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2
3 CELLULAR BASE STATION WITH
4 INTELLIGENT CALL ROUTING

5
6 RELATED APPLICATIONS

7 The present application incorporates the following
8 patent applications by reference:

9 CELLULAR PRIVATE BRANCH EXCHANGES, U.S. Ser. No.
10 08/435,709, filed on May 4, 1995, Attorney docket No.
11 WAVEP001;

12 METHODS AND APPARATUSSES FOR AN INTELLIGENT SWITCH, U.S.
13 Ser. No. 08/435,838 filed on May 4, 1995, Attorney docket No.
14 WAVEP004;

15 SPREAD SPECTRUM COMMUNICATION NETWORK WITH ADAPTIVE
16 FREQUENCY AGILITY, U.S. Ser. No. 08/434,597, filed on May 4,
17 1995, Attorney docket No. A-60820; and

18 SPREAD SPECTRUM COMMUNICATION NETWORK SIGNAL PROCESSOR,
19 U.S. Ser. No. 08/434,554, filed on May 4, 1995, Attorney
20 docket No. A-60910.

21
22 FIELD

23 The present invention relates to a cellular base station
24 with intelligent call routing. In particular, the present
25 invention is used in a cellular network to communicate with
26 mobile stations and control the information routing to reduce
27 network congestion and improve network performance.

28
29 BACKGROUND

30 Cellular communication networks typically employ base
31 transceiver stations that communicate with mobile stations.
32 When a mobile station (MS) initiates a call to the base
33 transceiver station (BTS), it does so with an identification
34 code. The BTS sends the identification code to a base
35 station controller (BSC) and mobile switching center (MSC)
36 for authentication. The MSC determines if the identification
37 code matches one in a valid subscriber registry. Once

1 authenticated, the BTS is authorized to communicate with the
2 MS and the network places the call.

3 Ordinarily, this procedure is efficient. For example,
4 when a MS wishes to communicate with a person at home, via
5 land line, the mobile transmission is routed through the base
6 station, BSC, MSC, public switch telephone network (PSTN),
7 and then via land line to the person at home.

8 However, when one MS wishes to communicate with another
9 MS, the communication is still required to route through the
10 MSC. This type of routing is not efficient because it
11 reserves a portion of valuable BSC, MSC, and sometimes PSTN
12 resources for the call. Moreover, when the base station
13 employs a transcoder rate adapter (TRAU), a private branch
14 exchange (PBX), or other subsystems, a portion of those
15 resources are also reserved for the call.

16 Hence, one limitation of existing cellular communication
17 networks is that the BTS and BSC must always communicate with
18 the MSC in order to place a call from one MS to another.
19 Moreover, this routing may require a rate adaptation even
20 when the two MS are operating at the same rate.

21 Another limitation of existing cellular communication
22 networks is that they employ dedicated hardware that lacks
23 flexibility. For example, the BTS and BSC may be required to
24 route calls to the MSC whether this routing is most efficient
25 or not. As another example, these networks may impose rate
26 adaptation on all communications to match a standard rate
27 (e.g., 64Kbps), whether adaptation is necessary or not.

28 Still another limitation of existing cellular
29 communication networks is that they lack flexibility to
30 incorporate advanced features such as call routing in the BTS
31 and BSC. These networks lack the ability to be scaled and
32 modularized, and lack the flexibility to perform multiple
33 tasks. Moreover, since existing communication networks use a
34 great deal of dedicated hardware, a fault can cause data
35 loss, or even cause the network to malfunction. When a BTS
36 or BSC is broken, the network must operate in a reduced
37 capacity, if it can operate at all.

38

1 SUMMARY

2 The present invention relates to a cellular base station
3 with intelligent call routing. In particular, the present
4 invention is used in a cellular network to communicate with
5 mobile stations and control the information routing to reduce
6 network congestion and improve network performance.
7 Exemplary embodiments are provided for use with the Global
8 Systems for Mobile Communication (GSM) protocol.

9 A base station communicates with a plurality of mobile
10 stations over a cellular network. In one embodiment, the
11 base station includes a transceiver configured to receive
12 inbound information from the mobile station and transmit
13 outbound information to the mobile station. The transceiver
14 equalizes and decodes the inbound information and encodes the
15 outbound information. The transceiver is coupled to a data
16 bus for communicating the inbound and outbound information
17 with the other elements in the base station. The transceiver
18 is also coupled to a control bus. A trunk module is coupled
19 to the data bus and to a mobile switching center. The trunk
20 module communicates inbound and outbound information with the
21 transceiver and the mobile switching center. The trunk
22 module is also coupled to the control bus. Finally, a
23 cellular central processor is coupled to the control bus to
24 control the transceiver and the trunk module.

25 In another embodiment, the base station may include a
26 plurality of transceivers, cellular central processors, and
27 trunk modules. The base station architecture is modular and
28 scalable. As a result, the base station can be modified to
29 perform a variety of tasks and scaled to accommodate various
30 performance requirements. For example, a low performance
31 base station may have only one transceiver, one cellular
32 central processor, and one trunk module. A high performance
33 base station may have several transceivers, cellular central
34 processors, and trunk modules.

35 Advantages of the present invention include modularity,
36 scalability, distributed processing, improved performance,
37 reduced network congestion, fault tolerance, and more
38 efficient and cost-effective base stations.

1 BRIEF DESCRIPTION OF THE DRAWINGS

2 Additional advantages of the invention will become
3 apparent upon reading the following detailed description and
4 upon reference to the drawings, in which:
5 Figure 1 depicts a cellular network;
6 Figures 2A-D are flow charts showing steps performed to
7 process inbound information and outbound information;
8 Figure 3 depicts a base transceiver station according to
9 one embodiment of the invention;
10 Figure 4 depicts a radio frequency (RF) distribution
11 module according to one embodiment of the invention;
12 Figure 5 depicts a transceiver (TRX) module according to
13 one embodiment of the invention;
14 Figure 6 depicts a cellular central processor according
15 to one embodiment of the invention;
16 Figure 7 depicts a trunk module according to one
17 embodiment of the invention;
18 Figure 8 depicts a detailed schematic of a trunk module
19 according to another embodiment of the invention;
20 Figures 9A-D depict a configuration for switching
21 information at sub-64Kbps rate;
22 Figure 10 depicts a base transceiver station according
23 to another embodiment of the invention;
24 Figure 11 depicts a base transceiver station according
25 to another embodiment of the invention;
26 Figure 12 depicts a base transceiver station according
27 to another embodiment of the invention;
28 Figure 13 is a table depicting various embodiments of a
29 base station according to the invention;
30 Figures 14A-D are flow charts showing steps performed to
31 process inbound information and outbound information; and
32 Figures 15A-D are flow charts showing steps performed to
33 process inbound information and outbound information;

34

35 DETAILED DESCRIPTION

36 The present invention relates to a cellular base station
37 having an intelligent routing control switch. In particular,
38 the present invention is used in a cellular network to

1 communicate with mobile stations and control the information
2 routing to reduce network congestion and improve network
3 performance. Exemplary embodiments are provided for use with
4 the Global Systems for Mobile Communication (GSM) protocol.

5 The exemplary embodiments are described herein with
6 reference to specific configurations and protocols. Those
7 skilled in the art will appreciate that various changes and
8 modifications can be made to the exemplary embodiments while
9 remaining within the scope of the present invention.

10 For purposes of this description, the term base station
11 (BS) includes the structure and features present in any of
12 the BTS, BSC, or MSC. The exemplary embodiments are capable
13 of performing any of these functions depending on their
14 individual configuration, as explained below. Further, the
15 term information includes both RF signals and digital words
16 that can represent voice, data, or both.

17 A first embodiment is described with reference to
18 Figures 1 through 3. Figure 1 depicts a cellular network
19 showing mobile stations (MS) 20 communicating with base
20 transceiver stations (BTS) 40. When a MS initiates a call to
21 BTS 40, it does so with an international mobile subscriber
22 identification code (IMSI). BTS 40 sends the IMSI to a base
23 station controller (BSC) 50 and mobile services center (MSC)
24 60 for authentication. MSC 60 determines if the IMSI matches
25 one in a visitor location registry (VLR) 70. If the IMSI is
26 not found in VLR 70, MSC 60 looks into a home location
27 registry (HLR) 80 to try to match the IMSI. If the IMSI is
28 not found in HLR 80, MSC 60 looks out through the public
29 switched telephone network (PSTN) 90 to try to match the IMSI
30 in other network HLRs. Once authenticated, BTS 40 is
31 authorized to communicate with MS 20 and the network places
32 the call.

33 Figures 2A-D show the procedures for BS 30 to
34 communicate with MS 20. These flowcharts are indicative of a
35 separate BTS 40, BSC 50, MSC 60 configuration, and show what
36 processing steps are performed in what location. The Figure
37 2A flowchart shows inbound information processing beginning
38 with step 102 where the information is received from the MS.

1 Step 104 involves framing a GSM TDMA word. In step 106, the
2 information is equalized to compensate for multipath effects.
3 Step 108 decodes the information. Step 110 de-interleaves
4 the inbound information. Steps 112 and 114 are information
5 transport steps over a trunk module (TM) which, for
6 convenience is hereinafter described by way of example as an
7 exemplary E1 trunk. Step 116 is a TRAU function that is
8 performed only when required, as explained below. Steps 118
9 and 120 are information transport steps over an exemplary E1
10 trunk. Step 122 is a switching step that routes the inbound
11 information to a correct destination. If the destination is
12 at the BTS, the information can be routed back to the BTS as
13 outbound information (goto Figure 2C step 152). However, if
14 the inbound information is destined for PSTN 90, step 124 is
15 performed to echo cancel the information. Then, step 126
16 sends the inbound information over an exemplary E1 trunk to
17 an outbound destination.

18 The Figure 2B flowchart shows the inbound control signal
19 processing. This represents the control information
20 necessary to support voice and data communication with MS 20.
21 Steps 102 through 110 are the same as those in the Figure 2A
22 flowchart. Step 130 involves base station control functions
23 including control of the base station radio and MS power and
24 timing. Step 132 is an Abis function which is a protocol
25 between the BTS and BSC. Steps 112 and 114 are information
26 transport steps over an exemplary E1 trunk. Step 134 is an
27 Abis function which is a protocol between the BTS and BSC.
28 Step 136 is a radio resource management (RR) procedure. Step
29 138 is an A function which is a protocol between the BSC and
30 MSC. Steps 118 and 120 are information transport steps over
31 an exemplary E1 trunk. Step 140 is an A function which is a
32 protocol between the BSC and MSC. Step 142 can represent a
33 variety of management procedures including radio resource
34 management (RR), mobility management (MM), call control (CC),
35 supplemental services (SS), and short message service (SMS).
36 Step 144 is SS7 protocol processing, which enables
37 cooperative interworking between other elements of the GSM
38 network and the PSTN. Step 126 sends the inbound signal

1 information over an exemplary E1 trunk to an outbound
2 destination.

3 The Figure 2C flowchart shows outbound information
4 processing. Step 150 receives the outbound information from
5 an exemplary E1 trunk. Step 152 is a switching step that
6 routes the outbound information to a correct destination.
7 Steps 154 and 156 are information transport steps over an
8 exemplary E1 trunk. Step 158 is a TRAU step. Steps 160 and
9 162 are information transport steps over an exemplary E1
10 trunk. Step 164 interleaves the outbound information. Step
11 166 encodes the outbound information. Steps 168 places the
12 outbound information into TDMA frames. Step 170 transmits
13 the outbound information to MS 20.

14 The Figure 2D flowchart shows the outbound signal path
15 processing. Step 150 receives the outbound information from
16 an exemplary E1 trunk. Step 172 is a SS7 protocol
17 processing, which enables cooperative interworking between
18 other elements of the GSM network and the PSTN. Step 174 can
19 represent a variety of management procedures including radio
20 resource management, mobility management, call control,
21 supplemental services, and short message service. Step 176
22 is an A function which is a protocol between the MSC and BSC.
23 Steps 154 and 156 are information transport steps over an
24 exemplary E1 trunk. Step 178 is an A function which is a
25 protocol between the MSC and BSC. Step 180 is a radio
26 resource management procedure. Step 182 is an Abis function
27 which is a protocol between the BSC and BTS. Steps 160 and
28 162 are information transport steps over an exemplary E1
29 trunk. Step 184 is an Abis function which is a protocol
30 between the BSC and BTS. Step 186 involves base station
31 control functions including control of the radio and MS power
32 and timing. Step 164 interleaves the outbound information.
33 Step 166 encodes the outbound information. Steps 168 places
34 the outbound information into TDMA frames. Step 170
35 transmits the outbound information to MS 20.

36 Figure 3 depicts an embodiment of a base station that
37 communicates with MSs 20a, 20b and performs the inbound
38 information processing and outbound information processing.

1 A radio frequency (RF) distribution module 210 amplifies and
2 distributes inbound information to each transceiver (TRX)
3 250a-c. Each TRX 250 receives the inbound information and
4 transforms the RF information into GSM TDMA format
5 information. TRX 250 then frames, equalizes, decodes, and
6 deinterleaves the inbound information, corresponding to steps
7 104, 106, 108, and 110 of Figure 2A-B.

8 TRX 250 is controlled by a cellular central processor
9 (CCPU) 300 via a control bus (VME). CCPU 300 schedules all
10 information processing and keeps track of communication with
11 MS 20. CCPU 300 also controls a trunk module (TM) 400 via
12 the VME bus.

13 TRX 250 then sends the information to TM 400 via a data
14 bus (TDM), which contains 16 8Mbps subbusses. Each TRX
15 module 250a-c can receive on any subbus and is given a
16 predetermined subbus on which to send information to TM 400.
17 TM 400 is a sophisticated module that includes a time/space
18 switch, explained below. CCPU 300 controls the operation of
19 TM 400 and determines whether TM 400 should perform any rate
20 adaptation, echo cancelling, or interface functions,
21 corresponding to steps 116, 122, and 124.

22 The outbound information processing is similarly
23 performed as follows. TM 400 performs, if required, the
24 interface functions and rate adaptation, corresponding to
25 step 158. TM 400 then sends the information to TRX 250 via
26 TDM bus for interleaving, encoding, framing and RF
27 transmission, corresponding to steps 164, 166, 168, and 170.

28 In particular, Figure 4 depicts RF distribution module
29 210. Antennae 212, 214 are coupled to diplexers 216, 218
30 respectively. Diplexers 216, 218 serve as filters that
31 permit reception and transmission on the same antenna since
32 the receive frequency is disjoint from the transmit
33 frequency. Distribution circuits 220, 222 are used to
34 provide fan out of received RF information. One of the
35 circuit 220, 222 outputs are fed to a diversity switch 224.
36 This switch 224 is controlled by downstream processing in
37 order to select antenna 212, 214 with the best reception. In
38 mixer 226, a 13MHz clock frequency is superimposed on the

1 received signal to synchronize downstream elements such as
2 TRX 250.

3 Figure 5 depicts TRX 250. Filter 227 extracts the 13MHz
4 clock for TRX 250 synchronization. A diversity control 228
5 is coupled to the RF distribution module 210 to control
6 diversity switch 224. Diversity control 228 monitors the
7 incoming received signal to detect signal degradation. If,
8 for example, diversity control 228 detects sufficient signal
9 degradation in antenna 212, it sends a signal to switch 224
10 in RF distribution module 210 to select antenna 214. The RF
11 communication and reception aspect is discussed in detail in
12 SPREAD SPECTRUM COMMUNICATION NETWORK WITH ADAPTIVE FREQUENCY
13 AGILITY, U.S. Ser. No. 08/434,597, filed on May 4, 1995,
14 Attorney docket No. A-60820.

15 Once the inbound information is received at TRX 250 and
16 converted to a baseband frequency, a GSM baseband module 230
17 performs a GMSK procedure to obtain TDMA frame data. GSM
18 baseband module 230 can perform both inbound demodulation
19 resulting in in-phase and quadrature-phase information as
20 well as outbound modulation resulting in a baseband
21 frequency. A processor that works well for this purpose is
22 the Analog Devices AD7002. Then MUX/DMUX 252 directs the
23 inbound information to a plurality of processing paths to
24 distribute the processing load. The signal processing aspect
25 is discussed in detail in SPREAD SPECTRUM COMMUNICATION
26 NETWORK SIGNAL PROCESSOR, U.S. Ser. No. 08/434,554, filed on
27 May 4, 1995, Attorney docket No. A-60910. One example of
28 demultiplexing that works well is to send all even TDMA time
29 slots to a first DSP string 254, 256, and to send all odd
30 TDMA time slots to a second DSP string 258, 260. However,
31 MUX/DMUX 252 can distribute the information to any number of
32 DSP strings. Once DSPs 256, 260 complete the inbound
33 information processing, they send the information to the TDM
34 bus.

35 For outbound information processing, DSPs 256, 260
36 receive outbound information from the TDM bus. The
37 information is divided among a plurality of processing
38 strings. One example that works well is to send all even

1 TDMA time slots to a first DSP string 256, 254, and to send
2 all odd TDMA time slots to a second DSP string 260, 258. The
3 processing is performed in parallel and the resulting
4 outbound information is presented to MUX/DMUX 252, which
5 multiplexes the time slots to form TDMA frames, sends them to
6 GSM baseband module 230 and then to RF distribution module
7 210 for transmission.

8 While TRX 250 is described for TDMA, any type of
9 modulation, multiple access, or other information coding
10 techniques are possible. For example, GSM baseband converter
11 230 can be replaced or supplemented with a converter for
12 performing CDMA, and DSP 254, 256, 258, 260 program memory
13 can be replaced or supplemented with procedures to perform
14 CDMA. Thus, the modular architecture is capable of
15 performing as any type of base station for a variety of
16 different types of networks.

17 A Real Time Processor (RTP) 262 provisions and controls
18 DSPs 254, 256, 258, 260 in order to schedule information
19 processing. RTP 262 also performs power control and
20 measurement preprocessing and link access protocols (LAPDm)
21 for information error detection and correction. Moreover,
22 RTP 262 keeps track of inbound information and outbound
23 information to further enhance TRX 250 efficiency and permit
24 the communication of inbound information and outbound
25 information over the TDM bus.

26 RTP 262 communicates control information over the VME
27 bus with CCPU 300, and receives instructions from CCPU 300
28 regarding operating parameters and processing requirements.
29 Included in this control information is base station radio
30 and MS power and timing information collected by TRX 250 as
31 well as other packetized information from the MS. Because
32 RTP 262 is incorporated in TRX 250, and since RTP 262 is a
33 dedicated processor, the TRX processing performance is
34 predicable and guaranteed.

35 RTP 262 is also very useful in microcell configurations
36 where a TRX service area is small and the signal degrades
37 rapidly. In microcell configurations, the signal strength
38 rapidly attenuates with respect to distance. As a result,

1 microcell configurations may require very frequent statistics
2 gathering and error checking in order to adequately manage
3 the MSs. A conventional radio architecture lacks the
4 processing power to handle frequent statistics gathering with
5 a number of MSs in a microcell configuration and may drop the
6 MS, which may have already left the service. The invention
7 overcomes the processing hurdle by incorporating RTP 262 in
8 TRX 250 to provide processing that supports microcell
9 configurations and frequent statistics gathering.

10 RTP 262 serves the goal to distribute processing power
11 and delegate processing tasks to where the tasks can be most
12 efficiently performed. In a single TRX configuration, RTP
13 262 can even perform all the necessary functions so that a
14 CCPU 300 is not required. Also, as described below, when the
15 number of TRX cards increases, the processing power scales
16 proportionally. By performing the processing tasks in the
17 TRX, the control traffic is minimized between the TRX and
18 CPU, and the CPU load is not significantly increased with
19 additional TRXs.

20 Figure 6 depicts CCPU 300. A VME interface 302 is
21 coupled to the VME bus and buffers all communication
22 therewith. A redundancy control 304 is coupled to interface
23 302 to monitor interface 302 and to take over if necessary.
24 Processor 306 is coupled to interface 302 to communicate over
25 the VME bus. Processor 306 receives the packetized
26 information from a MS when a call is placed. Processor 306
27 controls the signalling path of the call and configures TM
28 400 to accommodate the call switching. Additionally,
29 processor 306 performs many of the housekeeping and
30 scheduling functions required in the BS such as maintaining a
31 record of active MSs, MS information rates, call connection
32 information, and other information. Moreover, relating back
33 to Figures 2B and 2D, processor 306 can provide BCF, RR, MM,
34 SS, CC, or SMS functions if desired (steps 136, 142, 174,
35 180). Clock adjust 308 receives a clock signal and
36 correlates the signal with other tracking information, such
37 as data transfer clocks, to conform the clock to a uniform
38 standard. CCPU 300 also has a variety of ports for modules

1 such as DRAM 310, flash memory 312, a spare port 314 for IDE,
2 SCSI, or RS232, and ethernet 316.

3 Some configurations described below have several CCPUs.
4 Benefits of additional CCPUs include redundancy, flexibility
5 and increased central processing power. When the base
6 station is coupled to several other network elements, central
7 processing power is useful to coordinate inbound and outbound
8 information, and to control TM 400 switching as described
9 below.

10 Figures 7 and 8 depict TM 400. At the heart of TM 400
11 is a time/space switch 402, which is coupled to both the TDM
12 bus for data and the VME bus for control. Time/space switch
13 402 is capable of routing information between the TDM bus,
14 processor 404, interface framers 410, and DSPs 420a-f.
15 Time/space switch 402 is described herein according to its
16 communication data rates and switch capabilities. Any device
17 of performing these functions can be used in the present
18 invention, such as the 3C Ltd. C3280 processor.

19 Time/space switch 402 has many ports as shown in Figure
20 8. A PCM input port is coupled to all 16 TDM subbuses,
21 which can each transfer 8Mbps. In essence, time/space switch
22 402 can communicate with up to 16 modules such as TRXs, other
23 TMs, or any other type modules attached to the TDM bus. A
24 larger number is possible if time/space switch 402 is
25 configured to have even more ports and the TDM bus is
26 configured to have even more subbuses.

27 Time/space switch 402 supports many of the switching
28 functions described in CELLULAR PRIVATE BRANCH EXCHANGES,
29 U.S. Ser. No. 08/435,709, filed on May 4, 1995, Attorney
30 docket No. WAVEP001, and METHODS AND APPARATUSSES FOR AN
31 INTELLIGENT SWITCH, U.S. Ser. No. 08/435,838, filed on May 4,
32 1995, Attorney docket No. WAVEP004. Moreover, when the base
33 station is configured to perform switching functions, the
34 base station can perform functions of a cellular PBX, a local
35 loop, or other similar functions.

36 Processor 404 is coupled to time/space switch 402 via
37 8Mbps CPU360Y and CPU360Z input ports, and further coupled to
38 8Mbps PathY and PathZ output ports, as shown. Processor 404

1 is also coupled to VME bus, as shown in Figure 7. Processor
2 404 is provided to perform protocol processing. Possible
3 protocols include Abis, A, SS#7, and ISDN. This processing
4 enables cooperative interworking between other elements of
5 the GSM network and the PSTN. Moreover, processor 404
6 provides distributed processing that is dedicated to the TM
7 400 and becomes scaled as the number of TMs increases.
8 Processor 404 also serves as a protocol engine for TM 400 and
9 helps reduce latency and improve performance for handling
10 SS#7 signalling. If protocol processing is not required, and
11 a CCPU 300 is present in the configuration, then processor
12 404 may be omitted since CCPU 300 includes processor 306 for
13 performing general functions.

14 Framers 410, 412 are coupled to time/space switch 402
15 via 2Mbps framer ports TxA and TxB. The 2Mbps is an E1
16 interface rate, but can be modified for any interface rate.
17 Framers 410, 412 are configured to communicate with other
18 network elements such as a BTS, BSC, MSC, PBX, PSTN, or
19 others. Since the base station can be configured to perform
20 the functions of a BTS, BSC, or MSC, the type of interface
21 may be changed to accommodate the particular required
22 interface function. For example, framers 410, 412 shown in
23 Figure 7 can interface with an E1 at 2Mbps, a T1 at
24 1.544Mbps, DS0 at 64Kbps, or other digital interface.

25 DSPs 420a-f are coupled to time/space switch via 8Mbps
26 PathY and pathZ output ports. DSPs 420a-f can perform a
27 variety of functions including transcode rate adaptation,
28 echo cancelling, or other special functions such as those
29 described below. Once DSPs 420a-f complete their respective
30 functions, the information is then delivered back to
31 time/space switch 402 via pathY and pathZ input ports.

32 As explained above with reference to Figure 2A, the
33 required information processing may sometimes include echo
34 cancelling (step 124), transcode rate adaptation TRAU (step
35 116), or other internetwork functions (IWF). Time/space
36 switch 402 receives control signals from CCPU 300 over the
37 VME bus, instructing time/space switch 402 what to switch or
38 connect.

1 When echo cancelling, rate adaptation, or some other
2 function is required, time/space switch 402 routes the
3 information to a DSP 420 to perform the processing. As
4 shown, there are 6 DSPs 420a-f, however, there may be from
5 zero to any number as required for the processing. Further,
6 the DSPs 420a-f may each have 2 or 4 processor engines such
7 as AT&T DSP1611 or TI TMS320C52 to perform the required
8 processing function.

9 With regard to the TRAU function, the GSM MS
10 communicates compressed voice at 16Kbps, while the PSTN DS0
11 interface is 64Kbps. A DSP 420 modifies the compression to
12 accommodate this rate change. The DSP 420 can also
13 accommodate a rate change between any rates such as 8Kbps,
14 16Kbps and 64Kbps.

15 As mentioned above, information traffic switching at
16 rates below 64Kbps is a feature of the invention. Two
17 aspects of the sub-64Kbps information switching are
18 described. First, a communication is described that enables
19 sub-64Kbps data streams to be assembled into a standard DS0
20 64Kbps data stream. To accomplish this aspect, the DSPs
21 420a-f are employed to assemble sub-64Kbps data streams into
22 DS0 data streams to send to other network elements, and to
23 disassemble DS0 data streams from other network elements.
24 For example, Figure 9A shows an 8-bit 64Kbps DS0 data stream
25 502 containing 4 16Kbps data streams (W1, W2, W3, W4) and an
26 8-bit 64Kbps DS0 data stream 504 containing 8 8Kbps data
27 streams (W1, W2, W3, W4, W5, W6, W7, W8). This permits
28 either 4 16Kbps calls or 8 8Kbps calls to be communicated in
29 a single DS0 data stream, where conventionally only one call
30 is supported. Moreover, the DS0 data stream can contain a
31 lesser number by padding the data streams with predetermined
32 bits.

33 Figure 9B depicts how DSPs 420a-f can be configured to
34 perform the assembly and disassembly required to read and
35 write the sub-64Kbps data streams into 64Kbps data streams.
36 Each DSP 420 that is instructed to perform the communication
37 has its memory configured with 4 buffers and a map, where the
38 first 4 (M1, M2, M3, M4) are buffers for storing the data

1 streams and number 5 (M5) is for storing the memory map to
2 direct the DSP function buffer memory mapping. Figure 9B
3 shows how buffer M1 is mapped to buffer M3 and buffer M2 is
4 mapped to buffer M4, although any mapping can be programmed.

5 Figure 9C is a flowchart describing the procedure for
6 mapping TDM information into a DS0 64Kbps data stream. Step
7 520 is where time/space switch 402 receives time slots
8 information from the TDM bus. Step 522 switches desired time
9 slots to selected DSP 420a-f via PcmOut4-7 and PathZ or
10 PathY. In step 524, CCPU 300 sends a map via the VME bus to
11 selected DSP 420a-f that programs the mapping function into
12 M5. Step 526 shifts a portion of the time slot information
13 into buffer M1 while information is being shifted out from
14 buffer M4 via PathY or PathZ to time/space switch 402. Step
15 528 performs the mapping from buffer M1 to M3. Step 530
16 shifts a portion of the time slot information into buffer M2
17 while information is being shifted out from buffer M3 via
18 PathY or PathZ to time/space switch 402. Step 532 performs
19 the mapping from buffer M2 to M4. Step 534 determines
20 whether the DSP 420 should continue. Under normal
21 circumstances, DSP 420 would continuously process information
22 and the loop would continue. However, if the DSP is
23 instructed to end, step 534 sends the processing to step 536
24 where the processing ends. Thereafter, DSP 420 is free to
25 perform other processing.

26 Second, to comply with GSM, speech is sampled by MS 20
27 at 64Kbps and compressed to 13.2Kbps data streams using
28 standard vocoder algorithms. The information is then sent to
29 BTS 40 via RF communication. Each inbound 13.2Kbps data
30 stream is received by TRX 250 and typically packed into a
31 16Kbps data stream and routed within BTS 40. In conventional
32 equipment, these 16Kbps data streams are decompressed to
33 64Kbps and transferred to an MSC where standard 64Kbps
34 switching is performed. However, the present invention is
35 capable of intelligently routing calls at 8Kbps, 16Kbps, or
36 other rates, thus avoiding unnecessary rate conversions.

37 This second aspect is apparent when a call is made from
38 a first MS 20a to a second MS 20b within the base station

1 service area. Time/space switch 402 may simply route the
2 inbound information from the first MS 20a back out onto the
3 TDM bus as outbound information for the second MS 20b. This
4 type of switching is explained below with reference to
5 Figures 14A-D and 15A-D. Moreover, this type of switching is
6 further explained in CELLULAR PRIVATE BRANCH EXCHANGES, U.S.
7 Ser. No. 08/435,709, filed on May 4, 1995, Attorney docket
8 No. WAVEP001, and METHODS AND APPARATUSSES FOR AN INTELLIGENT
9 SWITCH, U.S. Ser. No. 08/435,838, filed on May 4, 1995,
10 Attorney docket No. WAVEP004.

11 The call routing function can also be performed in a
12 variety of other ways depending on the mobile station
13 communication with a base station. For example, if a first
14 MS 20a and a second MS 20b are communicating with a single
15 TRX 250a, and within a single DSP string 254, 256, the DSP
16 string can receive the inbound data from first MS 20a, and
17 then send it as outbound information to second MS 20b. Since
18 the inbound and outbound information is at 13.2Kbps, and is
19 routed inbound and outbound within a single DSP string, it
20 does not need to be packed into a 16Kbps data stream. As
21 another example, if a first MS 20a and a second MS 20b are
22 communicating with a single TRX 250a, but with different DSP
23 strings, TRX 250a may receive the inbound data from first MS
24 20a in one DSP string, and then send it as outbound
25 information to another DSP string and then to second MS 20b.
26 Since the inbound and outbound information are processed by
27 different DSP strings, the information is packed into a
28 16Kbps data stream for communication between the DSP strings.
29 Moreover, in one case, the first DSP string communicates the
30 information to the second DSP string over the TDM bus. As
31 still another example, if a first MS 20a is communicating
32 with a first TRX 250a and a second MS 20c is communicating
33 with a second TRX 250b, first TRX 250a may receive the
34 inbound information and send it via the TDM bus to second TRX
35 250b, which treats it as outbound information to second MS
36 20c. Since the inbound and outbound information are
37 processed by different TRXs, the information is packed into a
38 16Kbps data stream for communication between TRXs. Note that

1 these examples do not send the information to TM 400. Note
2 also that these examples do not decompress the information to
3 64Kbps.

4 Figure 10 depicts how the modular and scalable
5 architecture of the invention is implemented with a TDM bus
6 and a VME bus. RF distribution module 210 is coupled to TRX
7 250. TRX 250 is coupled to both the TDM bus and the VME bus.
8 In particular, DSPs 256, 260 are coupled to the TDM bus and
9 RTP 262 is coupled to the VME bus. CCPU 300 is coupled to
10 the VME bus. A clock module 307 is coupled to the TDM bus
11 and generates the reference clock which allows the subsystems
12 to operate in a synchronized fashion. TM 400 is coupled to
13 both the TDM bus and the VME bus. Figure 10 depicts a one-
14 TRX BTS configuration, which is also depicted in Figure 11.

15 Figure 11 depicts a commercial product that encloses the
16 various base station components into a chassis. The chassis
17 can operate as a stand alone unit, or can be mounted to an
18 equipment rack for deployment in the field. Moreover, any
19 card can be placed in any slot. It is possible, by removing
20 all TRXs, to build BSC or MSC configurations using just TM
21 and CCPU cards.

22 Since the architecture is fully scalable, Figure 12
23 depicts a base station having 6 TRXs, 2 CCPUs, and 3 TMs.
24 Any base station configuration and function can be
25 accommodated by selecting processing elements for deployment.
26 For example, Figure 13 shows various possible functions, such
27 as BTS, BSC, combined BTS/BSC, MSC, combined BSC/MSC, and
28 combined BTS/BSC/MSC, that can be achieved with the
29 invention. A configuration having a single TRX and single TM
30 is possible when the CCPU functions are incorporated in the
31 TRX RTP 262 and TM processor 404.

32 Figures 14A-D show the various functional division of
33 inbound information processing and outbound information
34 processing for a combined BTS/BSC and MSC. Those steps
35 common to Figures 2A-D have common numbers. Once the inbound
36 information is de-interleaved (step 110), it is sent to
37 time/space switch 402 (step 111). The time/space switch 402
38 can then route the inbound information to one of three

1 places: to the TRAU (step 116), to an E1 (step 118), or back
2 to the TDM bus as outbound information (goto Figure 14C step
3 163). If the switch step 111 routes the information to the
4 E1 (step 118), the inbound information is sent to the MSC.
5 Step 120 receives the information at the MSC and switch step
6 122 can then route the inbound information to one of four
7 places: to the TRAU (step 123), to an echo canceler (step
8 124), to an E1 (step 126), or back to the BTS/BSC as outbound
9 information (goto Figure 14C step 152).

10 The Figure 14B flowchart shows the inbound control
11 signal processing. Note the Faux Abis step 133. This step
12 is performed to retain the interface between steps 130 and
13 136 where the information transport steps 112, 114 over an
14 exemplary E1 trunk are removed.

15 With regard to outbound information, step 150 receives
16 information from a foreign network via an E1. The MSC in
17 this case only receives the information from the foreign
18 network when the destination MS is communicating with a TRX
19 under its control. A switch step 152 can then route the
20 information to a TRAU (step 153) or to an E1 (step 160). The
21 BTS/BSC receives the information on an E1 (step 162) and a
22 switch step 163 can then route the information to a TRAU
23 (step 158) or to a TRX that interleaves (step 164), encodes
24 (step 166), and frames (step 168) the information and sends
25 it to the destination MS via step 170. Note that both switch
26 steps 152 and 163 can be initiated from Figure 14A steps 122
27 and 111 respectively.

28 The Figure 14D flowchart shows the outbound control
29 signal processing. Note the Faux Abis step 183. This step
30 is performed to retain the interface between steps 180 and
31 186 where the information transport steps 160, 162 over an
32 exemplary E1 trunk are removed.

33 Figures 15A-D show the various functional division of
34 inbound information processing and outbound information
35 processing for a combined BTS/BSC/MSC. Those steps common to
36 Figures 2A-D have common numbers. Once the inbound
37 information is de-interleaved (step 110), it is sent to
38 time/space switch 402 (step 111). The time/space switch 402

1 can then route the inbound information to one of four places:
2 to a TRAU (step 116), to an echo canceler (step 124), to an
3 E1 (step 126), or back to the TDM bus as outbound information
4 (goto Figure 14C step 152). If the switch step 111 routes
5 the information to the E1 (step 126), the inbound information
6 is sent to a foreign network.

7 The Figure 15B flowchart shows the inbound control
8 signal processing. Note the Faux A step 139. This step is
9 performed to retain the interface between steps 136 and 142
10 where the information transport steps 118, 120 over an
11 exemplary E1 trunk are removed.

12 With regard to outbound information, step 150 receives
13 information from a foreign network via an E1. The
14 BTS/BSC/MS in this case only receives the information from
15 the foreign network when the destination MS is communicating
16 with a TRX under its control. A switch step 152 can then
17 route the information to a TRAU (step 158) or to a TRX that
18 interleaves (step 164), encodes (step 166), and frames (step
19 168) the information and sends it to the destination MS via
20 step 170. Note that switch step 152 can be initiated from
21 Figure 15A step 111.

22 The Figure 15D flowchart shows the outbound control
23 signal processing. Note the Faux A step 177. This step is
24 performed to retain the interface between steps 174 and 180
25 where the information transport steps 154, 156 over an
26 exemplary E1 trunk are removed.

27 An important feature of the scalable architecture is
28 that when TM cards are added, the switching ability of the
29 base station increases. For example, by configuring a base
30 station with 3 TM modules, as shown in Figure 12, the base
31 station capacity is increased to 6 E1 output ports. This
32 configuration provides both greater communication capacity to
33 a MSC, as well as greater information switch capacity within
34 the base station itself, such as between TRX cards.

35 Advantages of the present invention include modularity,
36 scalability, distributed processing, improved performance,
37 reduced network congestion, fault tolerance, and more
38 efficient and cost-effective base stations.

1 As used herein, when a first element and a second
2 element are coupled, they are related to one another, but
3 need not have a direct path to one another. For example, an
4 antenna element may be coupled to a processing element via a
5 receiver. However, when a first element and second element
6 are connected, they are required to have a direct path to one
7 another.

8

9 **ALTERNATIVE EMBODIMENTS**

10 Having disclosed exemplary embodiments and the best
11 mode, modifications and variations may be made to the
12 disclosed embodiments while remaining within the scope of the
13 present invention as defined by the following claims.



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1 What is claimed is:

2

3 1. A base station for communicating with a mobile station,
4 said base station comprising:

5 a transceiver configured to receive inbound information
6 from the mobile station and transmit outbound information to
7 the mobile station;

8 a signal processor coupled to said transceiver and to a
9 data bus, said signal processor configured to equalize and
10 decode said inbound information and to transmit said inbound
11 information to said data bus, and configured to receive said
12 outbound information from said data bus and encode said
13 outbound information;

14 a trx processor coupled to said signal processor, said
15 trx processor configured to control said signal processor;
16 and

17 a trunk module having an interface processor coupled to
18 said data bus and configured to receive said inbound
19 information from said data bus and transmit said inbound
20 information to a foreign network, and configured to receive
21 said outbound information from a foreign network and transmit
22 said outbound information to said data bus;

23

24 2. The base station of claim 1, wherein:

25 said trunk module further includes a time/space switch
26 coupled to said data bus, a plurality of signal processors
27 coupled to said time/space switch, and an interface framer
28 coupled to said time/space switch.

29

30 3. The base station of claim 1, further comprising:

31 a control bus coupled to said trx processor and said
32 trunk module; and

33 a central processor coupled to said control bus and
34 configured to control said trx processor and said trunk
35 module.

36

37 4. The base station of claim 3, wherein:

38 said trunk module further includes a time/space switch





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- 1 coupled to said data bus, a plurality of signal processors
2 coupled to said time/space switch, and an interface framer
3 coupled to said time/space switch.
4
- 5 5. A base station for communicating with a mobile station
6 comprising:
7 a trunk module having an interface processor coupled to
8 a data bus and configured to receive inbound information from
9 said data bus and transmit said inbound information to a
10 foreign network, and configured to receive outbound
11 information from a foreign network and transmit said outbound
12 information to said data bus.
13
- 14 6. The base station of claim 5, wherein:
15 said trunk module further includes a time/space switch
16 coupled to said data bus, a plurality of signal processors
17 coupled to said time/space switch, and an interface framer
18 coupled to said time/space switch.
19
- 20 7. The base station of claim 6, further comprising:
21 a control bus coupled to said trunk module; and
22 a central processor coupled to said control bus and
23 configured to control said trunk module.
24
- 25 8. The base station of claim 6 further comprising:
26 a trx module including:
27 a transceiver configured to receive inbound
28 information from the mobile station and transmit outbound
29 information to the mobile station;
30 a signal processor coupled to said transceiver and
31 to a data bus, said signal processor configured to equalize
32 and decode said inbound information and to transmit said
33 inbound information to said data bus, and configured to
34 receive said outbound information from said data bus and
35 encode said outbound information; and
36 a trx processor coupled to said signal processor,
37 said trx processor configured to control said signal
38 processor.





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- 1 9. The base station of claim 8, further comprising:
2 a control bus coupled to said trx processor and said
3 trunk module; and
4 a central processor coupled to said control bus and
5 configured to control said trx module and said trunk module.
6
- 7 10. The base station of claim 9, further comprising:
8 a second trunk module having a second interface
9 processor coupled to said data bus and configured to receive
10 inbound information from said data bus and transmit said
11 inbound information to a foreign network, and configured to
12 receive outbound information from a foreign network and
13 transmit said outbound information to said data bus.
14
- 15 11. The base station of claim 7, further comprising:
16 a plurality of trx modules each including:
17 a transceiver configured to receive inbound
18 information from the mobile station and transmit outbound
19 information to the mobile station;
20 a signal processor coupled to said transceiver and
21 to a data bus, said signal processor configured to equalize
22 and decode said inbound information and to transmit said
23 inbound information to said data bus, and configured to
24 receive said outbound information from said data bus and
25 encode said outbound information; and
26 a trx processor coupled to said signal processor,
27 said trx processor configured to control said signal
28 processor.
29
- 30 12. The base station of claim 11, further comprising:
31 a control bus coupled to said trx processor and said
32 trunk module; and
33 a central processor coupled to said control bus and
34 configured to control said trx modules and said trunk module.
35
- 36 13. The base station of claim 12, further comprising:
37 a second trunk module having a second interface
38 processor coupled to said data bus and configured to receive





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1 inbound information from said data bus and transmit said
2 inbound information to a foreign network, and configured to
3 receive outbound information from a foreign network and
4 transmit said outbound information to said data bus.

5

6 14. The base station of claim 11, further comprising:
7 a control bus coupled to said trunk module; and
8 a plurality of central processors coupled to said
9 control bus and configured to control said trx modules and
10 said trunk modules.

11

12 15. A method of communicating with a mobile station, using a
13 base station comprising a trx module including a transceiver,
14 a signal processor and a trx processor, said method
15 comprising the steps of:

16 receiving inbound RF information from the mobile station
17 in the transceiver;

18 converting said inbound RF information to inbound
19 digital information;

20 processing the inbound digital information in the signal
21 processor; and

22 controlling said processing step in the trx processor.

23

24 16. The method of claim 16, further comprising the steps of:

25 converting the inbound digital information to outbound
26 digital information in the signal processor;

27 converting said outbound digital information to outbound
28 RF information;

29 transmitting said RF information to the mobile station
30 in the transceiver.

31

32 17. The method of claim 15, further comprising the steps of:

33 converting the inbound digital information to outbound
34 digital information in the trx processor;

35 converting the outbound digital information to outbound
36 RF information;

37 transmitting said RF information to the mobile station
38 in the transceiver.

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- 1 18. The method of claim 15 for further communicating with a
2 second mobile station, wherein said base station further
3 comprises a data bus and a second trx module, said method
4 further comprising the steps of:
5 communicating the inbound digital information from the
6 trx module to the data bus; and
7 receiving the inbound digital information from the trx
8 module in the second trx module; and
9 converting the inbound digital information to outbound
10 digital information in the second trx module;
11 converting the outbound digital information to outbound
12 RF information;
13 transmitting the RF information to the second mobile
14 station.
15
- 16 19. The method of claim 15 for further communicating with a
17 second mobile station, wherein said base station further
18 comprises a data bus and a trunk module, said method further
19 comprising the steps of:
20 communicating the inbound digital information from the
21 trx module to the data bus;
22 receiving the inbound digital information from the trx
23 module in the trunk module;
24 converting the inbound digital information to outbound
25 digital information in the trunk module;
26 communicating the outbound digital information to the
27 data bus;
28 converting said outbound digital information to outbound
29 RF information;
30 transmitting said RF information to the second mobile
31 station.
32
- 33 20. The method of claim 19, further comprising the step of:
34 performing one of an assembly and a disassembly of a
35 first data stream of one of said inbound digital information
36 and said outbound digital information to generate a second
37 data stream of one of said inbound digital information and
38 said outbound digital information.

