

TRANSMISSION OF GSM CIRCUIT-SWITCHED DATA OVER A CDMA LINK

FIELD OF THE INVENTION

5

The present invention relates generally to wireless telecommunications, and specifically to advanced cellular networks.

BACKGROUND OF THE INVENTION

10

The Global System for Mobile (GSM) telecommunications is used in cellular telephone networks in many countries around the world. GSM offers a useful range of network services and standards, including facilities for data, as well as voice, transmission. Existing GSM networks are based on time-division multiple access (TDMA) digital communications technology.

15

Code-division multiple access (CDMA) is an improved digital communications technology, which affords more efficient use of radio bandwidth than TDMA, as well as a more reliable, fade-free link between cellular telephone subscribers and base stations. The leading CDMA standard is IS-95, promulgated by the Telecommunications Industry Association (TIA).

20

PCT patent application PCT/US96/20764, which is incorporated herein by reference, describes a wireless telecommunications system that uses a CDMA air interface (i.e., basic RF communications protocols) to implement GSM network services and protocols. Using this system, at least some of the TDMA base stations (BSSs) and subscriber units of an existing GSM network would be replaced or supplemented by corresponding CDMA equipment. CDMA BSSs in this system are adapted to communicate with GSM mobile switching centers (MSCs) via a standard GSM A-interface. The core of GSM network services is thus maintained, and the changeover from TDMA to CDMA is transparent to users.

25

30

Hybrid cellular communications networks, incorporating both GSM and CDMA elements, are also described in PCT patent publications WO 95/24771 and WO 96/21999, and in an article by Tscha, et al., entitled "A Subscriber Signaling Gateway between CDMA Mobile Station and GSM Mobile Switching Center," in Proceedings of the 2nd International Conference on Universal Personal Communications, Ottawa (1993), pp. 181-185, which are incorporated herein by reference.

35

The above-mentioned publications do not relate specifically to issues of data communications through hybrid cellular networks. Such issues include both the need for protocol compatibility and the different demands of voice and data communications.

5

SUMMARY OF THE INVENTION

It is an object of the present invention to provide methods and apparatus for conveying data through a mixed GSM/CDMA cellular communications network.

10

In some aspects of the present invention, methods and apparatus are provided to enable GSM circuit-switched data service capabilities over a CDMA air interface.

15

In preferred embodiments of the present invention, a mixed GSM/CDMA cellular communications system includes one or more CDMA base stations, controlled by a GSM mobile switching center (MSC). Systems of this type are further described in a U.S. patent application entitled "Base Station Handover in a Hybrid GSM/CDMA Network," filed July 20, 1998, which is assigned to the assignee of the present patent application and is incorporated herein by reference. A subscriber unit in the system, also referred to herein as a mobile station (MS), which is in communication with one of the CDMA base stations over a CDMA air interface, transmits and receives data through the system via the CDMA base station. The data are adapted by the mobile station and the base station so that the data transmitted and received at the MSC are substantially in accordance with GSM data networking protocols for circuit switched data.

20

The term "data" as used in the context of the present patent application and in the claims refers to substantially all types of data that are typically conveyed through communications networks, with the exception of real-time (coded or uncoded) voice transmission.

30

There is therefore provided, in accordance with a preferred embodiment of the present invention, in a GSM mobile wireless telecommunications system, a method for conveying data from terminal equipment to a network via a CDMA air interface, including:

35

- receiving the data as input from the terminal equipment;
- transmitting the data at a CDMA data transfer rate over the CDMA air interface; and

transferring the data to the network over a GSM A-interface using a GSM circuit switched data protocol.

Preferably, receiving the data includes receiving a fax input or, alternatively or additionally, receiving an input from a computer.

5 There is further provided, in accordance with a preferred embodiment of the present invention, in a GSM mobile wireless telecommunications system, a method for conveying data received over a network to terminal equipment via a CDMA air interface, including:

10 receiving the data from the network using a GSM protocol for circuit switched data services;

transmitting the data at a CDMA data transfer rate over the CDMA air interface; and

outputting the data to the terminal equipment.

15 Preferably, outputting the data includes outputting data to a fax or, alternatively or additionally, to a computer.

Preferably, transmitting the data includes adapting synchronous data for transmission at an IS-95 CDMA data rate, wherein receiving the data includes receiving asynchronous data and padding the asynchronous data to generate a synchronous bit stream at the CDMA data rate, and wherein
20 padding the asynchronous data includes applying a GSM rate adaptation function to fit the data to a GSM synchronous data channel.

Preferably, transmitting the data includes using a GSM Layer 2 relay function to transmit the data over the CDMA air interface, wherein using the GSM Layer 2 relay function includes using services of a GSM radio link
25 protocol to transport Layer 2 information.

Preferably, the method includes receiving high-speed circuit-switched data via a terrestrial network, and conveying at least a portion of the high-speed data to the terminal equipment via the GSM A-interface and the CDMA air interface.

30 In a preferred embodiment, transmitting the data includes transferring data at a variable rate, responsive to a data volume to be conveyed over the air interface, wherein transferring the data includes opening a fundamental channel for conveying the data and signaling thereover, and responsive to the data volume opening one or more supplemental channels to carry the data.
35 Preferably, opening the supplemental channels includes opening a different number of channels in forward and reverse directions over the air interface.

Alternatively or additionally, one or more of the supplemental channels are closed in response to a decrease in the data rate.

There is also provided, in accordance with a preferred embodiment of the present invention, wireless communications apparatus, for use in a mobile telecommunications system, including:

5 a mobile station, coupled to exchange data with terminal equipment, and which communicates the data at a CDMA data transfer rate over a CDMA air interface; and

10 a base station, which communicates with the mobile station over the CDMA air interface, and which is coupled to a network so as to exchange data over the network in accordance with a GSM circuit switched data protocol.

Preferably, the data include fax data. Additionally or alternatively, the data terminal equipment includes a computer.

15 In a preferred embodiment, the terminal equipment generates asynchronous data, which are padded to generate a synchronous bit stream at a GSM data rate, wherein a GSM rate adaptation function is applied to fit the data to a GSM synchronous data rate.

20 Preferably, a GSM Layer 2 relay function is used to transmit the data over the CDMA air interface, wherein the GSM Layer 2 relay function uses a GSM radio link protocol to transport Layer 2 information.

Preferably, a data transfer rate over the air interface is varied responsive to a data volume to be conveyed thereover.

25 The present invention will be more fully understood from the following detailed description of the preferred embodiments thereof, taken together with the drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

30 Fig. 1 is a schematic block diagram of a hybrid GSM/CDMA cellular communications system, in accordance with a preferred embodiment of the present invention; and

Figs. 2A and 2B are schematic block diagrams illustrating communications protocol stacks between elements of the system of Fig. 1, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is now made to Fig. 1, which is a schematic block diagram of a hybrid GSM/CDMA cellular communications system 20, in accordance with a preferred embodiment of the present invention. System 20 is built around a public land mobile network (PLMN) 22, which is based on the GSM communications standard, as is known in the art and described briefly hereinabove. Infrastructure for such networks already exists and is in wide use in many countries, and the present invention has the advantage of enabling gradual introduction of CDMA service in conjunction with such a network without requiring major changes to the existing switching infrastructure.

PLMN 22 comprises at least one mobile-services switching center (MSC) 24, or possibly a number of such centers (although only one MSC is shown here for clarity of illustration), which controls network operations within a geographical area. Among other functions, MSC 24 is responsible for location registration of subscriber units and handover of subscriber units between base stations, as well as linking PLMN 22 to a public switched telephone network (PSTN) and/or packet data network (PDN) 48. The MSC also includes or is linked to an inter-working function (IWF), which supports data communications as described hereinbelow, in accordance with GSM standards. The PLMN also comprises a network management center (NMC) 26 and a cell broadcast center (CBC) 28. The functions of these elements, as well as other aspects of system 20 and details regarding a mobile station (MS) 40 in the system, are described further in the above-mentioned U.S. and PCT Patent Applications.

System 20 includes a plurality of MSs 40, which communicate with PLMN 22 via a plurality of base station subsystems (BSS) 30 and 32 over a wireless RF link at one or more of the accepted cellular communications frequencies. MS 40, which is also known as a subscriber unit, is preferably capable of communicating with both GSM BSS 30, using a standard GSM TDMA radio communications protocol, and CDMA BSS 32, using CDMA-based communication methods described hereinbelow. Although for the sake of clarity, only one each of MS 40, GSM BSS 30 and CDMA BSS 32 is shown in Fig. 1, it will be understood that in actuality, system 20 typically comprises a plurality of each of these system elements.

Both GSM BSS 30 and CDMA BSS 32 communicate with and are controlled by MSC 24, substantially in accordance with GSM standards, i.e., via the GSM standard A-interface, as further described hereinbelow with reference to Figs. 2A and 2B. BSS 32 also communicates with CBC 28, so as to
5 receive messages to be broadcast over the air, and comprises a radio operation and maintenance center (OMC-R) 38, which communicates with NMC 26 over a GSM-standard Q3 interface. Optionally, BSS 32 may be linked to a general packet data service (GPRS), such as has been proposed by the European Telecommunications Standards Institute (ETSI). Communications between
10 BSS 32 and the GPRS are further described in a U.S. patent application entitled "CDMA Transmission of Packet-Switched Data," filed on even date, which is assigned to the assignee of the present patent application and incorporated herein by reference.

Communications between CDMA BSS 32 and MS 40 are built on a
15 CDMA radio "air interface," which is preferably based on the IS-95 standard for CDMA communications, and most preferably with the TIA/EIA-95-B version of the standard, with necessary modifications as described herein. BSS 32 is built around a base station controller (BSC) 34, which controls and communicates with a number of base station transceivers (BTS) 36. Each BTS
20 transmits RF signals to and receives RF signals from MS 40 when the MS is within a geographical area, or cell, served by the particular BTS. On the other hand, when MS 40 is within a cell served by GSM BSS 30, the MS communicates with BSS 30 over a GSM/TDMA air interface.

In order to sustain both of these interfaces, MS 40 comprises mobile
25 equipment (ME) 42, which preferably includes either two radio transceivers, one configured for TDMA operation and one for CDMA, or a single transceiver which can dynamically switch between TDMA and CDMA. The MS includes mobile termination (MT), which supports terminal equipment (TE) 46 for data input and output. Preferably, TE 46 comprises a user
30 terminal, such as a personal computer or fax machine, coupled to input and output data via the MT. In addition, MS 40 comprises a subscriber identity module (SIM) 44, in accordance with GSM standards.

Fig. 2A is a block diagram that schematically illustrates protocol stacks used in signaling interfaces between MS 40, CDMA BSS 32 and GSM MSC 24,
35 in accordance with a preferred embodiment of the present invention. These interfaces enable MS 40 to communicate with GSM MSC 24 over a CDMA air interface. Operation of these interfaces, and particularly message flow

through these interfaces, is described in greater detail in the above-mentioned PCT application PCT/US96/20764, as well as in the above-mentioned U.S. patent application entitled "Base Station Handover in a Hybrid GSM/CDMA Network." When MS 40 is in communication with MSC 24 via GSM BSS 30,
5 the protocol stacks are in accordance with GSM standards, substantially without modification.

MS 40 communicates with CDMA BSS 32 over a CDMA Um interface, based on a CDMA air interface which is modified for compatibility of signaling with the GSM standard. The CDMA air interface between MS 40
10 and CDMA BSS 32 comprises CDMA Layer 1, which preferably operates on a standard IS-95 protocol, and GSM-CDMA Layer 2, in which IS-95 operation is adapted to accommodate the needs of GSM Layer 3 protocols. Layer 2 supports transmission of frames between MS 40 and BSS 30 or 32. GSM-CDMA Layer 2 includes functionality, such as message ordering, priority and
15 fragmentation, and suspension and resumption of communications, which is normally supported by the standard GSM Layer 2, but not by CDMA IS-95. GSM-CDMA Layer 2 also supports message sizes up to at least the maximum message size permitted by GSM Layer 2 (251 bytes), which is greater than the maximum IS-95 message size. Vis-a-vis GSM BSS 30, air interface Layers 1
20 and 2 are in accordance with GSM standards, substantially without modification.

Standard GSM protocols include three Radio Interface sub-layers (RIL3) above the physical and framing layers GSM Layer 1 and Layer 2: Radio Resource (RR) management, Mobile Management (MM) and Connection
25 Management (CM). The CM layer supports signaling for call processing, as well as GSM supplementary services and short message service (SMS). The MM layer supports signaling required for locating MS 40, authentication and encryption key management.

In order to support the substantially unmodified GSM MM and CM
30 layers, a GSM-CDMA RR layer is introduced in the MS 40 and BSS 32 protocol stacks. The GSM-CDMA RR layer, which manages radio resources and maintains radio links between MS 40 and BSSs 30 and 32, is "aware" of the existence of the dual GSM and CDMA lower layers (Layers 1 and 2) in the MS 40 protocol stack. It invokes the appropriate lower layers in the MS stack to
35 communicate with either the standard RIL3-RR layer over the GSM Um interface or the GSM-CDMA RR layer of BSS 32 over the CDMA Um interface, depending on instructions it receives from the BSS with which it is in

communication. The RR layer in the MS stack also controls the handover between the corresponding air interfaces defined in Layers 1 and 2, under instructions from MSC 24, BSS 30 and BSS 32.

Regardless of which of the air interfaces is in use, the GSM-CDMA RR
5 layer supports the standard GSM RIL3-MM and CM layers above it. The MM and CM layers are not processed by BSS 32, but are rather relayed through between MS 40 and MSC 24 for processing in a manner substantially transparent to the CDMA air interface layers below. Further features of the RR layer are described in the above-mentioned U.S. patent application entitled
10 "Base Station Handover in a Hybrid GSM/CDMA Network."

CDMA BSS 32 communicates with GSM MSC 24 over a standard, substantially unmodified GSM A-interface. This interface is based on the GSM SS7 and BSS Application Part (BSSAP) protocols, as are known in the art, preferably in accordance with the GSM 08.06 and 08.08 standard. BSSAP
15 supports procedures between MSC 24 and BSS 32 that require interpretation and processing of information related to single calls and resource management, as well as transfer of call control and mobility management messages between MSC 24 and MS 40. BSS 32 translates CDMA Layer 1, GSM-CDMA Layer 2 and GSM-CDMA RR protocols exchanged between the
20 BSS and MS 40 into appropriate SS7 and BSSAP protocols for transmission to MSC 24, and vice versa.

Because CDMA BSC 34 communicates with GSM MSC 24 using the standard A-interface, substantially no modifications are required in the core GSM MSC in order to enable the addition of CDMA BSS 32 to GSM system 20.
25 Furthermore, MSC 24 need not be aware that there is any difference in identity between GSM/TDMA BSS 30 and CDMA BSS 32, since both communicate with the MSC in a substantially identical manner over the A-interface.

Fig. 2B is a block diagram that schematically illustrates transmission
30 protocol stacks involved in providing circuit-switched data via MS 40 and CDMA BSS 32 and MSC/IWF 24, in accordance with a preferred embodiment of the present invention. ME/MT 42 exchanges user data with TE 46 via a connection at a reference point R, using a GSM-compatible terminal adaptation function (TAF) in the MS. The TAF is adapted to whatever TE
35 protocol is in use, such as an asynchronous protocol, as is known in the art, or alternatively a synchronous protocol. When the incoming data are asynchronous, MS 40 applies a rate adaptation (RA0) function, in accordance

with GSM protocols, which pads the asynchronous data with additional stop elements so as to fit the nearest available GSM synchronous data channel. These data channels have rates of $2^n \times 600$ bit/sec (so that 75 bit/sec and 300 bit/sec signaling rates are adapted to a synchronous 600 bit/sec stream).

5 MSC/IWF 24 includes a RA0 function that is a "mirror image" of RA0 in MS 40. MS 40 and MSC/IWF 24 also include a GSM fax adapter function, which provides a standard fax interface in the MS and compensates for differences in transmission delays encountered in cellular, as opposed to wired, communication networks.

10 Known (non-transparent) user protocols are transported from MS 40 to MSC 24 through BSS 32 using a GSM Layer 2 relay (L2R) function, preferably in accordance with GSM standard 07.01, which is incorporated herein by reference. Whereas transparent protocols generally transmit an input
15 bitstream without modification, non-transparent protocols modify the bitstream before transmission, typically in order to reduce the required transmission data rate. L2R uses the services provided by a GSM radio link protocol (RLP), preferably in accordance with GSM standard 04.22, which is incorporated herein by reference, to reliably transport the L2R protocol information over the air.

20 Synchronous user data output by RA0 and by the fax adapter and RLP functions of MS 40 are adapted for transport over the CDMA Um interface by a rate adapter 1' (RA1') function. RA1' adapts the data rates of RA0, the fax adapter and RLP to IS-95 radio interface data rates, which are generally different from the GSM data rates. Higher data rates, over 9,600 bps, can be
25 accommodated by IS-95 medium data rate (MDR) transmission, as further described hereinbelow.

Rate adaptation between BSS 32 and MSC /IWF 24 is performed by GSM rate adaptation 1 (RA1) and rate adaptation 2 (RA2) functions, so that the data are conveyed over the A-interface at a standard GSM circuit switched
30 data rate. The RA1 function adapts the synchronous data conveyed by RA1' to intermediate data rates of 8 or 16 kbit/sec. The RA2 function is specified by CCITT standard V.110 and is used to adapt RA1 data to a 64 kbit/sec rate, as required by CCITT E1 data transport protocols. These protocols are based on a 2 Mbit/sec data stream, with a frame structure of 32 x 64 kbit/sec. The
35 MSC/IWF is shown schematically to include an L1 layer, by means of which the user data from TE 46 are output to a compatible terminal or fax (not shown in the figures), generally after transport over PSTN/PDN 48.

Although the communications protocol layers above are described generally with reference to functions required to adapt a data stream from TE 46 for transport to MSC/IWF 24, it will be understood that the same protocol layers are also used to adapt synchronous, high-speed data from MSC/IWF 24 for transport to and output by TE 46. MSC/IWF 24 thus transmits and receives data to and from TE 46 via ME/MT 42 and BSS 32 substantially without regard to the fact that the data between the BSS and MS 40 are CDMA-encoded, as though MS 40 were operating in GSM/TDMA mode.

As noted hereinabove, when the user data rate exceeds ordinary CDMA traffic channel rates, the IS-95 MDR feature for high-speed data services is preferably used to accommodate the excess data. In this case, MS 40 and BSS 32 open multiple traffic channels between them. Since there is frequently a greater volume of data being transported in one direction than in the other (most frequently in a forward direction, i.e., from BSS 32 to MS 40) the number of channels opened in the two directions need not be equal. For example, there may be four forward channels and only two reverse channels opened. In each direction, there is preferably one fundamental code traffic channel, which carries signaling (Fig. 2A) along with data, and up to seven supplemental code traffic channels for high-speed data. The fundamental channel is active substantially continuously, whereas the supplemental channels are activated as needed based on the total data rate at any time.

IS-95 MDR can be used to provide high-speed data service comparable to that defined in the GSM Phase 2+ standard for high-speed circuit-switched data (HSCSD). The IS-95 MDR CDMA transmission has the advantage, however, of dynamic bandwidth allocation, as opposed to static allocation of TDMA time slots in HSCSD. This CDMA approach thus allows more efficient use of the available transmission spectrum, both at MDR and at normal data rates, than does the conventional GSM TDMA approach.

Although preferred embodiments are described hereinabove with reference to a particular hybrid GSM/CDMA system, it will be appreciated that the principles of the present invention may similarly be applied to effect over-the-air data transfer in other hybrid communication systems, as well. The scope of the present invention encompasses not only the complete systems and communications processes described hereinabove, but also various innovative elements of these systems and processes, as well as combinations and sub-combinations thereof.

It will thus be appreciated that the preferred embodiments described above are cited by way of example, and the full scope of the invention is limited only by the claims.

CLAIMS:

1. In a GSM mobile wireless telecommunications system, a method for
2 conveying data from terminal equipment to a network via a CDMA air
interface, comprising:
4 receiving the data as input from the terminal equipment;
transmitting the data at a CDMA data transfer rate over the CDMA air
6 interface; and
transferring the data to the network over a GSM A-interface using a
8 GSM circuit switched data protocol.
2. A method according to claim 1, wherein receiving the data comprises
2 receiving a fax input.
3. A method according to claim 1, wherein receiving the data comprises
2 receiving an input from a computer.
4. A method according to claim 1, wherein transmitting the data comprises
2 adapting synchronous data for transmission at an IS-95 CDMA data rate.
5. A method according to claim 4, wherein receiving the data comprises
2 receiving asynchronous data and padding the asynchronous data to generate a
synchronous bit stream at the CDMA data rate.
6. A method according to claim 5, wherein padding the asynchronous data
2 comprises applying a GSM rate adaptation function to fit the data to a GSM
synchronous data channel.
7. A method according to claim 1, wherein transmitting the data comprises
2 using a GSM Layer 2 relay function to transmit the data over the CDMA air
interface.
8. A method according to claim 7, wherein using the GSM Layer 2 relay
2 function comprises using services of a GSM radio link protocol to transport
Layer 2 information.
9. A method according to claim 1, and comprising receiving high-speed
2 circuit-switched data via a terrestrial network, and conveying at least a portion



- 4 of the high-speed data to the terminal equipment via the GSM A-interface and
the CDMA air interface.
10. A method according to claim 1, wherein transmitting the data comprises
2 transferring data at a variable rate, responsive to a data volume to be conveyed
over the air interface.
11. A method according to claim 10, wherein transferring the data comprises
2 opening a fundamental channel for conveying the data and signaling thereover,
and responsive to the data volume opening one or more supplemental channels
4 to carry the data.
12. A method according to claim 11, wherein opening the supplemental
2 channels comprises opening a different number of channels in forward and
reverse directions over the air interface.
13. A method according to claim 11, and comprising closing one or more of
2 the supplemental channels in response to a decrease in the data rate.
14. In a GSM mobile wireless telecommunications system, a method for
2 conveying data received over a network to terminal equipment via a CDMA air
interface, comprising:
4 receiving the data from the network using a GSM protocol for circuit
switched data services;
6 transmitting the data at a CDMA data transfer rate over the CDMA air
interface; and
8 outputting the data to the terminal equipment.
15. A method according to claim 14, wherein outputting the data comprises
2 outputting data to a fax.
16. A method according to claim 14, wherein outputting the data comprises
2 outputting data to a computer.
17. A method according to claim 14, wherein transmitting the data
2 comprises adapting synchronous data for transmission at an IS-95 CDMA data
rate.



18. A method according to claim 17, wherein receiving the data comprises
2 receiving asynchronous data and padding the asynchronous data to generate a
synchronous bit stream at the CDMA data rate.
19. A method according to claim 18, wherein padding the asynchronous
2 data comprises applying a GSM rate adaptation function to fit the data to a
GSM synchronous data rate.
20. A method according to claim 14, wherein transmitting the data
2 comprises using a GSM Layer 2 relay function to transmit the data over the
CDMA air interface.
21. A method according to claim 20, wherein using the GSM Layer 2 relay
2 function comprises using services of a GSM radio link protocol to transport
Layer 2 information.
22. A method according to claim 14, wherein transmitting the data
2 comprises transferring data at a variable rate, responsive to a data volume to be
conveyed over the air interface.
23. A method according to claim 22, wherein transferring the data comprises
2 opening a fundamental channel for conveying the data and signaling thereover,
and responsive to the data volume opening one or more supplemental channels
4 to carry the data.
24. A method according to claim 23, wherein opening the supplemental
2 channels comprises opening a different number of channels in forward and
reverse directions over the air interface.
25. A method according to claim 23, and comprising closing one or more of
2 the supplemental channels in response to a decrease in the data rate.
26. Wireless communications apparatus, for use in a mobile
2 telecommunications system, comprising:
a mobile station, coupled to exchange data with terminal equipment, and
4 which communicates the data at a CDMA data transfer rate over a CDMA air
interface; and



6 a base station, which communicates with the mobile station over the
CDMA air interface, and which is coupled to a network so as to exchange data
8 over the network in accordance with a GSM circuit switched data protocol.

27. Apparatus according to claim 26, wherein the data comprise fax data.

28. Apparatus according to claim 26, wherein the data terminal equipment
2 comprises a computer.

29. Apparatus according to claim 26, wherein the terminal equipment
2 generates asynchronous data, and wherein the asynchronous data are padded
to generate a synchronous bit stream at a GSM data rate.

30. Apparatus according to claim 29, wherein a GSM rate adaptation
2 function is applied to fit the data to a GSM synchronous data rate.

31. Apparatus according to claim 26, wherein a GSM Layer 2 relay function
2 is used to transmit the data over the CDMA air interface.

32. Apparatus according to claim 31, wherein the GSM Layer 2 relay
2 function uses a GSM radio link protocol to transport Layer 2 information.

33. Apparatus according to claim 26, wherein a data transfer rate over the air
2 interface is varied responsive to a data volume to be conveyed thereover.

34. Apparatus according to claim 33, wherein the data transfer rate is varied
2 by opening, responsive to the data volume, one or more supplemental channels
between the mobile station and base station in addition to a fundamental
4 channel that is opened therebetween.

35. Apparatus according to claim 34, wherein different numbers of channels
2 are opened in forward and reverse directions between the mobile station and
base station.

36. Apparatus according to claim 34, and wherein one or more of the
2 supplemental channels are closed in response to a decrease in the data rate.

