

the base station node of the second radio access technology network including an indication of the quality determination with respect to the uplink transmission from the wireless terminal (30) in a link report message transmitted to the wireless terminal (30);

the wireless terminal (30) including the indication of the quality determination with respect to the uplink transmission from the wireless terminal (30) based on the link report message in a proxy link report message and transmitting the proxy link report message to a node of the first radio access technology network;

using the quality determination with respect to the uplink transmission from the wireless terminal (30) as included in the proxy link report message to determine whether to perform a radio access technology handover procedure.

22. The method of claim 21, further comprising the wireless terminal (30) including essentially the entire link report message in the proxy link report message.

23. The method of claim 21, further comprising the wireless terminal (30) processing the indication of the uplink quality and including a processed result as the indication of the quality determination in the proxy link report message.

24. The method of claim 21, further comprising:

the wireless terminal (30) also providing, to the node of the first radio access technology network, an indication of a quality determination regarding a transmission between the wireless terminal (30) and the first radio access technology network;

using the indication of the signal quality between the wireless terminal (30) and the first radio access technology network to determine whether to perform the radio access technology handover procedure.

25. The method of claim 24, further comprising the wireless terminal (30) also including, in the proxy link report message, the indication of the quality determination regarding a transmission between the wireless terminal (30) and the first radio access technology network in the proxy link report message.

26. The method of claim 24, further comprising the wireless terminal (30) including the indication of the quality determination regarding the transmission between the wireless terminal (30) and the first radio access technology network in a wireless terminal (30) separate link report message.

27. The method of claim 21, further comprising:

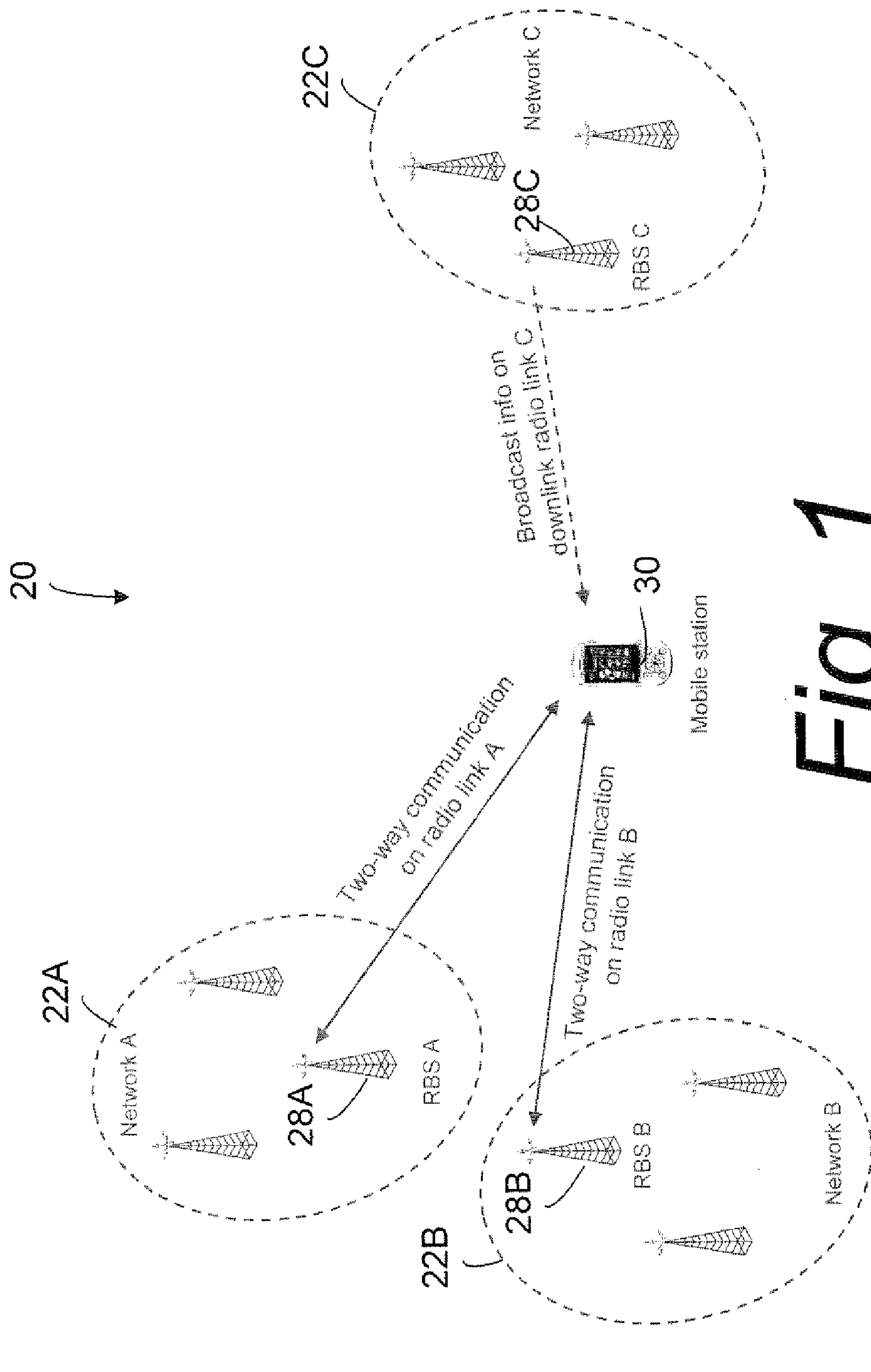
the wireless terminal (30) making a determination regarding signal quality of a third radio access technology network;

the wireless terminal (30) transmitting an indication of the determination regarding the signal quality of the third radio access technology network to the node of the first radio access technology network; and

using the indication of the signal quality of the third radio access technology network to determine whether to perform the radio access technology handover procedure.

28. The method of claim 27, further comprising the wireless terminal (30) including the indication of the signal quality of the third radio access technology network in the proxy link report message.

29. The method of claim 27, further comprising the wireless terminal (30) including the indication of the signal quality of the third radio access technology network in a wireless terminal (30) separate link report message.



20
22C
Network C
28C
RBS C
Broadcast info on downlink radio link C
30
Mobile station
Two-way communication on radio link A
Two-way communication on radio link B
22A
Network A
28A
RBS A
22B
28B
RBS B
Network B

Fig. 1

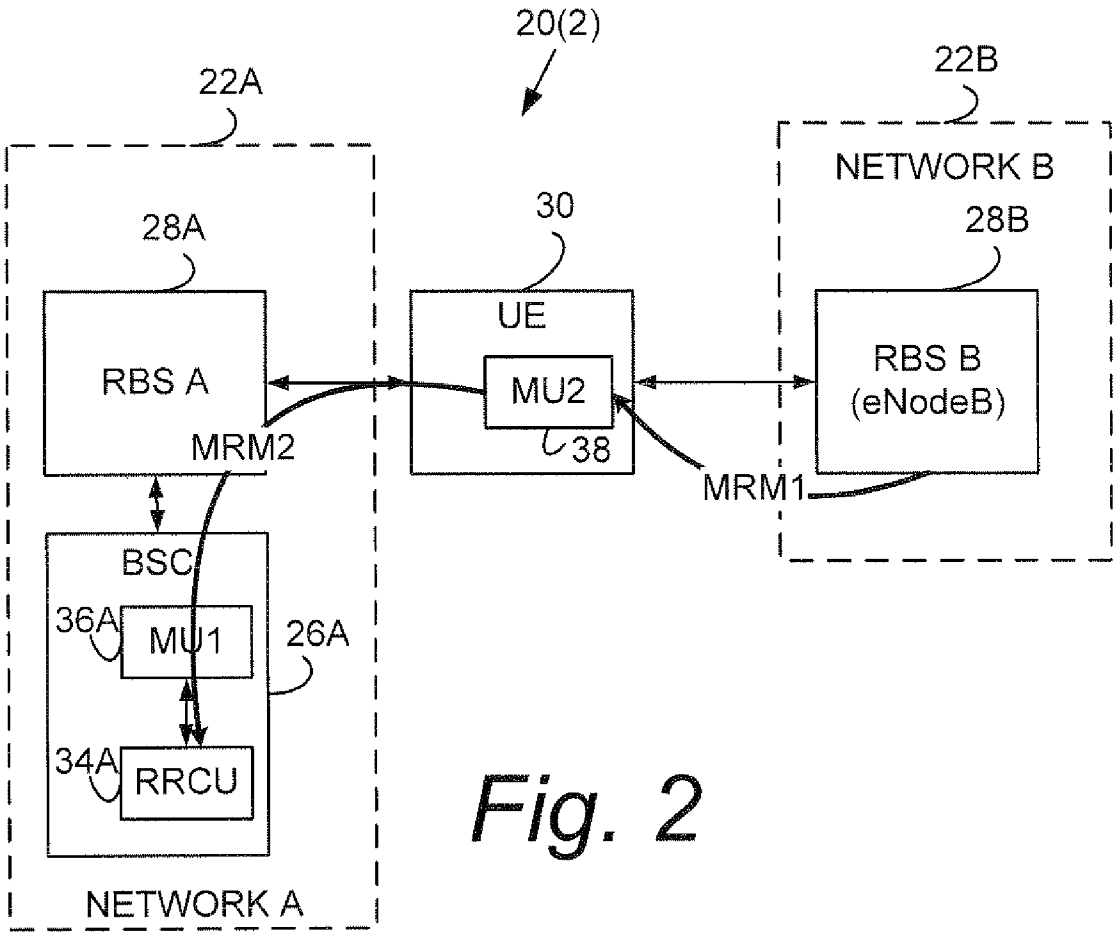

20(2)
22A
22B
NETWORK B
28A
30
28B
UE
RBS A
MU2
RBS B
(eNodeB)
MRM2
38
MRM1
BSC
36A
MU1
26A
34A
RRCU
NETWORK A

Fig. 2

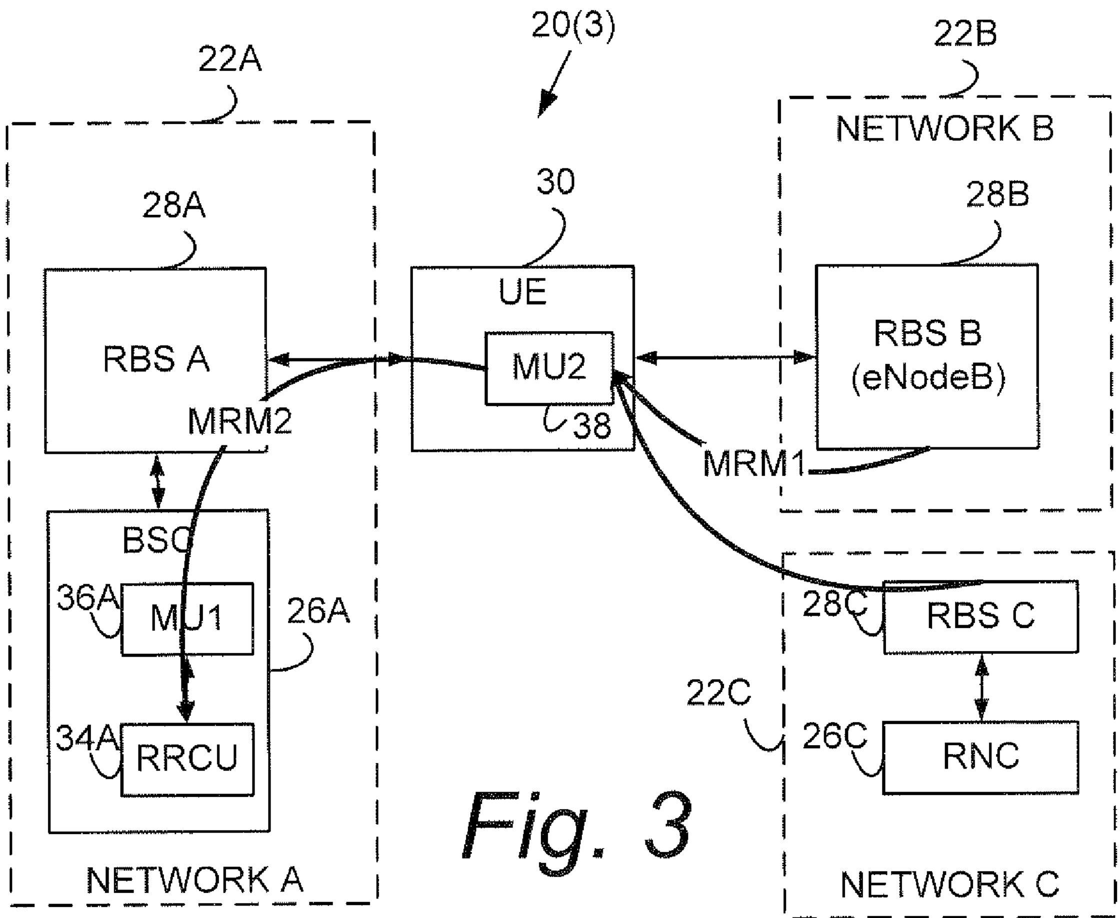

20(3)
22A
22B
NETWORK B
28A
30
28B
UE
RBS A
MU2
RBS B
(eNodeB)
MRM2
38
MRM1
BSC
36A
MU1
26A
28C
RBS C
22C
26C
RNC
34A
RRCU
NETWORK A
NETWORK C

Fig. 3

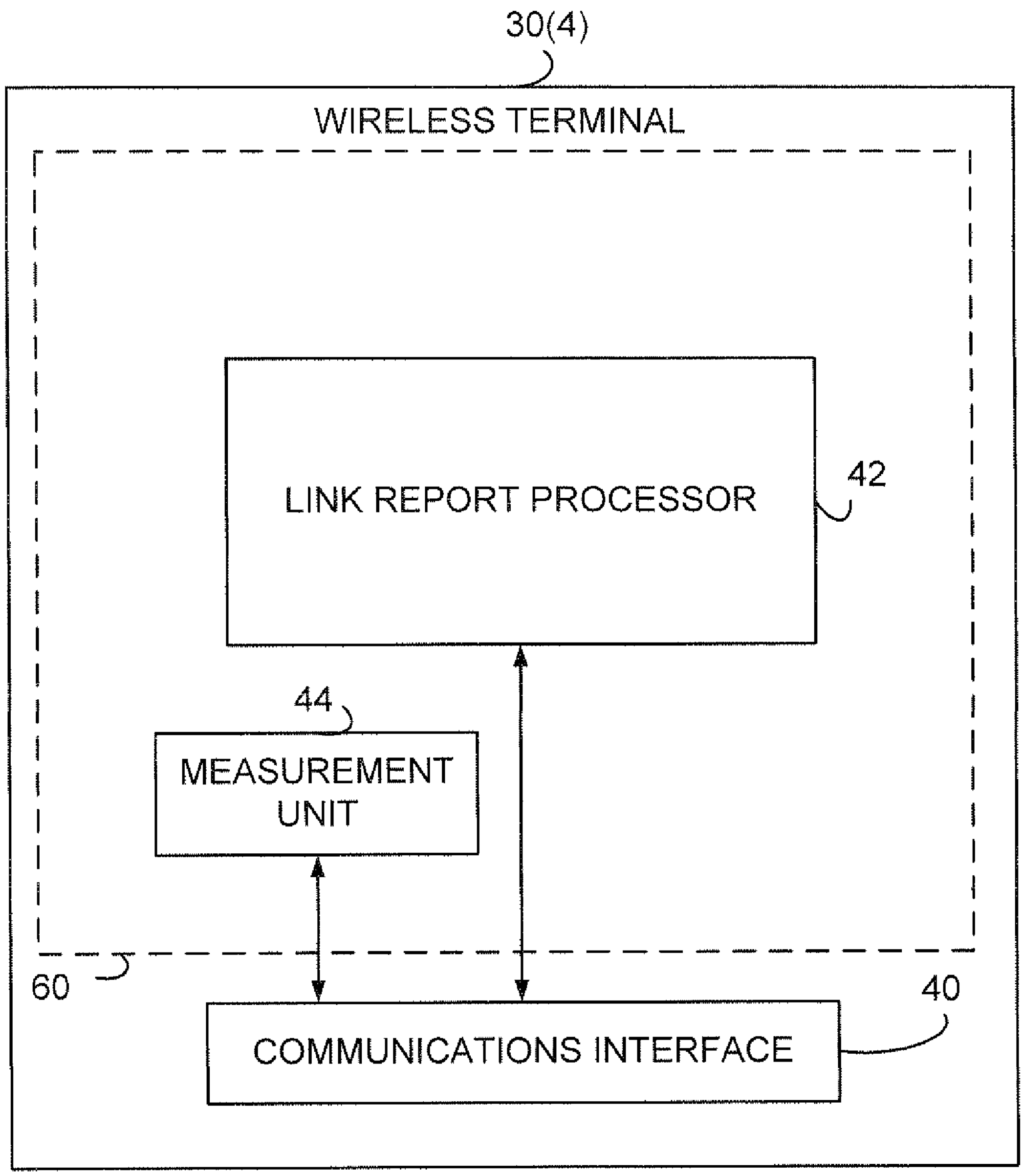

30(4)
WIRELESS TERMINAL
LINK REPORT PROCESSOR
42
44
MEASUREMENT UNIT
60
40
COMMUNICATIONS INTERFACE

Fig. 4A

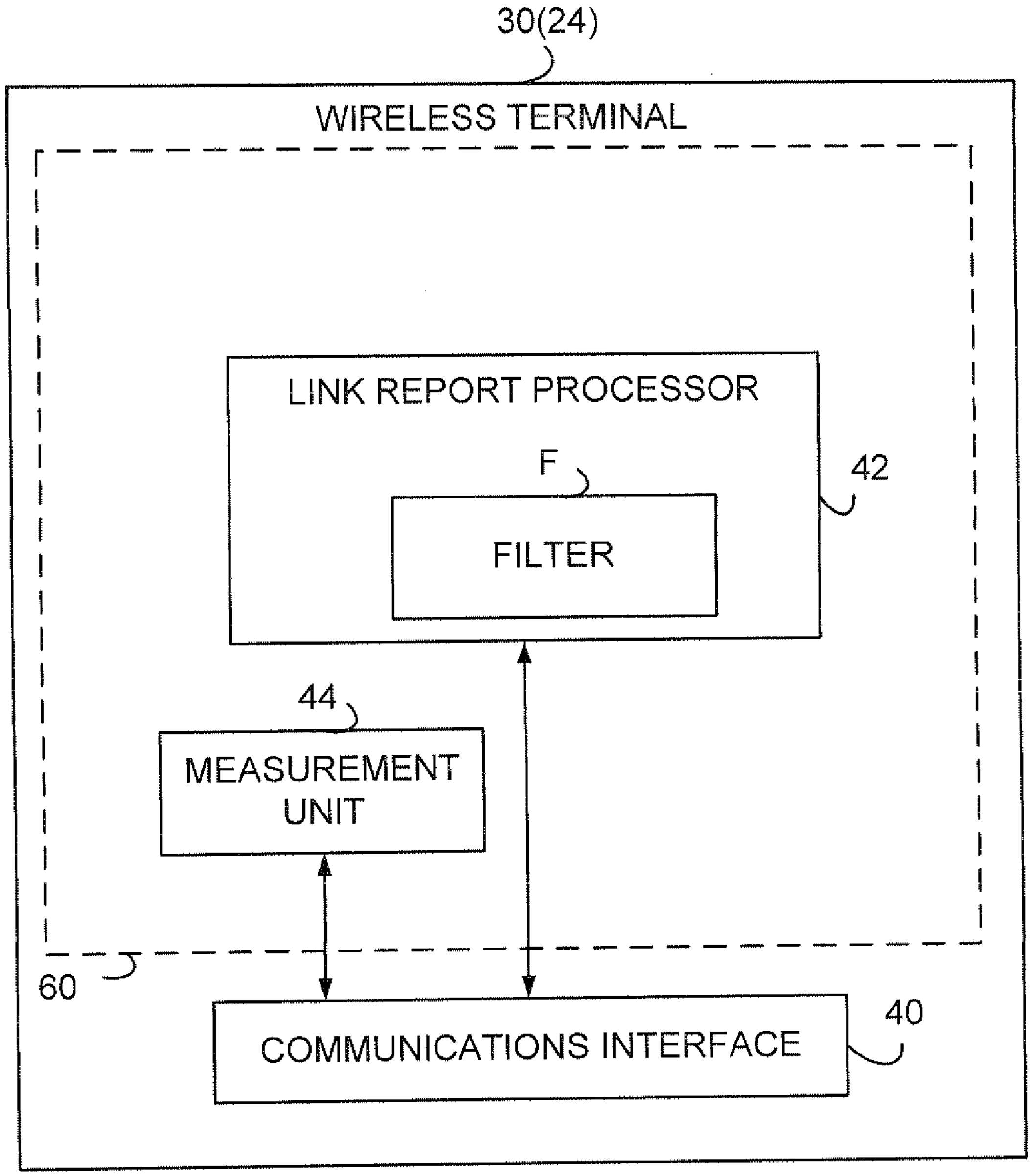

30(24)
WIRELESS TERMINAL
LINK REPORT PROCESSOR
F
42
FILTER
44
MEASUREMENT UNIT
60
COMMUNICATIONS INTERFACE
40

Fig. 4B

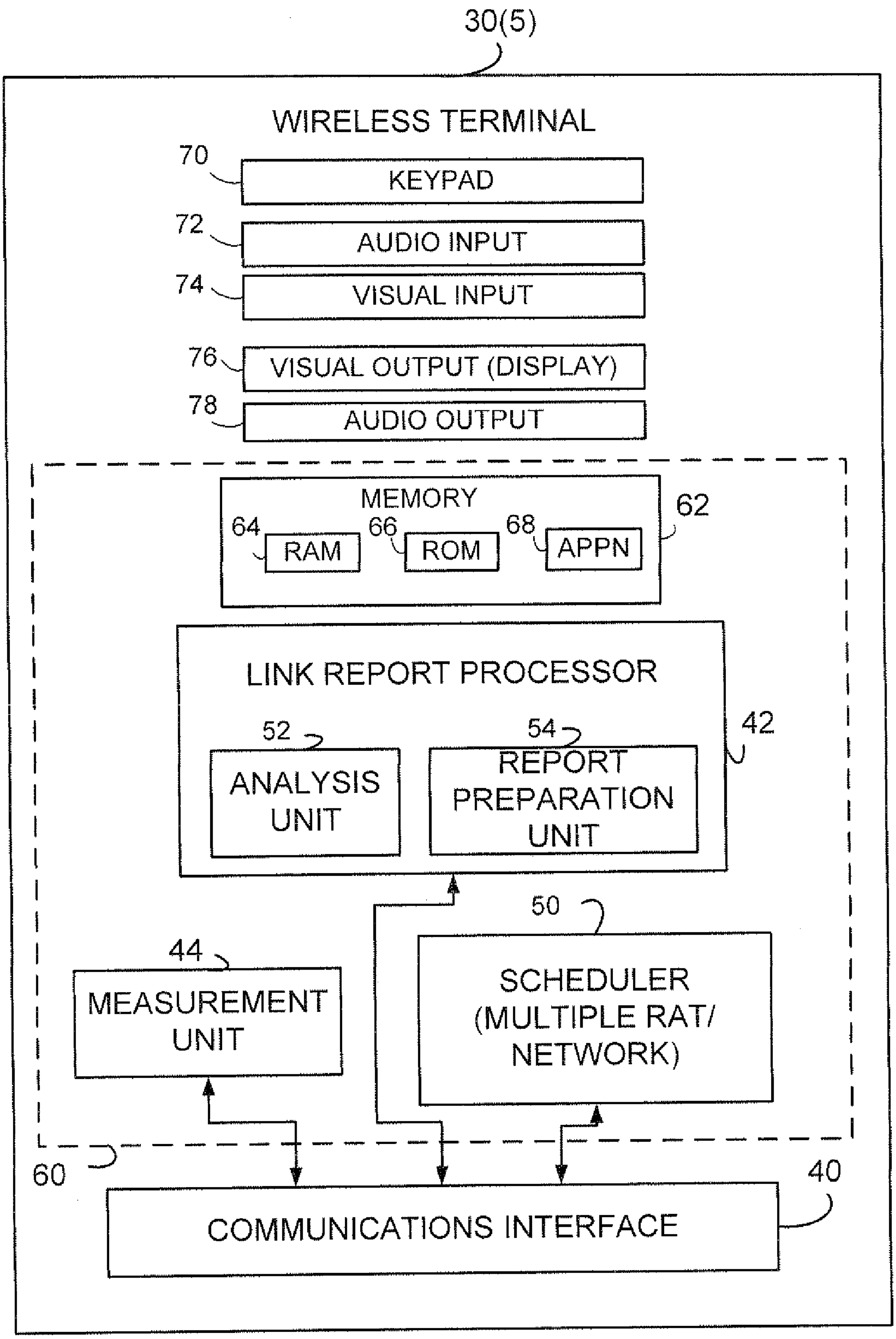

30(5)
WIRELESS TERMINAL
70
KEYPAD
72
AUDIO INPUT
74
VISUAL INPUT
76
VISUAL OUTPUT (DISPLAY)
78
AUDIO OUTPUT
MEMORY
62
64
RAM
66
ROM
68
APPN
LINK REPORT PROCESSOR
42
52
ANALYSIS UNIT
54
REPORT PREPARATION UNIT
50
SCHEDULER (MULTIPLE RAT/ NETWORK)
44
MEASUREMENT UNIT
60
40
COMMUNICATIONS INTERFACE

Fig. 5

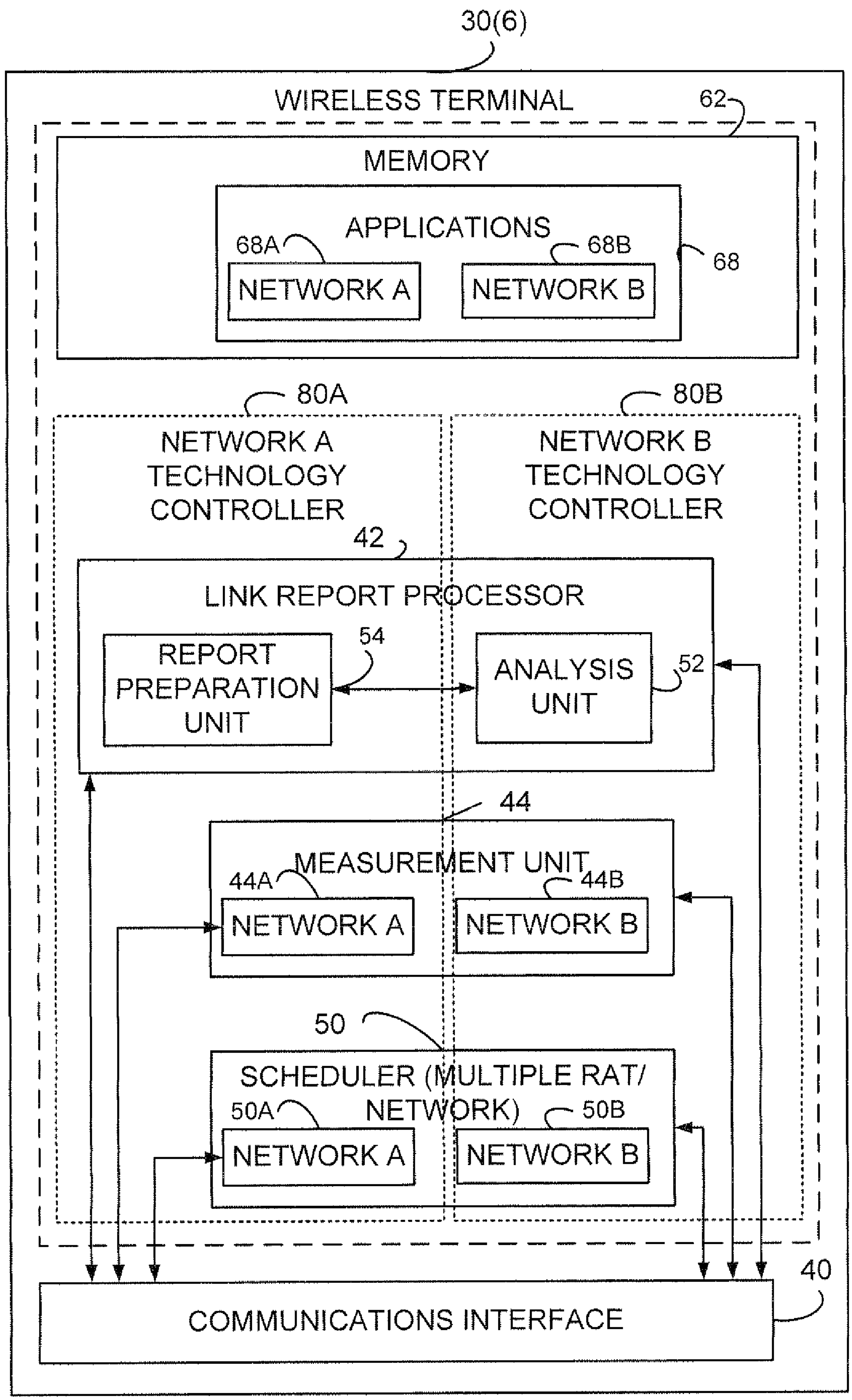

30(6)
WIRELESS TERMINAL
62
MEMORY
APPLICATIONS
68A
68B
68
NETWORK A
NETWORK B
80A
80B
NETWORK A TECHNOLOGY CONTROLLER
NETWORK B TECHNOLOGY CONTROLLER
42
LINK REPORT PROCESSOR
REPORT PREPARATION UNIT
54
ANALYSIS UNIT
52
44
MEASUREMENT UNIT
44A
44B
NETWORK A
NETWORK B
50
SCHEDULER (MULTIPLE RAT/ NETWORK)
50A
50B
NETWORK A
NETWORK B
40
COMMUNICATIONS INTERFACE

Fig. 6

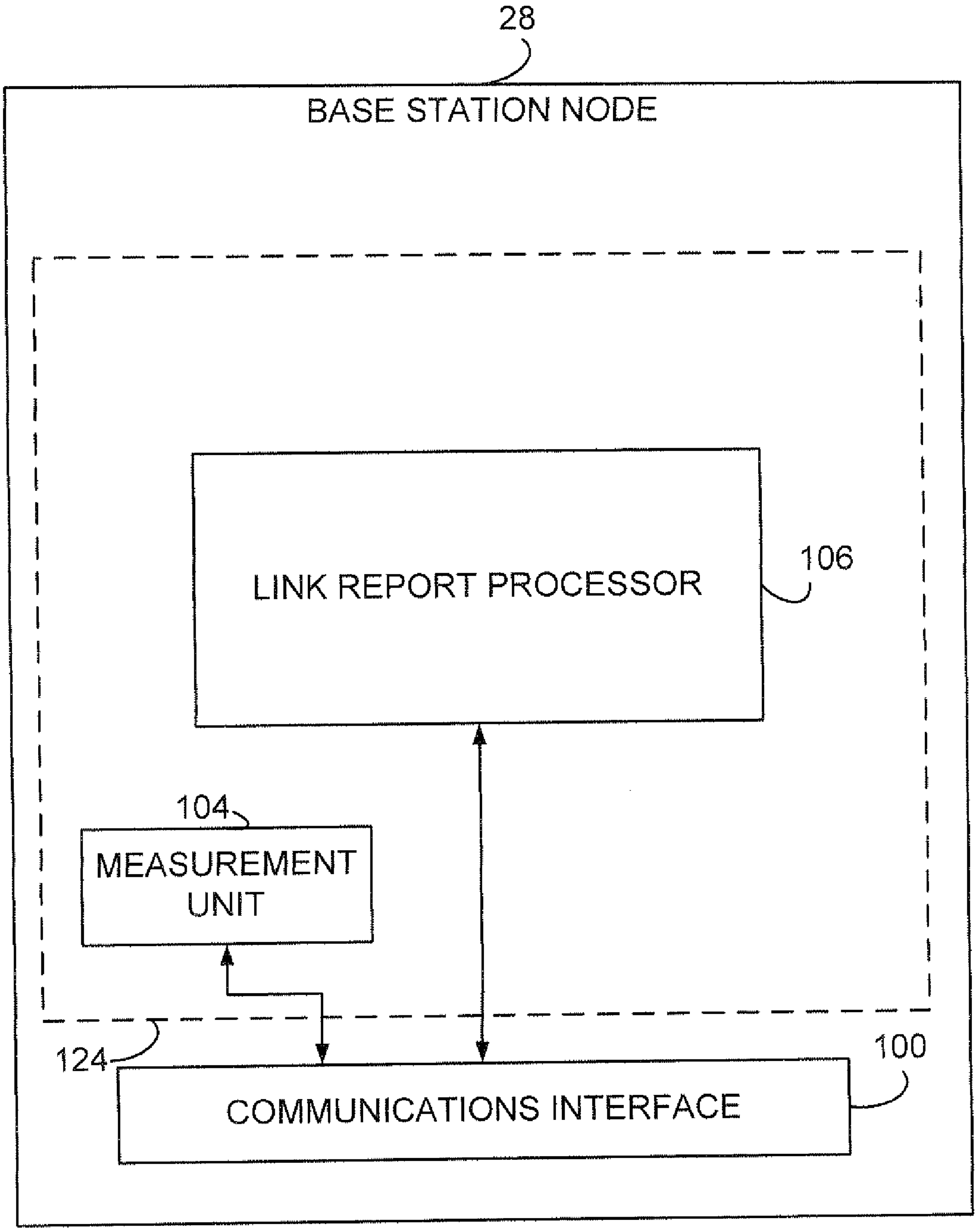

28
BASE STATION NODE
LINK REPORT PROCESSOR
106
104
MEASUREMENT UNIT
124
100
COMMUNICATIONS INTERFACE

Fig. 7

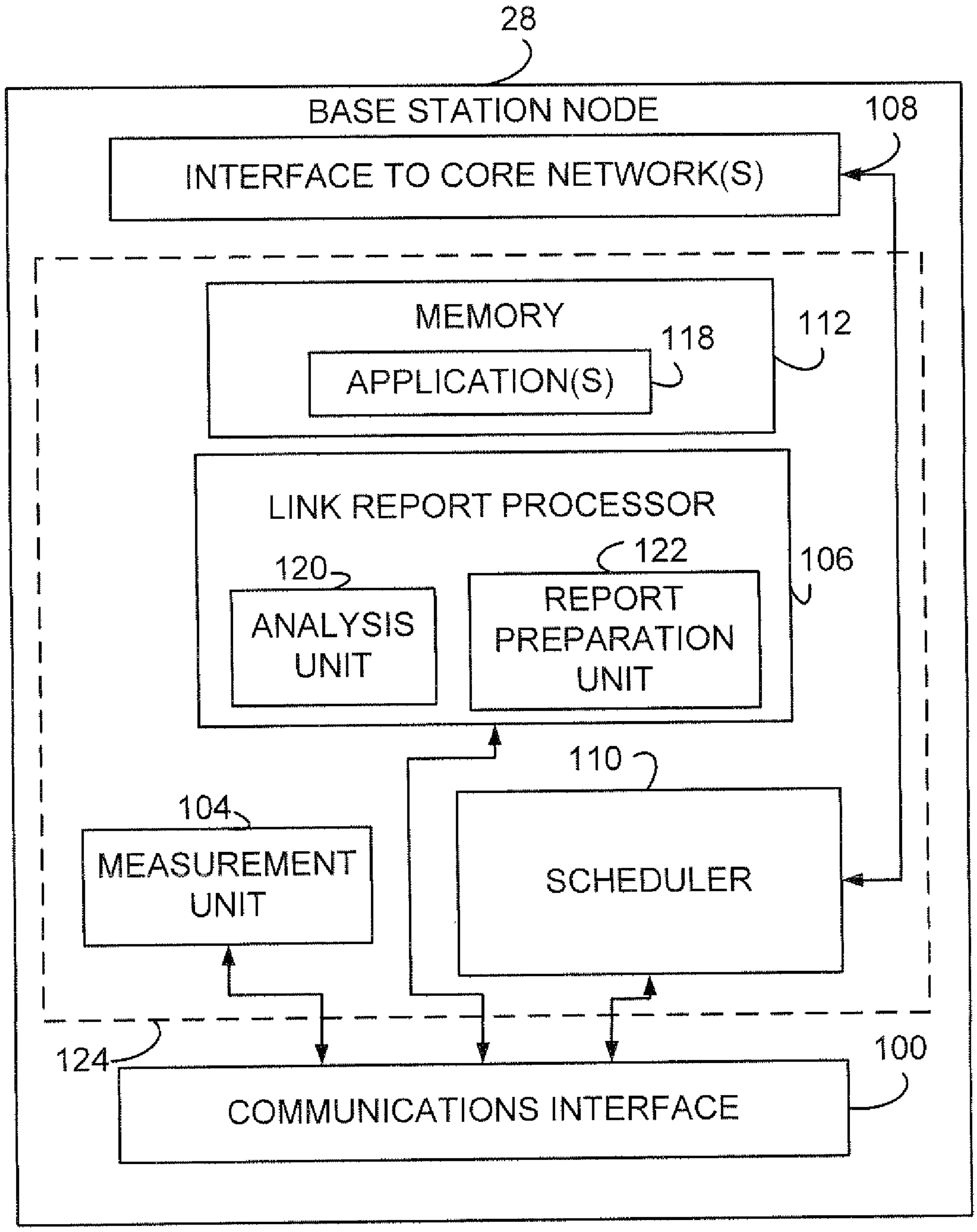

28
BASE STATION NODE
108
INTERFACE TO CORE NETWORK(S)
MEMORY
118
APPLICATION(S)
112
LINK REPORT PROCESSOR
120
122
106
ANALYSIS UNIT
REPORT PREPARATION UNIT
110
104
MEASUREMENT UNIT
SCHEDULER
124
100
COMMUNICATIONS INTERFACE

Fig. 8

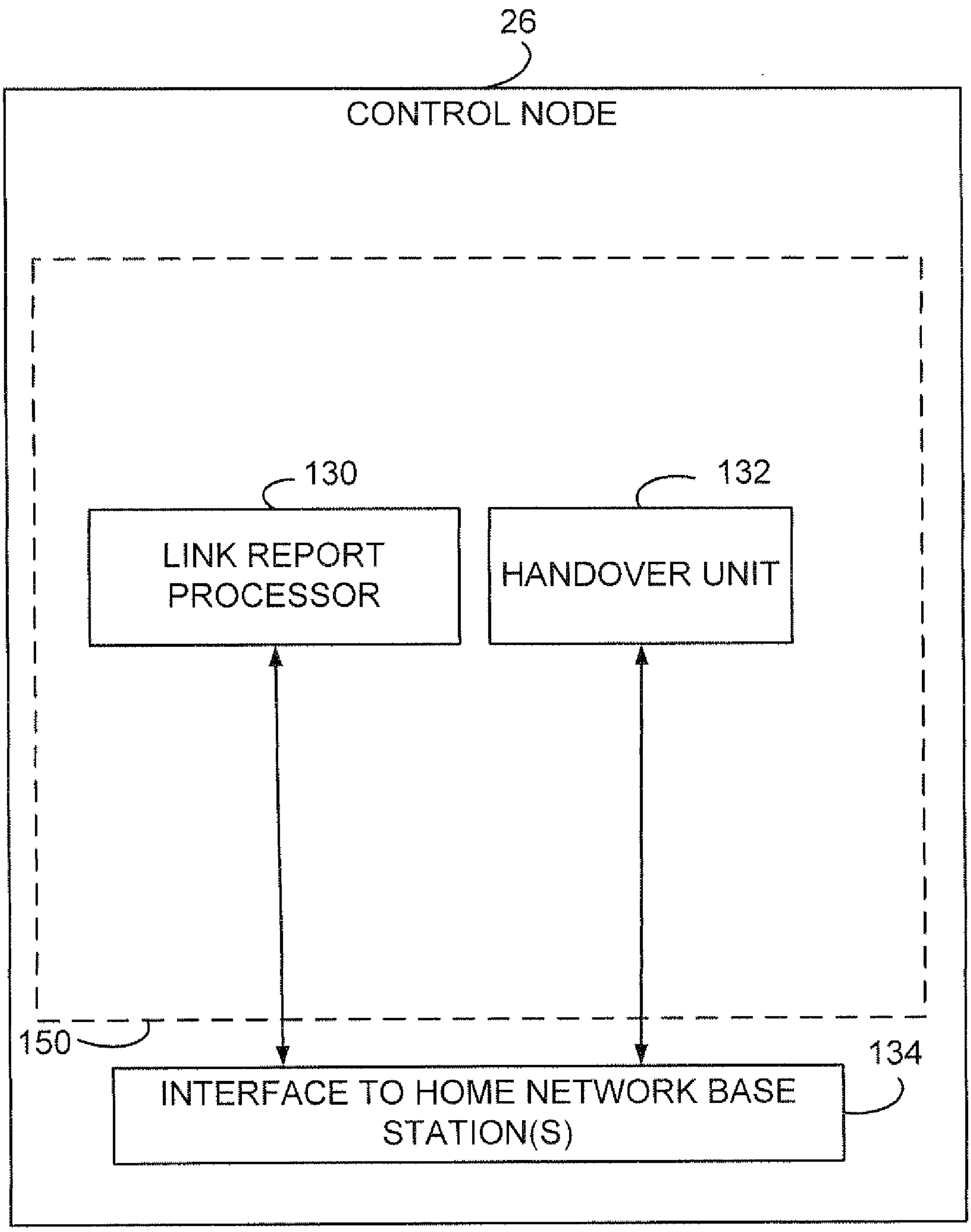

26
CONTROL NODE
130
LINK REPORT PROCESSOR
132
HANDOVER UNIT
150
INTERFACE TO HOME NETWORK BASE STATION(S)
134

Fig. 9

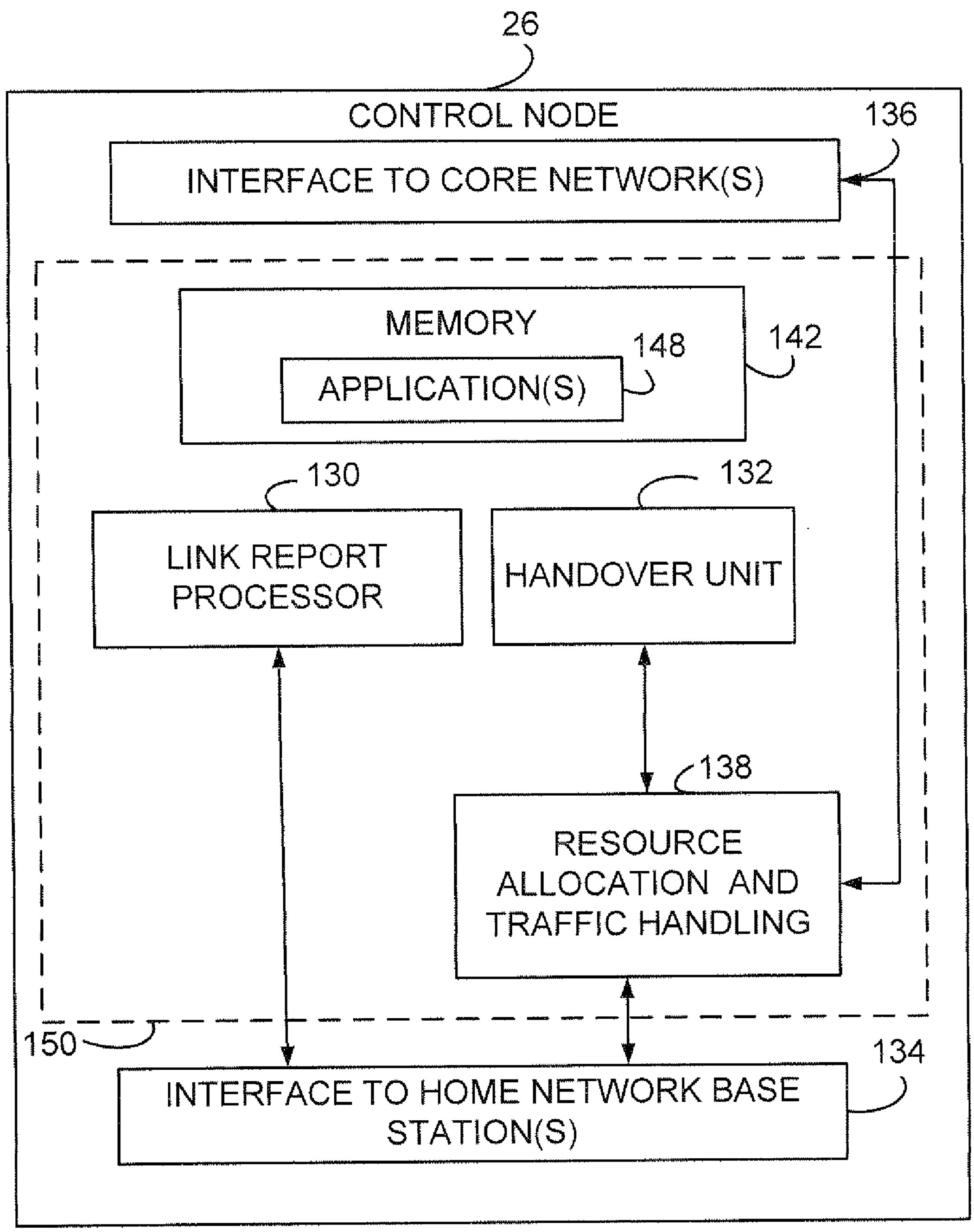

26
CONTROL NODE
136
INTERFACE TO CORE NETWORK(S)
MEMORY
148
APPLICATION(S)
142
130
132
LINK REPORT PROCESSOR
HANDOVER UNIT
138
RESOURCE ALLOCATION AND TRAFFIC HANDLING
150
134
INTERFACE TO HOME NETWORK BASE STATION(S)

Fig. 10

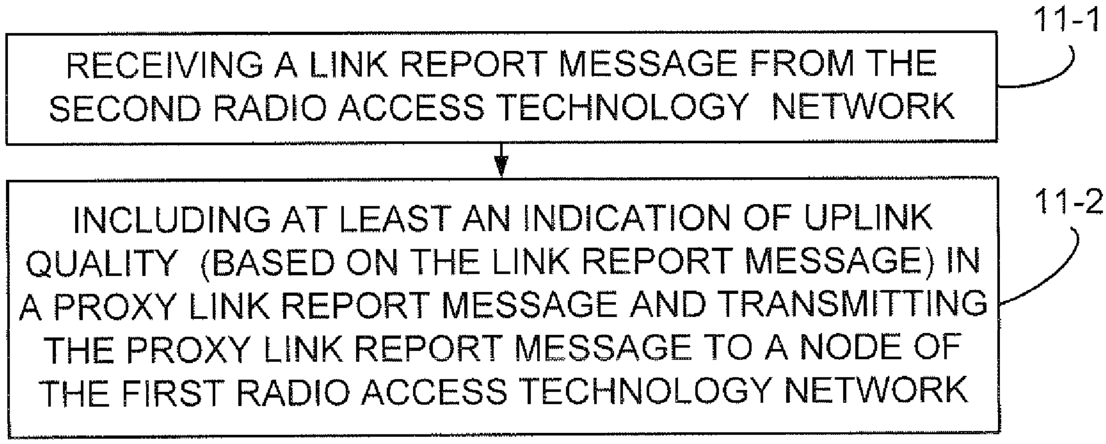


Fig. 11

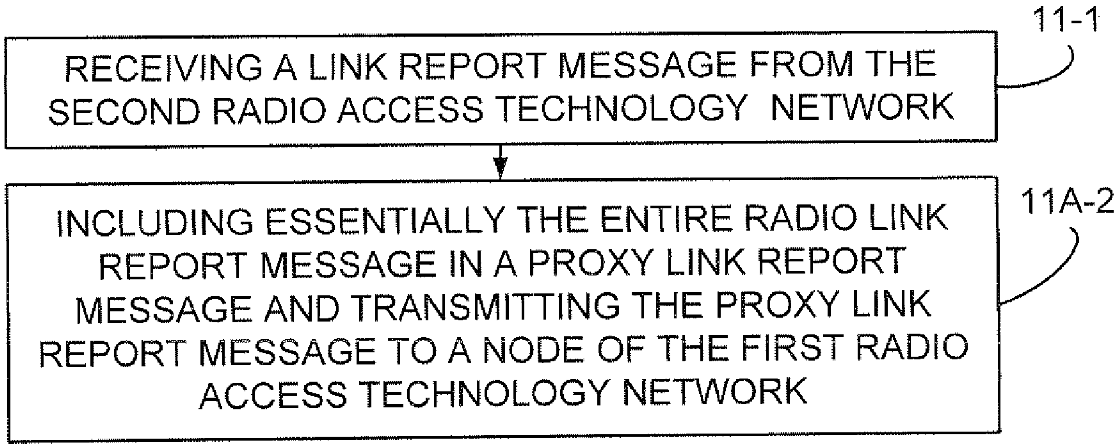


Fig. 11A

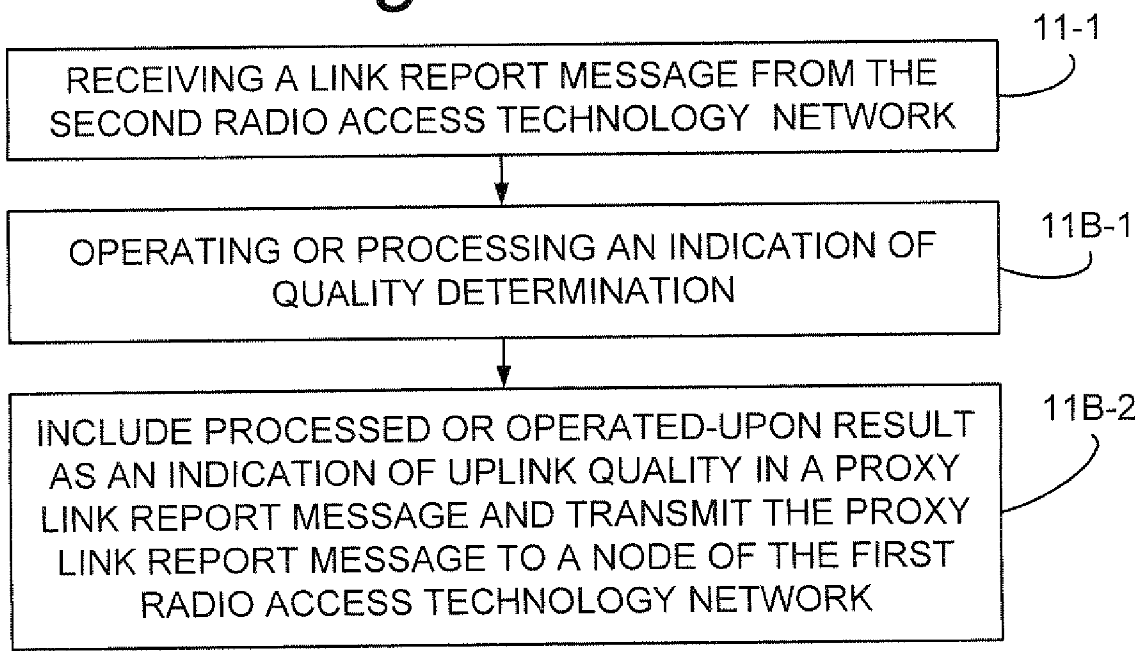


Fig. 11B

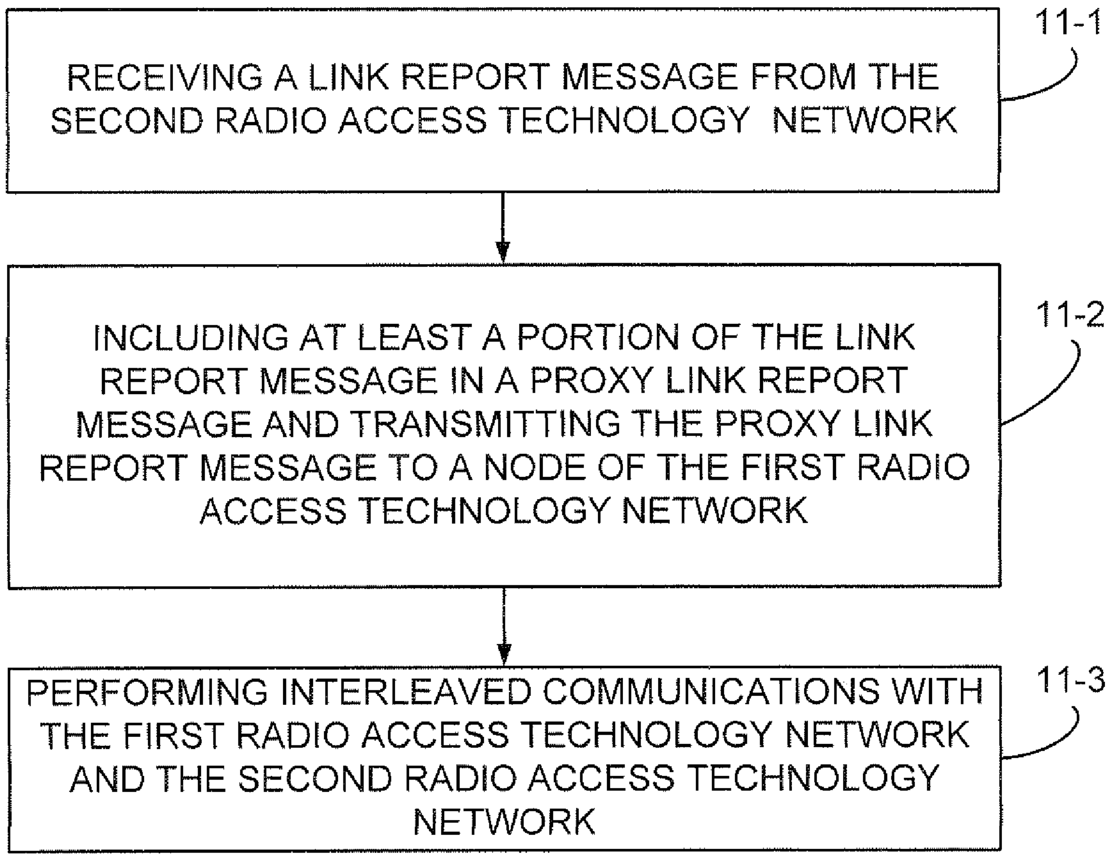

RECEIVING A LINK REPORT MESSAGE FROM THE SECOND RADIO ACCESS TECHNOLOGY NETWORK
11-1
INCLUDING AT LEAST A PORTION OF THE LINK REPORT MESSAGE IN A PROXY LINK REPORT MESSAGE AND TRANSMITTING THE PROXY LINK REPORT MESSAGE TO A NODE OF THE FIRST RADIO ACCESS TECHNOLOGY NETWORK
11-2
PERFORMING INTERLEAVED COMMUNICATIONS WITH THE FIRST RADIO ACCESS TECHNOLOGY NETWORK AND THE SECOND RADIO ACCESS TECHNOLOGY NETWORK
11-3

Fig. 12

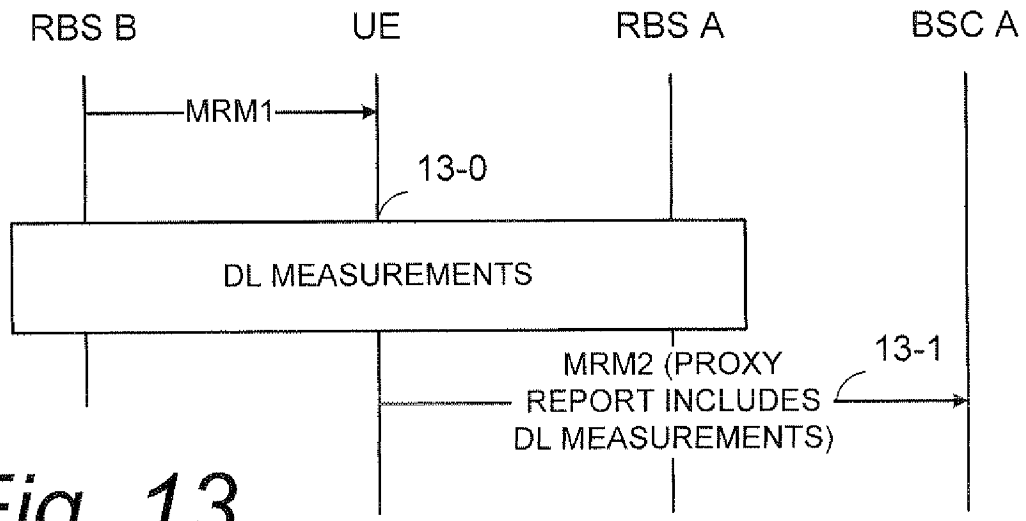


Fig. 13

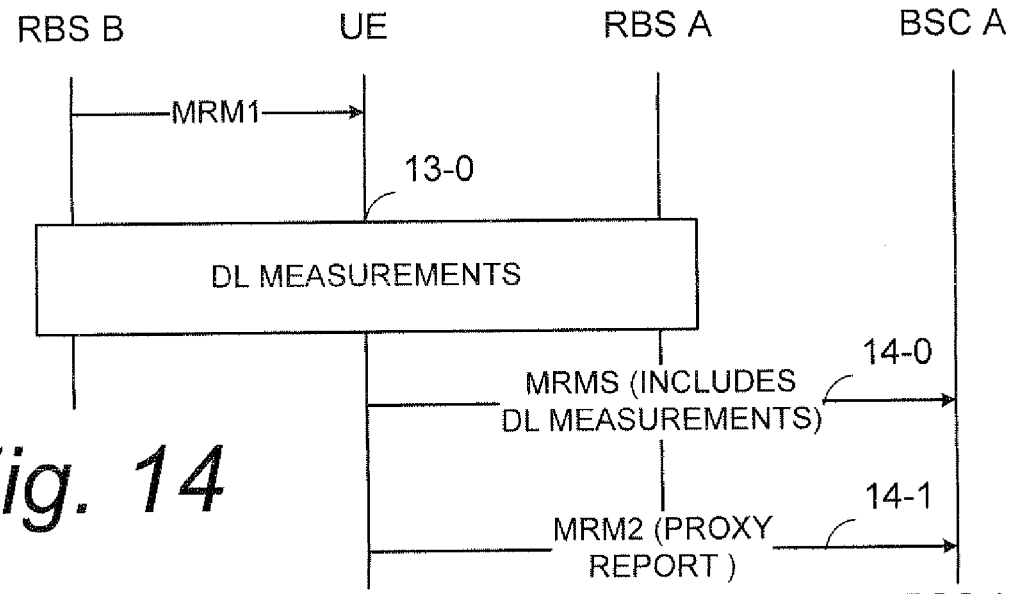


Fig. 14

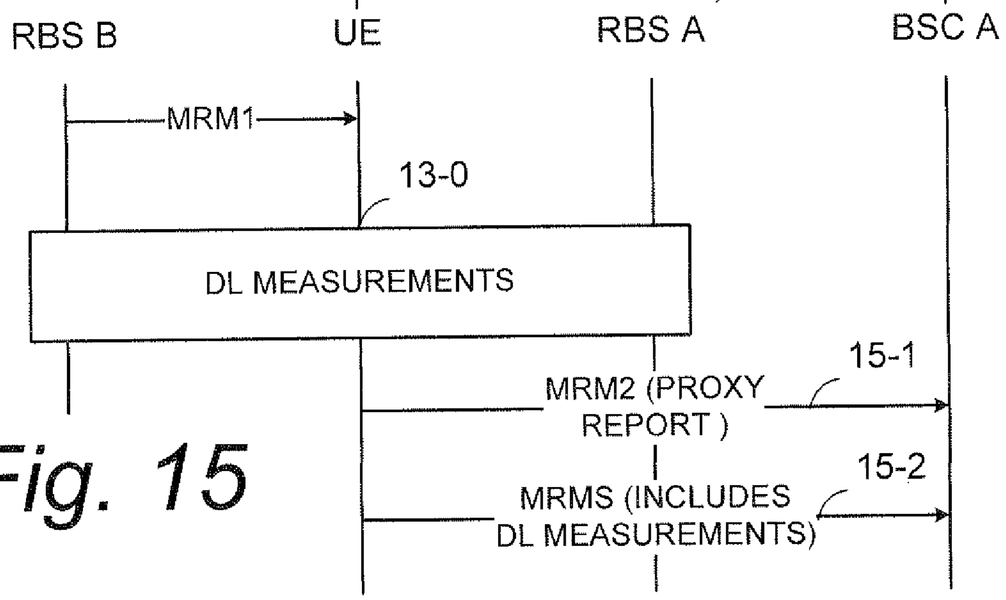


Fig. 15

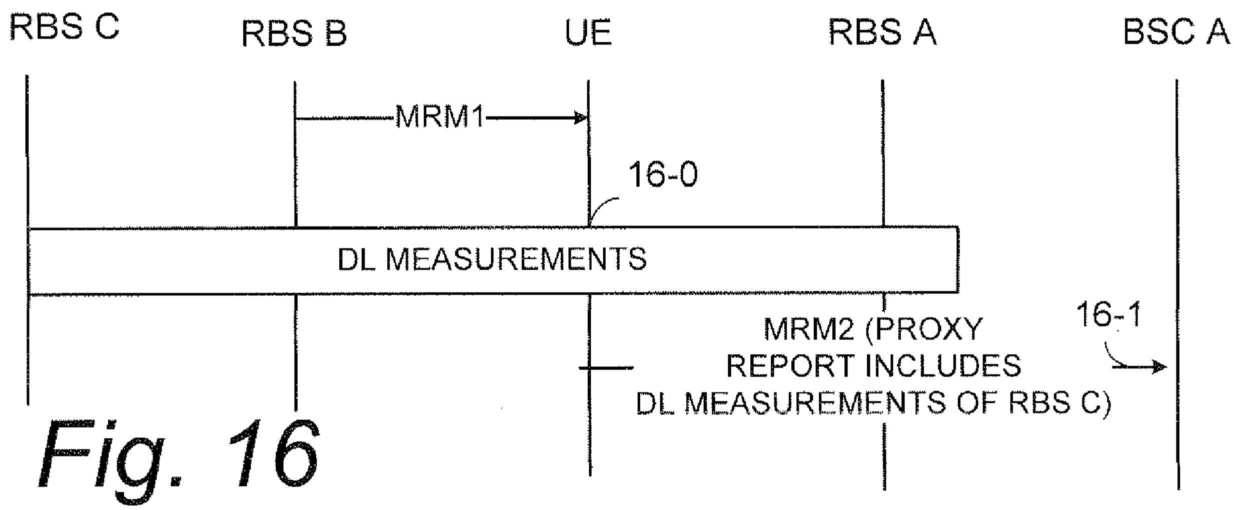


Fig. 16

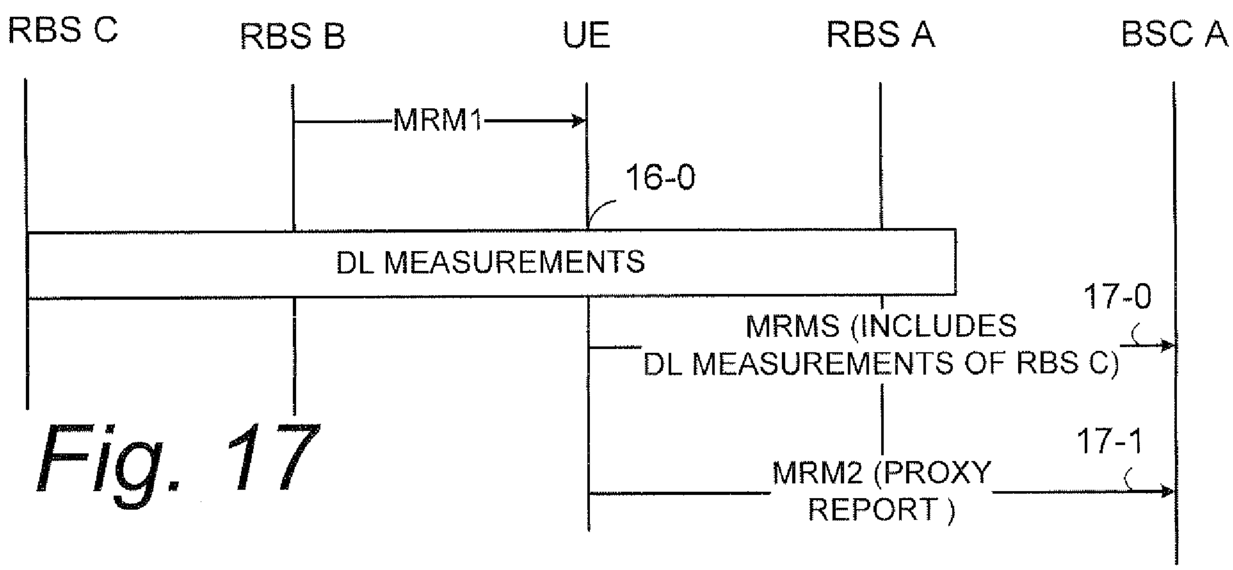


Fig. 17

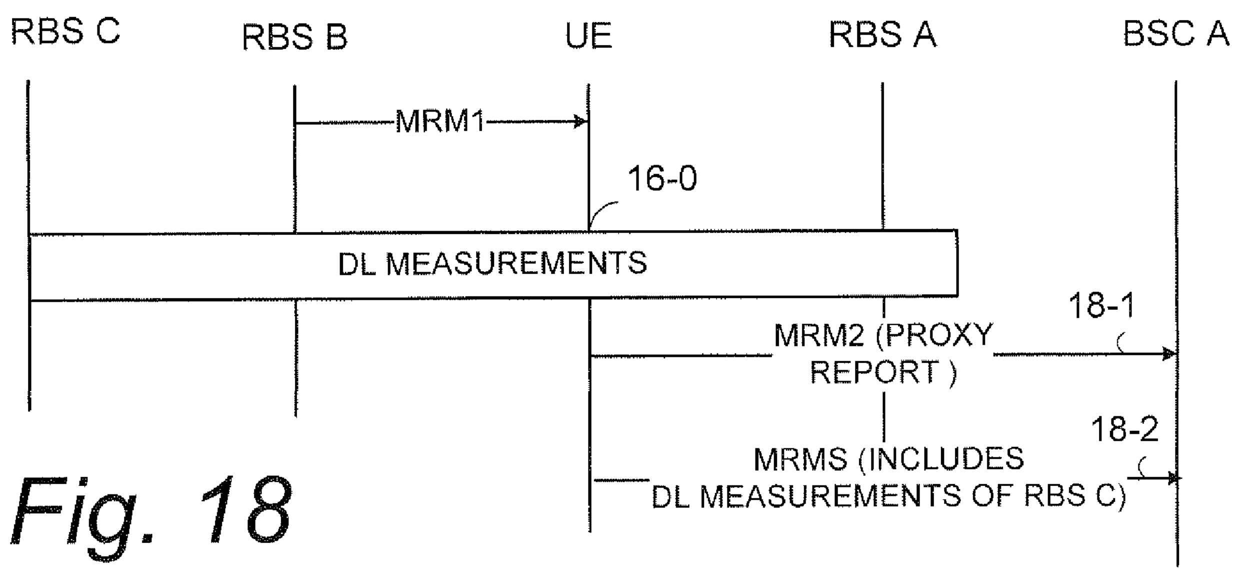


Fig. 18

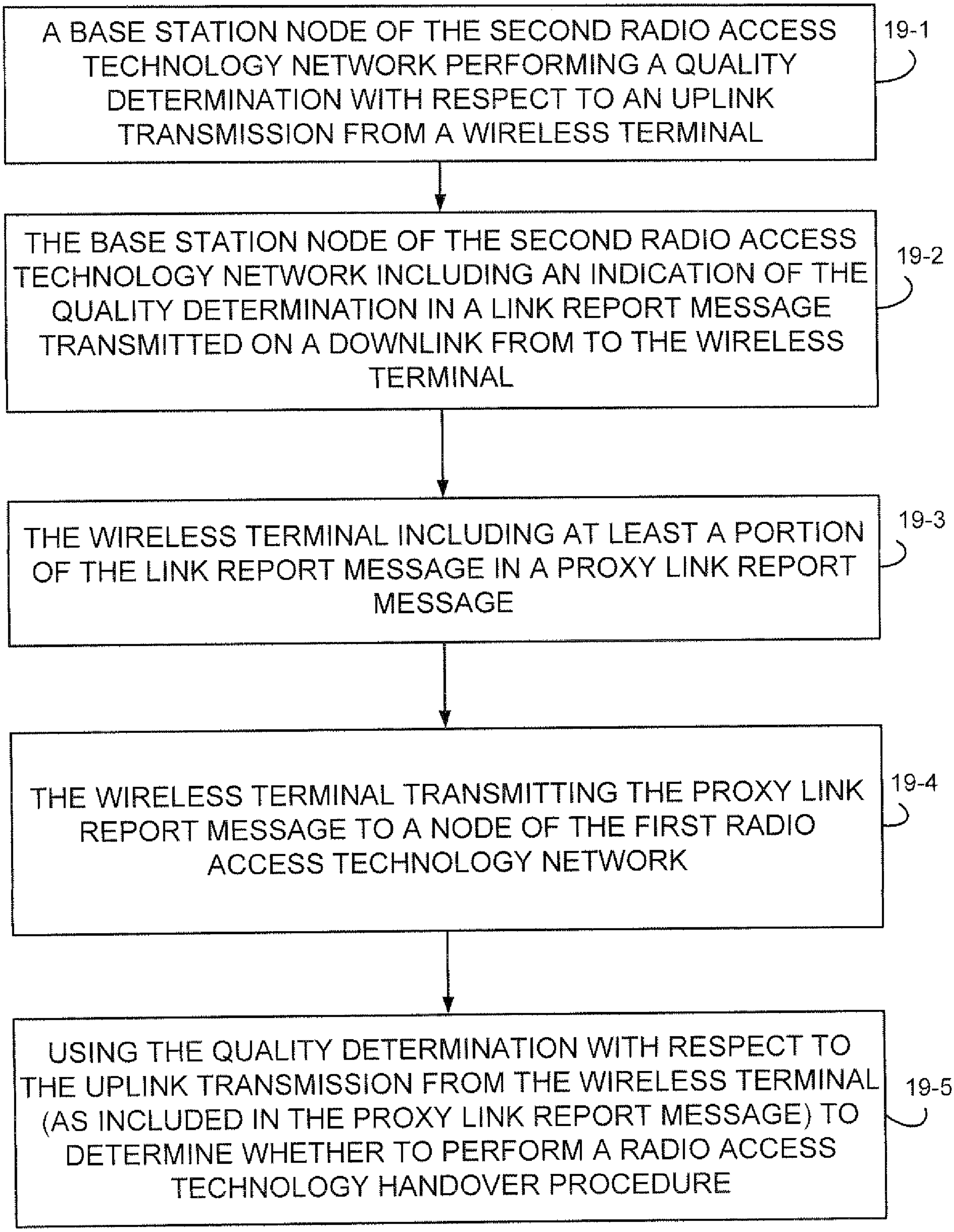

A BASE STATION NODE OF THE SECOND RADIO ACCESS TECHNOLOGY NETWORK PERFORMING A QUALITY DETERMINATION WITH RESPECT TO AN UPLINK TRANSMISSION FROM A WIRELESS TERMINAL
19-1
THE BASE STATION NODE OF THE SECOND RADIO ACCESS TECHNOLOGY NETWORK INCLUDING AN INDICATION OF THE QUALITY DETERMINATION IN A LINK REPORT MESSAGE TRANSMITTED ON A DOWNLINK FROM TO THE WIRELESS TERMINAL
19-2
THE WIRELESS TERMINAL INCLUDING AT LEAST A PORTION OF THE LINK REPORT MESSAGE IN A PROXY LINK REPORT MESSAGE
19-3
THE WIRELESS TERMINAL TRANSMITTING THE PROXY LINK REPORT MESSAGE TO A NODE OF THE FIRST RADIO ACCESS TECHNOLOGY NETWORK
19-4
USING THE QUALITY DETERMINATION WITH RESPECT TO THE UPLINK TRANSMISSION FROM THE WIRELESS TERMINAL (AS INCLUDED IN THE PROXY LINK REPORT MESSAGE) TO DETERMINE WHETHER TO PERFORM A RADIO ACCESS TECHNOLOGY HANDOVER PROCEDURE
19-5

Fig. 19

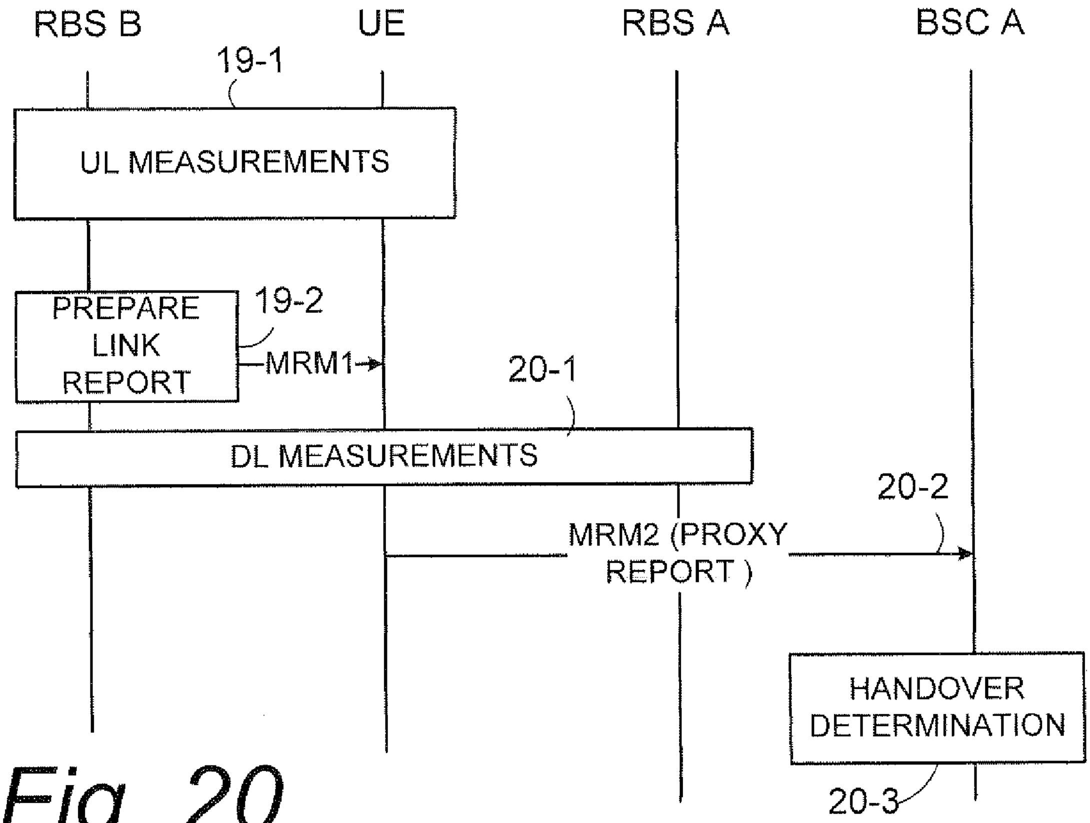

RBS B
UE
RBS A
BSC A
19-1
UL MEASUREMENTS
PREPARE LINK REPORT
19-2
MRM1
20-1
DL MEASUREMENTS
20-2
MRM2 (PROXY REPORT)
HANDOVER DETERMINATION
20-3

Fig. 20

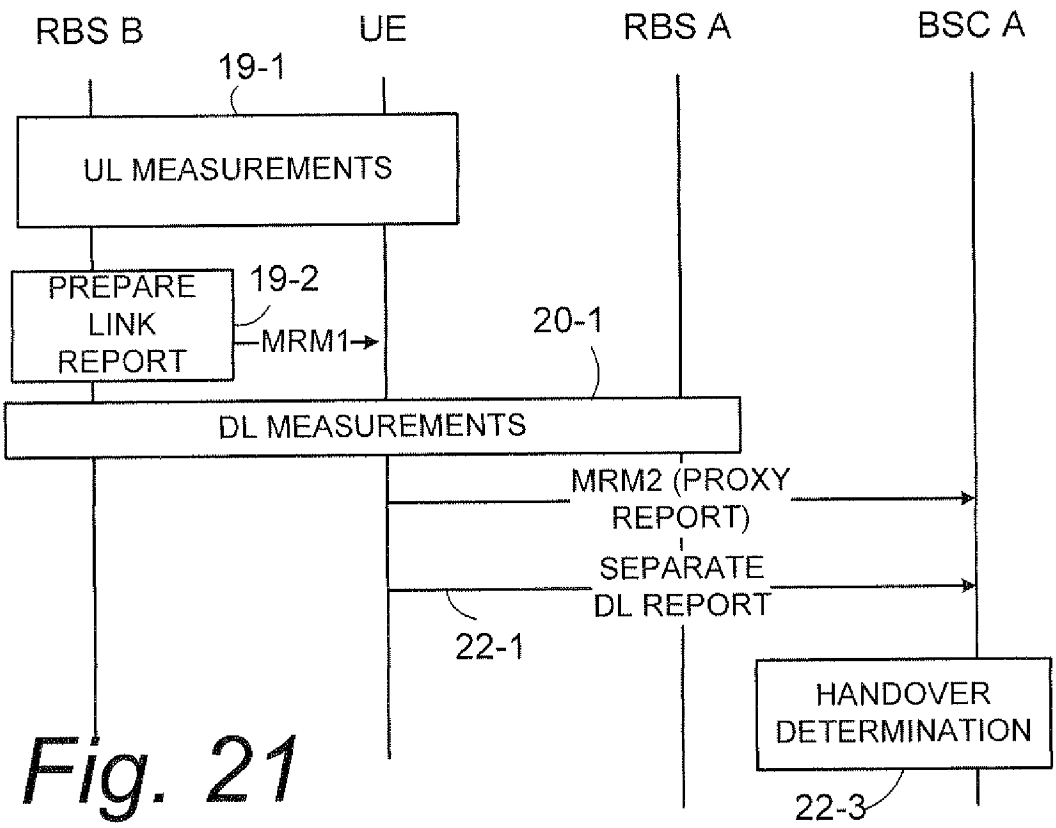

RBS B
UE
RBS A
BSC A
19-1
UL MEASUREMENTS
PREPARE LINK REPORT
19-2
MRM1
20-1
DL MEASUREMENTS
MRM2 (PROXY REPORT)
SEPARATE DL REPORT
22-1
HANDOVER DETERMINATION
22-3

Fig. 21

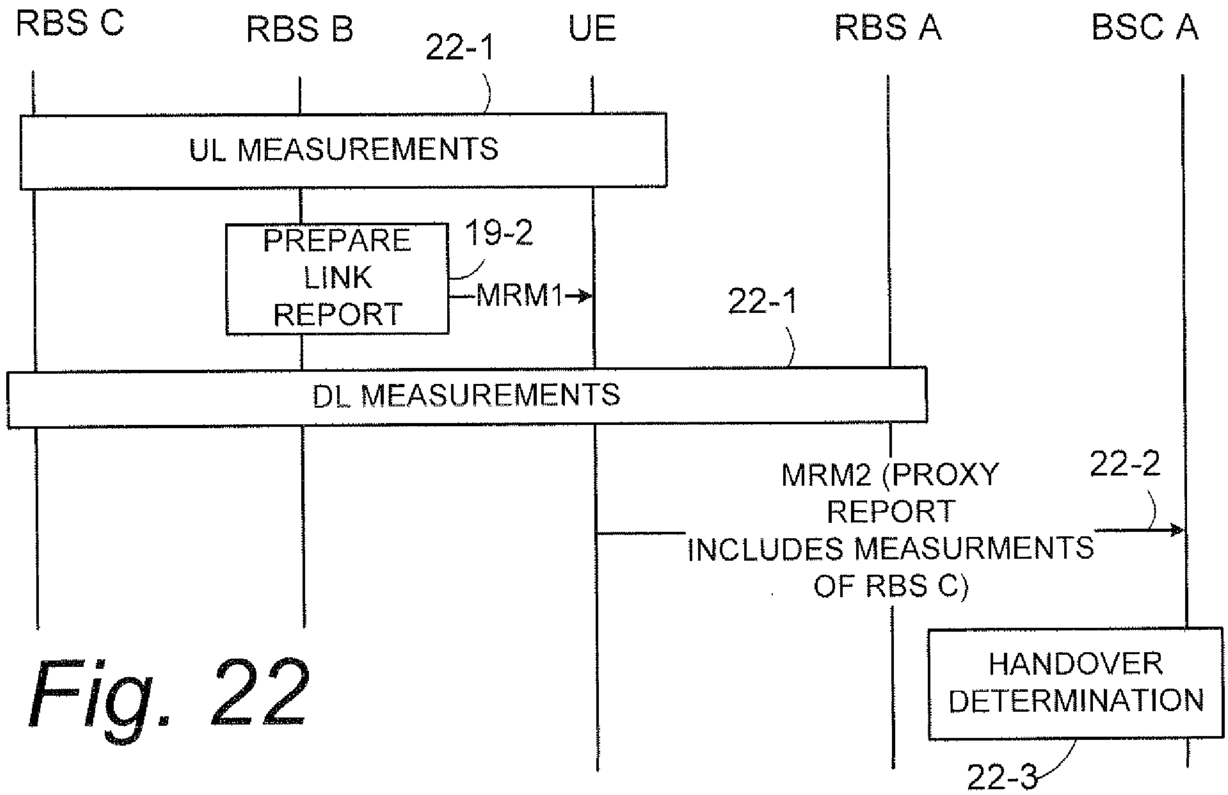

RBS C
RBS B
UE
RBS A
BSC A
22-1
UL MEASUREMENTS
PREPARE LINK REPORT
19-2
MRM1
22-1
DL MEASUREMENTS
MRM2 (PROXY REPORT INCLUDES MEASURMENTS OF RBS C)
22-2
HANDOVER DETERMINATION
22-3

Fig. 22

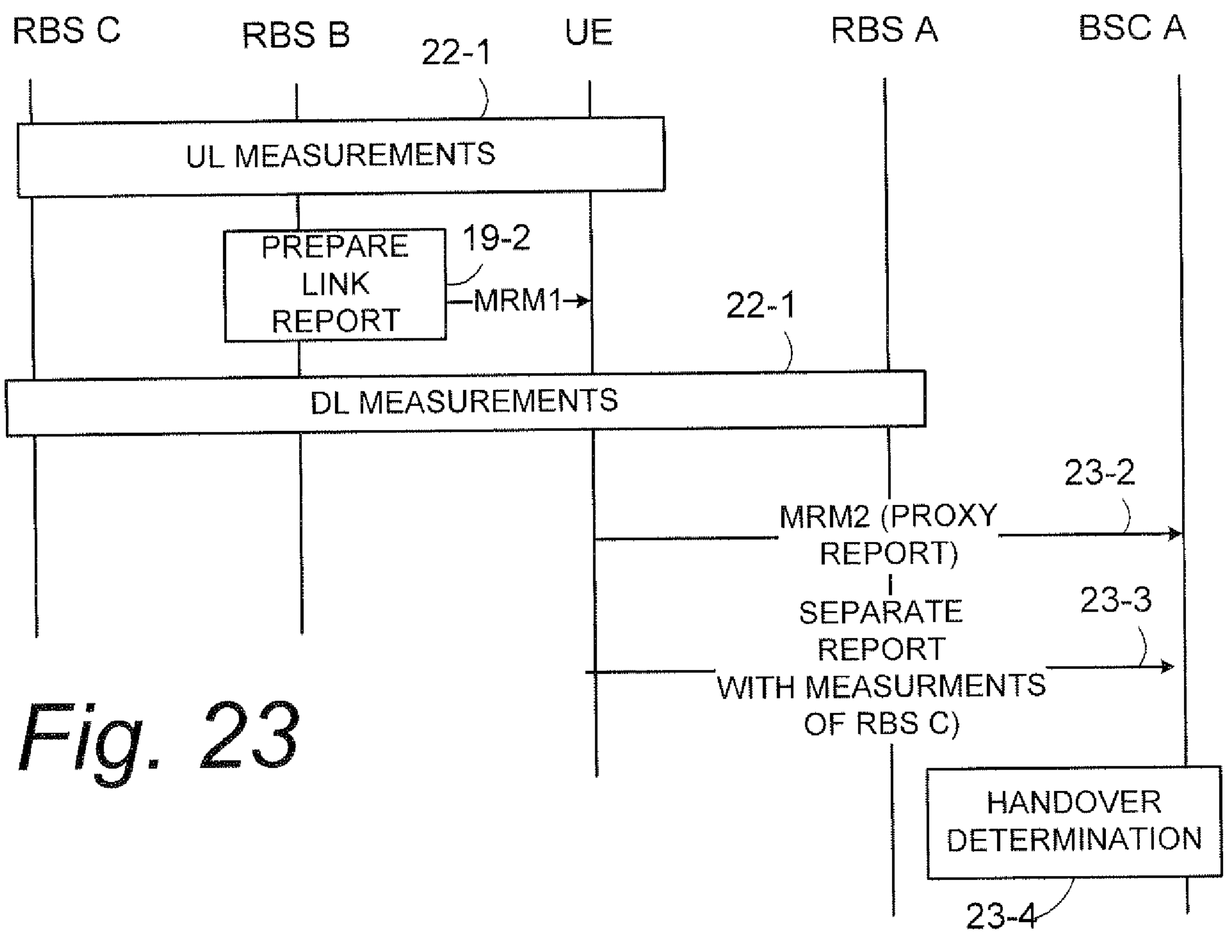

RBS C
RBS B
UE
RBS A
BSC A
22-1
UL MEASUREMENTS
PREPARE LINK REPORT
19-2
MRM1
22-1
DL MEASUREMENTS
MRM2 (PROXY REPORT)
23-2
SEPARATE REPORT WITH MEASURMENTS OF RBS C)
23-3
HANDOVER DETERMINATION
23-4

Fig. 23