PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04Q 7/38, 7/22	A1	(11) International Publication Number: WO 97/15163 (43) International Publication Date: 24 April 1997 (24.04.97)

(21) International Application Number: PCT/US96/16678

(22) International Filing Date: 18 October 1996 (18.10.96)

(30) Priority Data:
08/544,843 18 October 1995 (18.10.95) US

(71) Applicants: TELEFONAKTIEBOLAGET LM ERICSSON [SE/SE]; S-126 25 Stockholm (SE). ERICSSON INC. [US/US]; 7001 Development Drive, P.O. Box 13969, Research Triangle Park, NC 27709 (US).

(72) Inventors: RAITH, Alex, Krister; 805-A5 Park Ridge Road, Durham, NC 27713 (US). BILLSTÖM, Lars; Wiboms väg 25, S-171 60 Solna (SE). DIACHINA, John; 505 Kristin Drive, Garner, NC 27529 (US).

(74) Agents: GRUDZIECKI, Ronald, L. et al.; Burns, Doane, Swecker & Mathis, L.L.P., P.O. Box 1404, Alexandria, VA 22313-1404 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: AN ENHANCED CHANNEL ALLOCATION PROCESS

(57) Abstract

A method for improving the allocation of channels in a communication system is disclosed. During an access on a control channel, a mobile station sends an activity report to the system containing various measurements which indicate how the mobile station is currently perceiving the control channel. These measurements can then be used when assigning the mobile station a non-control channel. In addition, the system can use the activity report to determine if any of the plurality of random access parameters need to be changed so as to allow better access.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	**GB**	United Kingdom	**MW**	Malawi
AT	Austria	**GE**	Georgia	**MX**	Mexico
AU	Australia	**GN**	Guinea	**NE**	Niger
BB	Barbados	**GR**	Greece	**NL**	Netherlands
BE	Belgium	**HU**	Hungary	**NO**	Norway
BF	Burkina Faso	**IE**	Ireland	**NZ**	New Zealand
BG	Bulgaria	**IT**	Italy	**PL**	Poland
BJ	Benin	**JP**	Japan	**PT**	Portugal
BR	Brazil	**KE**	Kenya	**RO**	Romania
BY	Belarus	**KG**	Kyrgystan	**RU**	Russian Federation
CA	Canada	**KP**	Democratic People's Republic of Korea	**SD**	Sudan
CF	Central African Republic			**SE**	Sweden
CG	Congo	**KR**	Republic of Korea	**SG**	Singapore
CH	Switzerland	**KZ**	Kazakhstan	**SI**	Slovenia
CI	Côte d'Ivoire	**LI**	Liechtenstein	**SK**	Slovakia
CM	Cameroon	**LK**	Sri Lanka	**SN**	Senegal
CN	China	**LR**	Liberia	**SZ**	Swaziland
CS	Czechoslovakia	**LT**	Lithuania	**TD**	Chad
CZ	Czech Republic	**LU**	Luxembourg	**TG**	Togo
DE	Germany	**LV**	Latvia	**TJ**	Tajikistan
DK	Denmark	**MC**	Monaco	**TT**	Trinidad and Tobago
EE	Estonia	**MD**	Republic of Moldova	**UA**	Ukraine
ES	Spain	**MG**	Madagascar	**UG**	Uganda
FI	Finland	**ML**	Mali	**US**	United States of America
FR	France	**MN**	Mongolia	**UZ**	Uzbekistan
GA	Gabon	**MR**	Mauritania	**VN**	Viet Nam

AN ENHANCED CHANNEL ALLOCATION PROCESS

BACKGROUND

Applicants' invention relates to electrical telecommunication, and more particularly to wireless communication systems, such as cellular and satellite radio systems, for various modes of operation (analog, digital, dual mode, etc.), and access techniques such as frequency division multiple access (FDMA), time divisional multiple access (TDMA), code divisional multiple access (CDMA), hybrid FDMA/TDMA/CDMA, for example. The specific aspects of the present invention are directed to techniques for enhancing bandwidth allocation, traffic and capacity management, and the throughput and quality of transactions.

A description follows which is directed to environments in which the system of the present invention may be applied. This general description is intended to provide a general overview of known systems and the terminology associated therewith so that a better understanding of the invention can be achieved. In North America, digital communication and multiple access techniques such as TDMA are currently provided by a digital cellular radiotelephone system called the digital advanced mobile phone service (D-AMPS), some of the characteristics of which are specified in the interim standard TIA/EIA/IS-54-B, "Dual-Mode Mobile Station-Base Station Compatibility Standard", published by the Telecommunications Industry Association and Electronic Industries Association (TIA/EIA), which is expressly incorporated herein by reference. Because of a large existing consumer base of equipment operating only in the analog domain with frequency-division multiple access (FDMA), TIA/EIA/IS-54-B is a dual-mode (analog and digital) standard, providing for analog compatibility together with digital communication capability. For example, the TIA/EIA/IS-54-B standard provides for both FDMA analog voice channels (AVC) and TDMA digital traffic channels (DTC). The AVCs and DTCs are implemented by frequency modulating radio carrier signals, which have frequencies near 800 megahertz (MHz) such that each radio channel has a spectral width of 30 kilohertz (KHz).

In a TDMA cellular radiotelephone system, each radio channel is divided into a series of time slots, each of which contains a burst of information from a data source, e.g., a digitally encoded portion of a voice conversation. The time slots are grouped into successive TDMA frames having a predetermined duration. The number of time slots in each TDMA frame is related to the number of different users that can simultaneously share the radio channel. If each slot in a TDMA frame is assigned to a different user, the duration of a TDMA frame is the minimum amount of time between successive time slots assigned to the same user.

The successive time slots assigned to the same user, which are usually not consecutive time slots on the radio carrier, constitute the user's digital traffic channel, which may be considered a logical channel assigned to the user. As described in more detail below, digital control channels (DCCHs) can also be provided for communicating control signals, and such a DCCH is a logical channel formed by a succession of usually non-consecutive time slots on the radio carrier.

In only one of many possible embodiments of a TDMA system as described above, the TIA/EIA/IS-54-B standard provided that each TDMA frame consists of six consecutive time slots and has a duration of 40 milliseconds (msec). Thus, each radio channel can carry from three to six DTCs (e.g., three to six telephone conversations), depending on the source rates of the speech coder/decoders (codecs) used to digitally encode the conversations. Such speech codecs can operate at either full-rate or half-rate. A full-rate DTC requires twice as many time slots in a given time period as a half-rate DTC, and in TIA/EIA/IS-54-B, each full-rate DTC uses two slots of each TDMA frame, i.e., the first and fourth, second and fifth, or third and sixth of a TDMA frame's six slots. Each half-rate DTC uses one time slot of each TDMA frame. During each DTC time slot, 324 bits are transmitted, of which the major portion, 260 bits, is due to the speech output of the codec, including bits due to error correction coding of the speech output, and the remaining bits are used for guard times and overhead signalling for purposes such as synchronization.

It can be seen that the TDMA cellular system operates in a buffer-and-burst, or discontinuous-transmission, mode: each mobile station transmits (and receives) only during its assigned time slots. At full rate, for example, a mobile station might transmit during slot 1, receive during slot 2, idle during slot 3, transmit during slot 4, receive during slot 5, and idle during slot 6, and then repeat the cycle during succeeding TDMA frames. Therefore, the mobile station, which may be battery-powered, can be switched off, or sleep, to save power during the time slots when it is neither transmitting nor receiving.

In addition to voice or traffic channels, cellular radio communication systems also provide paging/access, or control, channels for carrying call-setup messages between base stations and mobile stations. According to TIA/EIA/IS-54-B, for example, there are twenty-one dedicated analog control channels (ACCs), which have predetermined fixed frequencies for transmission and reception located near 800 MHz. Since these ACCs are always found at the same frequencies, they can be readily located and monitored by the mobile stations.

For example, when in an idle state (i.e., switched on but not making or receiving a call), a mobile station in a TIA/EIA/IS-54-B system tunes to and then regularly monitors the strongest control channel (generally, the control channel of the cell in which the mobile station is located at that moment) and may receive or initiate a call through the corresponding base station. When moving between cells while in the idle state, the mobile station will eventually "lose" radio connection on the control channel of the "old" cell and tune to the control channel of the "new" cell. The initial tuning and subsequent re-tuning to control channels are both accomplished automatically by scanning all the available control channels at their known frequencies to find the "best" control channel. When a control channel with good reception quality is found, the mobile station remains tuned to this channel until the quality deteriorates again. In this way, mobile stations stay "in touch" with the system.

While in the idle state, a mobile station must monitor the control channel for paging messages addressed to it. For example, when an ordinary telephone (land-line) subscriber calls a mobile subscriber, the call is directed from the public switched telephone network (PSTN) to a mobile switching center (MSC) that analyzes the dialed number. If the dialed number is validated, the MSC requests some or all of a number of radio base stations to page the called mobile station by transmitting over their respective control channels paging messages that contain the mobile identification number (MIN) of the called mobile station. Each idle mobile station receiving a paging message compares the received MIN with its own stored MIN. The mobile station with the matching stored MIN transmits a page response over the particular control channel to the base station, which forwards the page response to the MSC.

Upon receiving the page response, the MSC selects an AVC or a DTC available to the base station that received the page response, switches on a corresponding radio transceiver in that base station, and causes that base station to send a message via the control channel to the called mobile station that instructs the called mobile station to tune to the selected voice or traffic channel. A through-connection for the call is established once the mobile station has tuned to the selected AVC or DTC.

The performance of the system having ACCs that is specified by TIA/EIA/IS-54-B has been improved in a system having digital control channels (DCCHs) that is specified in TIA/EIA/IS-136, which is expressly incorporated herein by reference. Using such DCCHs, each TIA/EIA/IS-54-B radio channel can carry DTCs only, DCCHs only, or a mixture of both DTCs and DCCHs. Within the TIA/EIA/IS-136-B framework, each radio carrier frequency can have up to three full-rate DTCs/DCCHs, or six half-rate DTCs/DCCHs, or any combination in between, for example, one full-rate and four half-rate DTCs/DCCHs.

In general, however, the transmission rate of the DCCH need not coincide with the half-rate and full-rate specified in TIA/EIA/IS-54-B, and the length of the DCCH slots may not be uniform and may not coincide with the length of the DTC slots. The DCCH may be defined on an TIA/EIA/IS-54-B radio channel and may consist, for example, of every n-th slot in the stream of consecutive TDMA slots. In this case, the length of each DCCH slot may or may not be equal to 6.67 msec, which is the length of a DTC slot according to TIA/EIA/IS-54-B. Alternatively (and without limitation on other possible alternatives), these DCCH slots may be defined in other ways known to one skilled in the art.

In cellular telephone systems, an air link protocol is required in order to allow a mobile station to communicate with the base stations and MSC. The communications link protocol is used to initiate and to receive cellular telephone calls. The communications link protocol is commonly referred to within the communications industry as a Layer 2 protocol, and its functionality includes the delimiting, or framing, of Layer 3 messages. These Layer 3 messages may be sent between communicating Layer 3 peer entities residing within mobile stations and cellular switching systems. The physical layer (Layer 1) defines the parameters of the physical communications channel, e.g., radio frequency spacing, modulation characteristics, etc. Layer 2 defines the techniques necessary for the accurate transmission of information within the constraints of the physical channel, e.g., error correction and detection, etc. Layer 3 defines the procedures for reception and processing of information transmitted over the physical channel.

Communications between mobile stations and the cellular switching system (the base stations and the MSC) can be described in general with reference to FIGS. 1 and 2. FIG. 1 schematically illustrates pluralities of Layer 3 messages 11, Layer 2 frames 13, and Layer 1 channel bursts, or time slots, 15. In FIG. 1, each group of channel bursts corresponding to each Layer 3 message may constitute a logical channel, and as described above, the channel bursts for a given Layer 3 message would usually not be consecutive slots on an TIA/EIA/136 carrier. On the other hand, the channel bursts could be consecutive; as soon as one time slot ends, the next time slot could begin.

Each Layer 1 channel burst 15 contains a complete Layer 2 frame as well as other information such as, for example, error correction information and other overhead information used for Layer 1 operation. Each Layer 2 frame contains at least a portion of a Layer 3 message as well as overhead information used for Layer 2 operation. Although not indicated in FIG. 1, each Layer 3 message would include various information elements that can be considered the payload of the message, a header portion for identifying the respective message's type, and possibly padding.

Each Layer 1 burst and each Layer 2 frame is divided into a plurality of different fields. In particular, a limited-length DATA field in each Layer 2 frame contains the Layer 3 message 11. Since Layer 3 messages have variable lengths depending upon the amount of information contained in the Layer 3 message, a plurality of Layer 2 frames may be needed for transmission of a single Layer 3 message. As a result, a plurality of Layer 1 channel bursts may also be needed to transmit the entire Layer 3 message as there is a one-to-one correspondence between channel bursts and Layer 2 frames.

As noted above, when more than one channel burst is required to send a Layer 3 message, the several bursts are not usually consecutive bursts on the radio channel. Moreover, the several bursts are not even usually successive bursts devoted to the particular logical channel used for carrying the Layer 3 message. Since time is required to receive, process, and react to each received burst, the bursts required for transmission of a Layer 3 message are usually sent in a staggered format, as schematically illustrated in FIG. 2(a) and as described above in connection with the TIA/EIA/IS-136 standard.

FIG. 2(a) shows a general example of a forward (or downlink) DCCH configured as a succession of time slots 1, 2, . . . , N, . . . included in the consecutive time slots 1, 2, . . . sent on a carrier frequency. These DCCH slots may be defined on a radio channel such as that specified by TIA/EIA/IS-136, and may consist, as seen in FIG. 2(a) for example, of every n-th slot in a series of consecutive slots. Each DCCH slot has a duration that may or may not be 6.67 msec, which is the length of a DTC slot according to the TIA/EIA/IS-136 standard.

As shown in FIG. 2(a), the DCCH slots may be organized into superframes (SF), and each superframe includes a number of logical channels that carry different kinds of information. One or more DCCH slots may be allocated to each logical channel in the superframe. The exemplary downlink superframe in FIG. 2(a) includes three logical channels: a broadcast control channel (BCCH) including six successive slots for overhead messages; a paging channel (PCH) including one slot for paging messages; and an access response channel (ARCH) including one slot for channel assignment and other messages. The remaining time slots in the exemplary superframe of FIG. 2(a) may be dedicated to other logical channels, such as additional paging channels PCH or other channels. Since the number of mobile stations is usually much greater than the number of slots in the superframe, each paging slot is used for paging several mobile stations that share some unique characteristic, e.g., the last digit of the MIN.

FIG. 2(b) illustrates a preferred information format for the slots of a forward DCCH. The information transferred in each slot comprises a plurality of fields, and FIG. 2(b) indicates the number of bits in each field above that field. The bits sent in the SYNC field are used in a conventional way to help ensure accurate reception of the coded superframe phase (CSFP) and DATA fields. The SYNC field includes a predetermined bit pattern used by the base stations to find the start of the slot. The shared channel feedback (SCF) field is used to control a random access channel (RACH), which is used by the mobile to request access to the system. The CSFP field conveys a coded superframe phase value that enables the mobile stations to find the start of each superframe. This is just one example for the information format in the slots of the forward DCCH.

For purposes of efficient sleep mode operation and fast cell selection, the BCCH may be divided into a number of sub-channels. A BCCH structure is known that allows the mobile station to read a minimum amount of information when it is switched on (when it locks onto a DCCH) before being able to access the system (place or receive a call). After being switched on, an idle mobile station needs to regularly monitor only its assigned PCH slots (usually one in each superframe); the mobile can sleep during other slots. The ratio of the mobile's time spent reading paging messages and its time spent asleep is controllable and represents a tradeoff between call-set-up delay and power consumption.

Since each TDMA time slot has a certain fixed information carrying capacity, each burst typically carries only a portion of a Layer 3 message as noted above. In the uplink direction, multiple mobile stations attempt to communicate with the system on a contention basis, while multiple mobile stations listen for Layer 3 messages sent from the system in the downlink direction. In known systems, any given Layer 3 message must be carried using as many TDMA channel bursts as required to send the entire Layer 3 message.

Digital control and traffic channels are desirable for reasons, such as supporting longer sleep periods for the mobile units, which results in longer battery life, for example. Digital traffic channels and digital control channels have expanded functionality for optimizing system capacity and supporting hierarchical cell structures, i.e., structures of macrocells, microcells, picocells, etc. The term "macrocell" generally refers to a cell having a size comparable to the sizes of cells in a conventional cellular telephone system (e.g., a radius of at least about 1 kilometer), and the terms "microcell" and "picocell" generally refer to progressively smaller cells. For example, a microcell might cover a public indoor or outdoor area, e.g., a convention center or a busy street, and a picocell might cover an office corridor or a floor of a high-rise building. From a radio coverage perspective, macrocells, microcells, and picocells may be distinct from one another or may overlap one another to handle different traffic patterns or radio environments.

FIG. 3 is an exemplary hierarchical, or multi-layered, cellular system. An umbrella macrocell 10 represented by a hexagonal shape makes up an overlying cellular structure. Each umbrella cell may contain an underlying microcell structure. The umbrella cell 10 includes microcell 20 represented by the area enclosed within the dotted line and microcell 30 represented by the area enclosed within the dashed line corresponding to areas along city streets, and picocells 40, 50, and 60, which cover individual floors of a building. The intersection of the two city streets covered by the microcells 20 and 30 may be an area of dense traffic concentration, and thus might represent a hot spot.

FIG. 4 represents a block diagram of an exemplary cellular mobile radiotelephone system, including an exemplary base station 110 and mobile station 120. The base station includes a control and processing unit 130 which is connected to the MSC 140 which in turn is connected to the PSTN (not shown). General aspects of such cellular radiotelephone systems are known in the art, as described by U.S. Patent No. 5,175,867 to Wejke et al., entitled "Neighbor-Assisted Handoff in a

Cellular Communication System," which is incorporated in this application by reference.

The base station 110 handles a plurality of voice channels through a voice channel transceiver 150, which is controlled by the control and processing unit 130. Also, each base station includes a control channel transceiver 160, which may be capable of handling more than one control channel. The control channel transceiver 160 is controlled by the control and processing unit 130. The control channel transceiver 160 broadcasts control information over the control channel of the base station or cell to mobiles locked to that control channel. It will be understood that the transceivers 150 and 160 can be implemented as a single device, like the voice and control transceiver 170, for use with DCCHs and DTCs that share the same radio carrier frequency.

The mobile station 120 receives the information broadcast on a control channel at its voice and control channel transceiver 170. Then, the processing unit 180 evaluates the received control channel information, which includes the characteristics of cells that are candidates for the mobile station to lock on to, and determines on which cell the mobile should lock. Advantageously, the received control channel information not only includes absolute information concerning the cell with which it is associated, but also contains relative information concerning other cells proximate to the cell with which the control channel is associated, as described in U.S. Patent No. 5,353,332 to Raith et al., entitled "Method and Apparatus for Communication Control in a Radiotelephone System," which is incorporated in this application by reference.

To increase the user's "talk time", i.e., the battery life of the mobile station, a digital forward control channel (base station to mobile station) may be provided that can carry the types of messages specified for current analog forward control channels (FOCCs), but in a format which allows an idle mobile station to read overhead messages when locking onto the FOCC and thereafter only when the information has changed; the mobile sleeps at all other times. In such a system, some types of messages are broadcast by the base stations more frequently than other types, and mobile stations need not read every message broadcast.

The systems specified by the TIA/EIA/IS-54-B and TIA/EIA/IS-136 standards are circuit-switched technology, which is a type of "connection-oriented" communication that establishes a physical call connection and maintains that connection for as long as the communicating end-systems have data to exchange. The direct connection of a circuit switch serves as an open pipeline, permitting the end-systems to use the circuit for whatever they deem appropriate. While circuit-switched data communication may be well suited to constant-bandwidth applications, it is relatively inefficient for low-bandwidth and "bursty" applications.

Packet-switched technology, which may be connection-oriented (e.g., X.25) or "connectionless" (e.g., the Internet Protocol, "IP"), does not require the set-up and tear-down of a physical connection, which is in marked contrast to circuit-switched technology. This reduces the data latency and increases the efficiency of a channel in handling relatively short, bursty, or interactive transactions. A connectionless packet-switched network distributes the routing functions to multiple routing sites, thereby avoiding possible traffic bottlenecks that could occur when using a central switching hub. Data is "packetized" with the appropriate end-system addressing and then transmitted in independent units along the data path. Intermediate systems, sometimes called "routers", stationed between the communicating end-systems make decisions about the most appropriate route to take on a per packet basis. Routing decisions are based on a number of characteristics, including: least-cost route or cost metric; capacity of the link; number of packets waiting for transmission; security requirements for the link; and intermediate system (node) operational status.

Packet transmission along a route that takes into consideration path metrics, as opposed to a single circuit set up, offers application and communications flexibility. It is also how most standard local area networks (LANs) and wide area networks (WANs) have evolved in the corporate environment. Packet switching is appropriate for data communications because many of the applications and devices used, such as keyboard terminals, are interactive and transmit data in bursts. Instead of a channel being idle while a user inputs more data into the terminal or pauses to think about a problem, packet switching interleaves multiple transmissions from several terminals onto the channel.

Packet data provides more network robustness due to path independence and the routers' ability to select alternative paths in the event of network node failure. Packet switching, therefore, allows for more efficient use of the network lines. Packet technology offers the option of billing the end user based on amount of data transmitted instead of connection time. If the end user's application has been designed to make efficient use of the air link, then the number of packets transmitted will be minimal. If each individual user's traffic is held to a minimum, then the service provider has effectively increased network capacity.

Packet networks are usually designed and based on industry-wide data standards such as the open system interface (OSI) model or the TCP/IP protocol stack. These standards have been developed, whether formally or de facto, for many years, and the applications that use these protocols are readily available. The main objective of standards-based networks is to achieve interconnectivity with other networks. The Internet is today's most obvious example of such a standards-based network pursuit of this goal.

Packet networks, like the Internet or a corporate LAN, are integral parts of today's business and communications environments. As mobile computing becomes pervasive in these environments, wireless service providers such as those using TIA/EIA/IS-136 are best positioned to provide access to these networks. Nevertheless, the data services provided by or proposed for cellular systems are generally based on the circuit-switched mode of operation, using a dedicated radio channel for each active mobile user.

A few exceptions to data services for cellular systems based on the circuit-switched mode of operation are described in the following documents, which include the packet data concepts.

U.S. Patent No. 4,887,265 and "Packet Switching in Digital Cellular Systems", Proc. 38th IEEE Vehicular Technology Conf., pp. 414-418 (June 1988) describe a cellular system providing shared packet data radio channels, each one capable of accommodating multiple data calls. A mobile station requesting packet data service is assigned to a particular packet data channel using essentially regular cellular signalling. The system may include packet access points (PAPS) for interfacing with packet data networks. Each packet data radio channel is connected to one particular PAP and is thus capable of multiplexing data calls associated with that PAP. Handovers are initiated by the system in a manner that is largely similar to the handover used in the same system for voice calls. A new type of handover is added for those situations when the capacity of a packet channel is insufficient.

These documents are data-call oriented and based on using system-initiated handover in a similar way as for regular voice calls. Applying these principles for providing general purpose packet data services in a TDMA cellular system would result in spectrum-efficiency and performance disadvantages.

U.S. Patent No. 4,916,691 describes a new packet mode cellular radio system architecture and a new procedure for routing (voice and/or data) packets to a mobile station. Base stations, public switches via trunk interface units, and a cellular control unit are linked together via a WAN. The routing procedure is based on mobile-station-initiated handovers and on adding to the header of any packet transmitted from a mobile station (during a call) an identifier of the base station through which the packet passes. In case of an extended period of time between subsequent user information packets from a mobile station, the mobile station may transmit extra control packets for the purpose of conveying cell location information.

The cellular control unit is primarily involved at call establishment, when it assigns to the call a call control number. It then notifies the mobile station of the call control number and the trunk interface unit of the call control number and the identifier of the initial base station. During a call, packets are then routed directly between the trunk interface unit and the currently serving base station.

The system described in U.S. Patent No. 4,916,691 is not directly related to the specific problems of providing packet data services in TDMA cellular systems.

"Packet Radio in GSM", European Telecommunications Standards Institute (ETSI) T Doc SMG 4 58/93 (Feb. 12, 1993) and "A General Packet Radio Service Proposed for GSM" presented during a seminar entitled "GSM in a Future Competitive Environment", Helsinki, Finland (Oct. 13, 1993) outline a possible packet access protocol for voice and data in GSM. These documents directly relate to TDMA cellular systems, i.e., GSM, and although they outline a possible organization of an optimized shared packet data channel, they do not deal with the aspects of integrating packet data channels in a total system solution.

"Packet Data over GSM Network", T Doc SMG 1 238/93, ETSI (Sept. 28, 1993) describes a concept of providing packet data services in GSM based on first using regular GSM signalling and authentication to establish a virtual channel between a packet mobile station and an "agent" handling access to packet data services. With regular signalling modified for fast channel setup and release, regular traffic channels are then used for packet transfer. This document directly relates to TDMA cellular systems, but since the concept is based on using a "fast switching" version of existing GSM traffic channels, it has disadvantages in terms of spectrum efficiency and packet transfer delays (especially for short messages) compared to a concept based on optimized shared packet data channels.

Cellular Digital Packet Data (CDPD) System Specification, Release 1.0 (July 1993), which is expressly incorporated herein by reference, describes a concept for providing packet data services that utilizes available radio channels on current Advanced Mobile Phone Service (AMPS) systems, i.e., the North American analog cellular system. CDPD is a comprehensive, open specification endorsed by a group of U.S. cellular operators. Items covered include external interfaces, air link interfaces, services, network architecture, network management, and administration.

The specified CDPD system is to a large extent based on an infrastructure that is independent of the existing AMPS infrastructure. Commonalities with AMPS systems are limited to utilization of the same type of radio frequency channels and the same base station sites (the base station used by CDPD may be new and CDPD specific) and employment of a signalling interface for coordinating channel assignments between the two systems.

Routing a packet to a mobile station is based on, first, routing the packet to a home network node (home Mobile Data Intermediate System, MD-IS) equipped with a home location register (HLR) based on the mobile station address; then, when necessary, routing the packet to a visited, serving MD-IS based on HLR information; and finally transferring the packet from the serving MD-IS via the current base station, based on the mobile station reporting its cell location to its serving MD-IS.

Although the CDPD System Specification is not directly related to the specific problems of providing packet data services in TDMA cellular systems that are addressed by this application, the network aspects and concepts described in the CDPD System Specification can be used as a basis for the network aspects needed for an air link protocol in accordance with this invention.

The CDPD network is designed to be an extension of existing data communications networks and the AMPS cellular network. Existing connectionless network protocols may be used to access the CDPD network. Since the network is always considered to be evolving, it uses an open network design that allows the addition of new network layer protocols when appropriate. The CDPD network services and protocols are limited to the Network Layer of the OSI model and below. Doing so allows upper-layer protocols and applications development without changing the underlying CDPD network.

From the mobile subscriber's perspective, the CDPD network is a wireless mobile extension of traditional networks, both data and voice. By using a CDPD service provider network's service, the subscriber is able to seamlessly access data applications, many of which may reside on traditional data networks. The CDPD system may be viewed as two interrelated service sets: CDPD network support services and CDPD network services.

CDPD network support services perform duties necessary to maintain and administer the CDPD network. These services are: accounting server; network management system; message transfer server; and authentication server. These services are defined to permit interoperability among service providers. As the CDPD network evolves technically beyond its original AMPS infrastructure, it is anticipated that the network support services shall remain unchanged. The functions of network support services are necessary for any mobile network and are independent of radio frequency (RF) technology.

CDPD network services are data transfer services that allow subscribers to communicate with data applications. Additionally, one or both ends of the data communications may be mobile.

To summarize, there is a need for a system providing general purpose packet data services in D-AMPS cellular systems, based on providing shared packet-data channels optimized for packet data. This application is directed to systems and methods that provide the combined advantages of a connection-oriented network like that specified by the TIA/EIA/IS-136 standard and a connectionless, packet data network.

One important aspect in such systems is the allocation of channels or bandwidth. One example of such channel allocation for IS-136 is mobile assisted channel allocation (MACA). In IS-136, a MACA report is received before assigning the traffic channel with requirements for mobile station transmission of MACA reports typically sent on the broadcast control channel (BCCH). For example, parameters used in making contention- or reservation-based access attempts may be sent in an access parameter message on the fast BCCH. Examples of such IS-136 random access parameters include maximum busy/reserved information, maximum retries information, maximum repetitions information, and a maximum stop counter. Since MACA reports are used before assigning traffic channels, MACA does not provide any information after the mobile station accesses the system.

Another important aspect of cellular telephone communication systems is equalization which is used to compensate for irregularities or deficiencies in the radio medium. An equalizer is primarily used in receiving circuits for the purpose of reducing the effects of multipath propagation and, in a cellular system, the effects of relative motion between the transmitter and receiver. This is described, for instance, in WO 88/05981, which relates to a TDMA system which includes so-called adaptive equalization. The setting of the equalizer incorporated in the radio receiver is contingent on synchronizing words that are time multiplexed with data words transmitted from the radio transmitter. With the aid of these synchronizing words, the equalizer can be set so as to compensate for the dispersion properties of the medium. Radio receivers which include equalizers are often used for high symbol rate communication (>100 kbit/s), where the bit sensitivity to multipath propagation is greater than the bit sensitivity of lower symbol rate communication. One disadvantage of using equalizers is that they increase a receiver's complexity and power consumption.

The absence of an equalizer affords the advantage of enabling noncoherent demodulation to be applied, which results in a lower degree of complexity in the receiver and a lower current consumption. In addition, a robust receiver is obtained with rapidly varying radio channels, due to high vehicle speeds. The disadvantage lies in the fact that the demodulation cannot be carried out with time dispersion, which constitutes a considerable part of the symbol time.

SUMMARY

According to exemplary embodiments of this invention, a method for improving the allocation of channels in a communication system is disclosed. During an access on a control channel, a mobile station sends an activity report to the system containing various measurements which indicate how the mobile station is currently perceiving the control channel. These measurements can then be used when assigning the mobile station a non-control channel. In addition, the system can use the activity report to determine if any of a plurality of random access parameters need to be changed.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of Applicants' invention will be understood by reading this description in conjunction with the drawings in which:

FIG. 1 schematically illustrates pluralities of Layer 3 messages, Layer 2 frames, and Layer 1 channel bursts, or time slots;

FIG. 2(a) shows a forward DCC configured as a succession of time slots included in the consecutive time slots sent on a carrier frequency;

FIG. 2(b) shows an example of an IS-136 DCCH field slot format;

FIG. 3 illustrates an exemplary hierarchical, or multi-layered, cellular system;

FIG. 4 is a block diagram of an exemplary cellular mobile radiotelephone system, including an exemplary base station and mobile station;

FIG. 5 illustrates one example of a possible mapping sequence;

FIG. 6 illustrates an example of PDCH reassignment;

FIG. 7 illustrates the RPDCH subchannels that are used in a full-rate PDCH; and

FIG. 8 illustrates an example of a dialogue between a mobile station and a communication system.

DETAILED DESCRIPTION

To aid in the understanding of the present invention, a description for one possible mapping sequence is illustrated in FIG. 5. It will be apparent to one skilled in the art that the present invention is not limited to this mapping sequence but also applies to other mapping sequences as well. FIG. 5 shows a dedicated packet digital control channel (PDCH) example of how one L3 message is mapped into several Layer 2 frames, an example of a Layer 2 frame mapping onto a time slot, and an example of time slot mapping onto a PDCH channel. The length of the forward packet digital control channel (FPDCH) time slots and reverse packet digital control channel (RPDCH) bursts are fixed, although there are three forms of RPDCH bursts which have different fixed lengths. The FPDCH time slots are assumed to be on the physical layer in FIG. 5. In the present invention, the TDMA frame structure is the same as for IS-136 DCCH and DTC. In the interest of maximal throughput when a multi-rate transmission is used (double rate PDCH and triple rate PDCH), an additional FPDCH slot format is specified.

The digital control channel (DCCH) of IS-136 is used to indicate PDCH operation. FIG. 6 illustrates the relationship between PDCH's belonging to one cell (or more specifically, having a common mother DCCH) and DCCH's in different cells (more specifically, indicated in the DCCH neighboring list as candidates for DCCH reselection). A mobile station always first goes to a DCCH (Mother DCCH) at initial cell selection. On the DCCH, the support for PDCH is indicated. If the DCCH indicates support for one or more dedicated PDCH's, the carrier frequency of one PDCH (beacon PDCH) is provided. A mobile station interested in packet data service then tunes to the Beacon PDCH and reads additional BCCH information to determine if a plurality of PDCHs exist. If more than one PDCH exists in the current service area a mobile station will select one as its Assigned PDCH according to a hashing algorithm. If the Beacon PDCH is the only PDCH in the current service area it becomes the mobile station's Assigned PDCH. After determining its Assigned PDCH a mobile station reads a full cycle of fast packet BCCH (F-PBCCH) and extended packet BCCH (E-PBCCH) information on its Assigned PDCH. The mobile station then registers, if necessary, on its Assigned RPDCH according to PDCH mobility management rules. A PDCH registration may result in the mobile station being directed to an alternate Assigned PDCH or maintaining its current Assigned PDCH. At this point the mobile station is activated for packet data service on its Assigned PDCH in addition to potentially being activated for cellular service on its Mother DCCH.

In prior communication systems, a mobile station makes a request for a call on a control channel and is then assigned to a traffic channel. In some systems, the mobile station sends the system an activity report which contains measurements of other frequencies, field strength of other channels, etc. The system can then use this information to decide which channel the mobile station should be assigned to. Thus, the activity report is sent prior to the intended communication, i.e., the traffic channel communication.

According to the present invention, the mobile station can further help the channel allocation process of the system by transmitting an activity report regarding the communication on the control communication channel, e.g., DCCH in IS-136, or a packet data channel. The activity report goes beyond the information provided according to mobile assisted channel allocation report disclosed in IS-136. In this invention, as the mobile station is communicating with the system on the control channel, the mobile station sends information to the system regarding the accessing of the system, e.g., how the mobile station actually perceives the control channel during the process of a system access. By reporting this information to the system, the system can adjust certain parameters or increase the bandwidth of the control channel to reduce the degree of difficulty in accessing the system when mobile stations are having a lot of access problems.

The system can be configured so that the mobile station sends an activity report at every access of the control channel. In the alternative, an indication can be provided in a message from the system to the mobile station which indicates when, i.e., in conjunction with certain accesses, the activity report should be sent. For example, a bit or a plurality of bits sent on the BCCH could indicate when an activity report should be attached to origination or registration accesses.

As will be explained below, several random access parameters can be tracked in a plurality of counters which get incremented and possibly decremented depending upon the various situations which arise in an access attempt. A mobile station may encounter numerous access failures. Some failures may be hard failures wherein the transmission must be restarted from the beginning and some failures may be soft failures wherein a random delay is introduced before the next transmission. After a hard failure, the mobile station includes all of the values of random access counters at the time of the hard failure in the activity report of the next access. If the mobile station experiences several hard failures in a row before gaining access, the mobile station may include the values of the counters at the time of each hard failure in the activity report. The counter values could be included in the activity report as a vector.

An example of an access procedure is described below. It will be appreciated that this invention is not limited to this described access procedure but rather can apply to various access procedures. The following description illustrates examples of when the random access parameter counters get incremented. Some of the random access parameters are summarized in Table 1 below.

Table 1 - Random Access Parameters

BCCH Parameter Names	Range of Parameters
Max Busy/Reserved	0, 1
Max Retries	0 - 7
Max Repetitions	0 - 3
Max Stop Counter	0, 1

A mobile station can attempt to make an access on either a contention or reservation basis. An access is only attempted after a mobile station has read the Access Parameters message on the F-PBCCH. For any given access, a mobile station is allowed a maximum of Max Retries + 1 access attempts before declaring the access to have failed. A given access attempt is considered to have failed if the mobile station does not decode BRI as Idle after one attempt (Max Busy/ Reserved = 0) or 10 attempts (Max Busy/Reserved = 1) or the mobile station does not find a PE match along with R/N = Received after sending the first burst of a contention based access attempt. In addition, the access attempt is considered to have failed if the mobile station does not successfully send any given burst after Max Repetitions repeated transmissions of that burst, or the mobile station detects a total of Max Stop Counter + 1 consecutive occurrences of any of the PCF conditions that result in Stop_ctr being incremented.

After failing its initial access attempt a mobile station proceeds in the following manner. If Max Retries = 0, the mobile station considers the access to have failed. If Max Retries = 1, the mobile station applies a uniformly distributed first random delay with a granularity of 1 TDMA block before making its next access attempt. If Max Retries > 1, the mobile station applies a uniformly distributed second random delay with a granularity of 1 TDMA block before making its second access attempt. IF Max Retries > 1, the mobile station applies a uniformly distributed third random delay with a granularity of 1 TDMA block before making its third or later access attempt.

If a mobile station attempts a random access in order to send a Page Response as a result of receiving a Triple Page Frame or a Variable Page Frame with a matching MSID the mobile station first applies a uniformly distributed random delay, which is dependent on the channel rate, with a granularity of 1 TDMA block before looking for BRI = Idle.

If a mobile station attempts a random access for any other reason and P_overload_status is set, the mobile station first applies a uniformly distributed random delay with a granularity of 1 TDMA block before looking for BRI = Idle. A mobile station then looks for BRI = Idle on all FPDCH slots of its current PDCH that it decides to read according to its bandwidth preference. After failing to read BRI = Idle during any given access attempt, a mobile station determines whether or not to continue its current access attempt based on Max Busy/Reserved. If the mobile station continues it current access attempt, it applies a uniformly distributed random delay with a granularity of 1 TDMA block before once again looking for BRI = Idle.

Upon finding a FPDCH slot with BRI = Idle, a mobile station sends the first burst of its access attempt using the corresponding RPDCH subchannel. The mobile station then reads the PCF corresponding to its first transmitted burst and respond to the received PE value in the following manner. If a PE match does not occur, the mobile station considers the access attempt to have failed, increments Rtr_ctr and then determines whether or not to make another access attempt based on Max Retries. If a PE match occurs and there are no more bursts to send, the mobile station proceeds according to Table 2, below. If a PE match occurs and there are more bursts to send, the mobile station proceeds according to Table 3, below.

Table 2 Random Access - No More Bursts

BRI	R/N	PEQ	Mobile Station Response
X	R	X	Declare an access success and enter the Idle state.
X	N	X	Declare an access attempt failure and then increment Rtr_ctr to determine whether or not to declare an access failure.

Table 3 Random Access - More Bursts

BRI	R/N	PEQ	Mobile Station Response
B	R	RSVD or INT_2	Declare an access attempt failure and then increment Rtr_ctr to determine whether not to declare an access failure.
B	R	INT_1	Relinquish ownership of the RPDCH subchannel corresponding to the current PCF, increment Burst_ctr, set Rep_ctr = 0 and Stop_ctr = 0, enter the More Bursts state and invoke the More Bursts procedure.
B	R	NO_INT	Maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule transmission of next burst, increment Burst_ctr, set REP_ctr = 0 and Stop_ctr = o, enter the More Bursts state and invoke the More Bursts procedure.
B	N	X	Declare an access attempt failure and then increment Rtr_ctr to determine whether or not to declare an access failure.
R,I	X	X	Declare an access attempt failure and then increment Rtr_ctr to determine whether or not to declare an access failure.

When soliciting a reservation based access, the specific FPDCH slot selected by the communication system for sending CPE and BRI information is completely independent of which RPDCH subchannel the mobile station may have previously used. A mobile station in this state as a result of responding to PRM=1 shall immediately begin looking at FPDCH slots selected for examination according to its bandwidth preference in an effort to find a PE match. A mobile station in this state as a result of receiving an ARQ Mode BEGIN or ARQ Mode CONTINUE frame shall, beginning with the FPDCH slot in which it received the ARQ frame, begin looking at FPDCH slots selected for examination according to its bandwidth preference, in an effort to find a PE match.

If the mobile station does not find a PE match along with BRI = Reserved within 8 TDMA blocks when attempting to send an ARQ STATUS frame on a reservation basis, the mobile station enters the Start Random Access state and invokes the Start Random Access procedure. If the mobile station does not find a PE match along with BRI = Reserved within 32 TDMA blocks when attempting to start sending a layer 3 message on a reservation basis, the mobile station enters the Start Random Access state and invokes the Start Random Access procedure. If the mobile station finds a PE match along with the BRI = Reserved within the expected timeframe, the mobile station sends the first burst of its access attempt using the next occurrence of the RPDCH subchannel corresponding to FPDCH slot in which the PE match and BRI = Reserved were detected.

The mobile station then reads the PCF corresponding to its first transmitted burst. If there are no more bursts to send the mobile station proceeds according to Table 4 based upon the specific PCF information. If there are more bursts to send, the mobile station proceeds according to Table 5 based upon the specific PCF information.

Table 4 Reserved Access - No More Bursts

BRI	R/N	PEQ	Mobile Station Response
X	R	X	Declare an access success and enter the Idle state.
B	N	X	Increment Rep_ctr and determine whether or not to continue the current access attempt based on Max Repetitions. If Rep_ctr ≤ Max Repetitions the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, reschedule the transmission of its current burst accordingly and set Stop-ctr = 0. If Rep_ctr > Max Repetitions the mobile station declares an access attempt failure and increments Rtr_ctr to determine whether or not to declare an access failure.
R,I	N	X	Declare an access attempt failure and then increment Rtr_ctr to determine whether or not to declare an access failure.

Table 5 - Reserved Access- More Bursts

BRI	R/N	PEQ	Mobile Station Response
B	R	X	Maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of its next burst accordingly, increment Burst_ctr, set Rep_ctr = 0 and Stop_ctr = 0, enter the More Bursts state and invoke the More Bursts procedure.
R	R	INT_2	Relinquish ownership of the RPDCH subchannel corresponding to the current PCF, Burst_ctr, enter the More Bursts state and invoke the More Bursts procedure.
R	R	RSVD INT_1 or NO_INT	Declare an access attempt failure and increment Rtr_ctr to determine whether or not to declare an access failure.
B	N	X	Increment Rep_ctr and determine whether or not to continue its current access attempt based on Max Repetitions. If Rep_ctr ≤ Max Repetitions the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, reschedule the transmission of its current burst accordingly, set Stop_ctr = 0, enter the More Bursts state and invoke the More Bursts procedure. If Rep_ctr > Max Repetitions the mobile station declares an access attempt failure and increments Rtr_ctr to determine whether or not to declare an access failure.
R	N	INT_2	Increment Rep_ctr and determine whether or not to continue the current access attempt based on Max Repetitions. If Rep_ctr ≤ Max Repetitions the mobile station shall relinquish ownership of the RPDCH subchannel corresponding to the current PCF, set Stop_ctr = 0, enter the More Bursts state and invoke the More Bursts procedure. If Rep_ctr > Max Repetitions the mobile station declares an access attempt failure and increment Rtr_ctr to determine whether or not to declare an access failure.
R	N	RSVD INT_1 or NO_INT	Declare an access failure and increment Rtr_ctr to determine whether or not to declare an access failure.
I	X	X	Declare an access attempt failure and increment Rtr_ctr to determine whether or not to declare an access failure.

After transmitting the first burst of its access attempt and responding to its associated PCF according to Table 3 or Table 5, and more bursts need to be sent, a mobile station begins examining the FPDCH slots for all RPDCH subchannels on the

PDCH that it is capable of operating on. The mobile station starts examining the PCF of these additional FPDCH slots immediately after reading the FPDCH slot containing the PCF corresponding to its first transmitted burst. The mobile station responds to PCF information read in these additional FPDCH slots in the following manner. Upon reading a FPDCH slot for a currently assigned RPDCH subchannel carrying PCF information for a previously transmitted burst, a mobile station responds as indicated in Table 6 based upon the specific PCF information. Upon reading a FPDCH slot for a currently unassigned RPDCH subchannel, a mobile station responds as indicated in Table 7 based upon the specific PCF information. A mobile station that has one or more bursts requiring transmission and that currently has no assigned RPDCH subchannels, considers its current access attempt to have failed if it does not receive a RPDCH subchannel assignment within 32 TDMA blocks of PCF examination.

Table 6 More Bursts - PCF for Assigned Subchannel

BRI	R/N	PEQ	Mobile Station Response
B	R	X	Maintain ownership of the RPDCH subchannel corresponding to the current PCF, increment Burst_ctr and schedule transmission of the next burst (if there is another) accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure.
R	R	INT_2	Relinquish ownership of the RPDCH subchannel corresponding to the current PCF and increment Burst_ctr.
R	R	RSVD INT_1 or NO_INT	Increment Stop_ctr and Rep_ctr, and then determine whether or not to continue its current access attempt based on Max Stop Counter and Max Repetitions. If Stop_ctr ≤ Max Stop Counter and Rep_ctr ≤ Max Repetitions, the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF and reschedule the transmission of the current burst accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If Stop_ctr > Max Stop Counter or Rep_ctr > Max Repetitions, the mobile station declares an access attempt failure and increment Rtr_ctr to determine whether or not to declare an access failure. If Rtr_ctr ≤ Max Retries the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of the first burst of the next L3 message (if there is one) or the first burst of the current L3 message (if there are no additional L3 messages pending), and set Stop_ctr = 0 and Rep_ctr = 0. If Rtr_ctr > Max Retries the mobile station declares an access failure.
I	R	RSVD	Relinquish ownership of the RPDCH subchannel corresponding to the current PCF and increment Burst.ctr.

BRI	R/N	PEQ	Mobile Station Response
I	R	INT_1 INT_2 or NO_INT	Increment Stop_ctr and Rep_ctr, and then determine whether or not to continue its current access attempt based on Max Stop Counter and Max Repetitions. If Stop_ctr ≤ Max Stop Counter and Rep_ctr ≤ Max Repetitions, the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF and reschedule the transmission of the current burst accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If Stop_ctr > Max Stop Counter or Rep_ctr > Max Repetitions, the mobile station declares an access attempt failure and increment Rtr_ctr to determine whether or not to declare an access failure. If Rtr_ctr ≤ Max Retries the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of the first burst of the next L3 message (if three is one) or the first burst of the current L3 message (if there are no additional L3 messages pending), and set Stop_ctr = 0 and Rep_ctr = 0. If Rtr_ctr > Max Retries the mobile station declares an access failure.
B	N	X	Increment Rep_ctr and determine whether or not to continue its current access attempt based on Max Repetitions. If Rep_ctr ≤ Max Repetitions, the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF and reschedule the transmission of the current burst accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If Rep_ctr > Max Repetitions, the mobile station declares an access attempt failure and increment Rtr_ctr to determine whether or not to declare an access failure. If Rtr_ctr ≤ Max Retries the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of the first burst of the next L3 message (if three is one) or the first burst of the current L3 message (if there are no additional L3 messages pending), and set Stop_ctr = 0 and Rep_ctr = 0. If Rtr_ctr > Max Retries the mobile station declares an access failure.
R	N	INT_2	Relinquish ownership of RPDCH subchannel corresponding to the current PCF.

BRI	R/N	PEQ	Mobile Station Response
R	N	RSVD INT_1 or NO_INT	Increment Stop_ctr and Rep_ctr, and then determine whether or not to continue its current access attempt based on Max Stop Counter and Max Repetitions. If Stop_ctr ≤ Max Stop Counter and Rep_ctr ≤ Max Repetitions, the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF and reschedule the transmission of the current burst accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If Stop_ctr > Max Stop Counter or Rep_ctr > Max Repetitions, the mobile station declares an access attempt failure and increments Rtr_ctr to determine whether or not to declare an access failure. If Rtr_ctr ≤ Max Retries the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of the first burst of the next L3 message (if three is one) or the first burst of the current L3 message (if there are no additional L3 messages pending), and set Stop_ctr = 0 and Rep_ctr = 0. If Rtr_ctr > Max Retries the mobile station declares an access failure.
I	N	RSVD	Relinquish ownership of the RPDCH subchannel corresponding to the current PCF.
I	N	INT_1 INT_2 or NO_INT	Increment Stop_ctr and Rep_ctr, and then determine whether or not to continue its current access attempt based on Max Stop Counter and Rep_ctr ≤ Max Repetitions, the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF and reschedule the transmission of the current burst accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If Stop_ctr > Max Stop Counter or Rep_ctr > Max Repetitions, the mobile station declares an access attempt failure and increments Rtr_ctr to determine whether or not to declare an access failure. If Rtr_ctr ≤ Max Retries the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of the first burst of the next L3 message (if three is one) or the first burst of the current L3 message (if there are no additional L3 messages pending), and set Stop_ctr = 0 and Rep_ctr = 0. If Rtr_ctr > Max Retries the mobile station declares an access failure.

Table 7 More Bursts - PCF For Unassigned Subchannel

BRI	R/N	PEQ	Mobile Station Response
B	X	INT_1	If a mobile station receives these PCF values in the first FPDCH slot (master or slave) following the FPDCH slot used to carry the PCF for the first burst of its current access attempt, it shall require the RPDCH subchannel corresponding to the current PCF and schedule the transmission of the next burst (if there is another) accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure.
B	X	INT_2 or NO_INT	Ignore the FPDCH subchannel corresponding to the current PCF.
R	X	INT_2	A mobile station rends the PE received in the current FPDCH slot. If a PE match does not occurs, it shall acquire the RPDCH subchannel corresponding to the current PCF and schedule the transmission of the next burst (if there is another) accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If a PE match does not occur the mobile station shall ignore the RPDCH subchannel corresponding to the current PCF.
R	X	RSVD INT_1 or NO_INT	Ignore the RPDCH subchannel corresponding to the current PCF.
I	X	X	Ignore the RPDCH subchannel corresponding to the current PCF.

After sending or resending the last burst of its access attempt, a mobile station waits for PCF feedback for its outstanding burst transmissions on all RPDCH subchannels it currently considers as assigned to it. Upon receiving PCF feedback on any of its assigned subchannels the mobile station responds according to Table 8.

Table 8 - After Last Burst - PCF For Assigned Subchannel

BRI	R/N	PEQ	Mobile Station Response
X	R	X	If all outstanding burst transmission have been confirmed as received according to PCF feedback, the mobile station shall declare an access success. Otherwise, the mobile station shall remain in the After Last Burst state.
B	N	X	Increment Rep_ctr and determine whether or not to continue its current access attempt based on Max Repetitions. If Rep_ctr ≤ Max Repetitions, the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF and reschedule the transmission of the current burst accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If Rep_ctr > Max Repetitions, the mobile station declares an access attempt failure and increment Rtr_ctr to determine whether or not to declare an access failure. If Rtr_ctr ≤ Max Retries the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of the first burst of the first burst of the current L3 message, and set Stop_ctr = 0 and Rep_ctr = 0. If Rtr_ctr > Max Retries the mobile station declares an access failure.
R	N	INT_2	Relinquish ownership of the RPDCH subchannel corresponding to the current PCF.
R	N	RSVD INT_1 or NO_INT	Increment Stop_ctr and Rep_ctr, and then determine whether or not to continue its current access attempt based on Max Stop Counter and Max Repetitions. If Stop_ctr ≤ Max Stop Counter and Rep_ctr ≤ Max Repetitions, the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF and reschedule the transmission of the current burst accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If Stop_ctr > Max Stop Counter or Rep_ctr > Max Repetitions, the mobile station declares an access attempt failure and increments Rtr_ctr to determine whether or not to declare an access failure. If Rtr_ctr ≤ Max Retries the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of the first burst of the current L3 message, and set Stop_ctr = 0 and Rep_ctr = 0. If Rtr_ctr > Max Retries the mobile station declares an access failure.

BRI	R/N	PEQ	Mobile Station Response
I	N	RSVD	Relinquish ownership of the RPDCH subchannel corresponding to the current PCF.
I	N	INT_1 INT_2 or NO_INT	Increment Stop_ctr and Rep_ctr, and then determine whether or not to continue its current access attempt based on Max Stop Counter and Max Repetitions. If Stop_ctr ≤ Max Stop Counter and Rep_ctr ≤ Max Repetitions, the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF and reschedule the transmission of the current burst accordingly. Upon sending the last burst of its access attempt a mobile station shall enter the After Last Burst state and invoke the After Last Burst procedure. If Stop_ctr > Max Stop Counter or Rep_ctr > Max Repetitions, the mobile station declares an access attempt failure and increments Rtr_ctr to determine whether or not to declare an access failure. If Rtr_ctr ≤ Max Retries the mobile station shall maintain ownership of the RPDCH subchannel corresponding to the current PCF, schedule the transmission of the first burst of the current L3 message, and set Stop_ctr = 0 and Rep_ctr = 0. If Rtr_ctr > Max Retries the mobile station declares an access failure.

If a mobile station decides to resend the last burst of its current access attempt, the mobile station immediately begins looking for its expected PARCH response starting with the next FPDCH slot, i.e., the FPDCH slot following the FPDCH slot from which it read PCF information that resulted in its decision to resend the last burst. If the mobile station receives its expected PARCH response prior to successfully resending its last burst, the mobile station considers the access attempt to be successfully completed. A mobile station that considers its access attempts to have failed (after attempting to resend the last burst) immediately stops looking for its expected PARCH response.

In a full-rate PDCH, the RPDCH bursts and the FPDCH slots are multiplexed so as to create three distinct access paths as illustrated in FIG. 7. Assuming that path 1 (P1) in the FPDCH indicates that the next P1 burst in the RPDCH is available, i.e., idle, and is selected for an access attempt, a mobile station sends the first burst of its access during the next instance of P1 on the RPDCH. The mobile station then begins reading the PCF flags in the next P1 FDCCH slot after completing transmission of its access burst to determine whether or not the communication system received the mobile station's initial burst.

FIG. 8 illustrates the relationship between FPDCH PCF flags and RPDCH bursts, wherein a mobile station makes a contention-based access and transmits a total of two bursts. The arrows show the order or events associated with the access attempt. Thus, following the arrows from left to right on RPDCH sub-channel P1, the BRI portion of the PCF flag first indicates the availability of the next P1 burst in the RPDCH. If a burst is transmitted in the RPDCH burst, then the mobile station reads the R/N portion of the PCF flags in the next P1 FPDCH slot to determine whether the communication system successfully received the mobile station's transmitted burst. For the first burst of a random access, the mobile station also reads the PE portion of the PCF flags to determine whether or not the mobile station's particular access was captured. The communication system sets the value of the PE flag to reflect the captured mobile station access, for example, the value of the PE flag can be set to reflect at least part of the mobile station's identification code. If the mobile station determines that it's access was captured based on the PE flag and that the R/N flag indicates that the burst was received, the mobile station proceeds to send any additional bursts it has pending beginning with the next P1 burst in the RPDCH.

As set forth above, the PCF flags provide information to a mobile station regarding when the mobile station is allowed to transmit, when the mobile station is requested to transmit, the reception status of a previously transmitted burst, and partial echo association. Since the PDCH channel may be a multi-rate channel (full-rate, double-rate, and triple-rate), many mobile stations may be operating on the channel using different rates. The PCF operation is the same for all mobile transmission rates. Thus, the multi-rate PDCH is not partitioned into dedicated bandwidth for full-rate, double rate, and triple rate transmissions.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A method for increasing the efficiency of a channel allocation process in a communication system, comprising the steps of:

attempting to access a control channel in said communication system;

measuring a plurality of access parameters during said attempt;

sending an activity report containing said measured access parameters to said system when an access attempt is successful, wherein said measured access parameters indicate the extent of access problems encountered by the mobile station.

2. A method according to claim 1, wherein said plurality of access parameters include at least one of: a number of non-idle BRI flags, a number of repeated bursts, a number of retries and a number of abnormal PCF conditions.

3. A method according to claim 1, further comprising the step of:

adjusting levels of access parameters to change the degree of difficulty in accessing the system.

4. A method according to claim 1, wherein said system adjusts the bandwidth of said control channel based upon said activity reports.

5. A method according to claim 1, wherein a value of said access parameters are kept in counters in said mobile station.

6. A method according to claim 1, wherein said counter values are included in the activity report as a vector.

7. A method according to claim 1, wherein an indication in a message from said system to said mobile station indicates when to send said activity report.

8. A method according to claim 6, wherein said indication is at least one bit.

9. A method according to claim 6, wherein said indication indicates that the activity report should be sent in origination accesses.

10. A method according to claim 6, wherein said indication indicates that the activity report should be sent in registration accesses.

11. A mobile station comprising:

means for attempting to access a control channel;

means for storing parameter values associated with failed attempts to access said control channel; and

means for reporting said stored parameters upon successful access.

12. The mobile station of claim 11, wherein said means for storing parameter values are counters.

13. The mobile station of claim 11, wherein said parameter values include a number of non-idle BRI flags.

14. The mobile station of claim 11, wherein said parameter values include a number of repeated bursts.

15. The mobile station of claim 11, wherein said parameter values include a number of retries.

16. The mobile station of claim 11, wherein said parameter values include a number of abnormal PCF conditions.

17. The mobile station of claim 11, wherein said means for reporting reports said parameter values after each access.

18. The mobile station of claim 11, wherein said means for reporting reports said parameter values on an as requested basis.

19. A base station comprising:

means for transmitting a control channel which provides access to a radiocommunication system;

means for receiving activity reports including parameter values associated with access attempts to said control channel; and

means for adjusting a parameter associated with said control channel based on said received parameter values.

20. The base station of claim 19, wherein said parameter values include a number of non-idle BRI flags.

21. The base station of claim 19, wherein said parameter values include a number of repeated bursts.

22. The base station of claim 19, wherein said parameter values include a number of retries.

23. The base station of claim 19, wherein said parameter values include a number of abnormal PCF conditions.

24. The base station of claim 19, wherein said means for adjusting a parameter adjusts a bandwidth associated with said control channel based on said received parameter values.

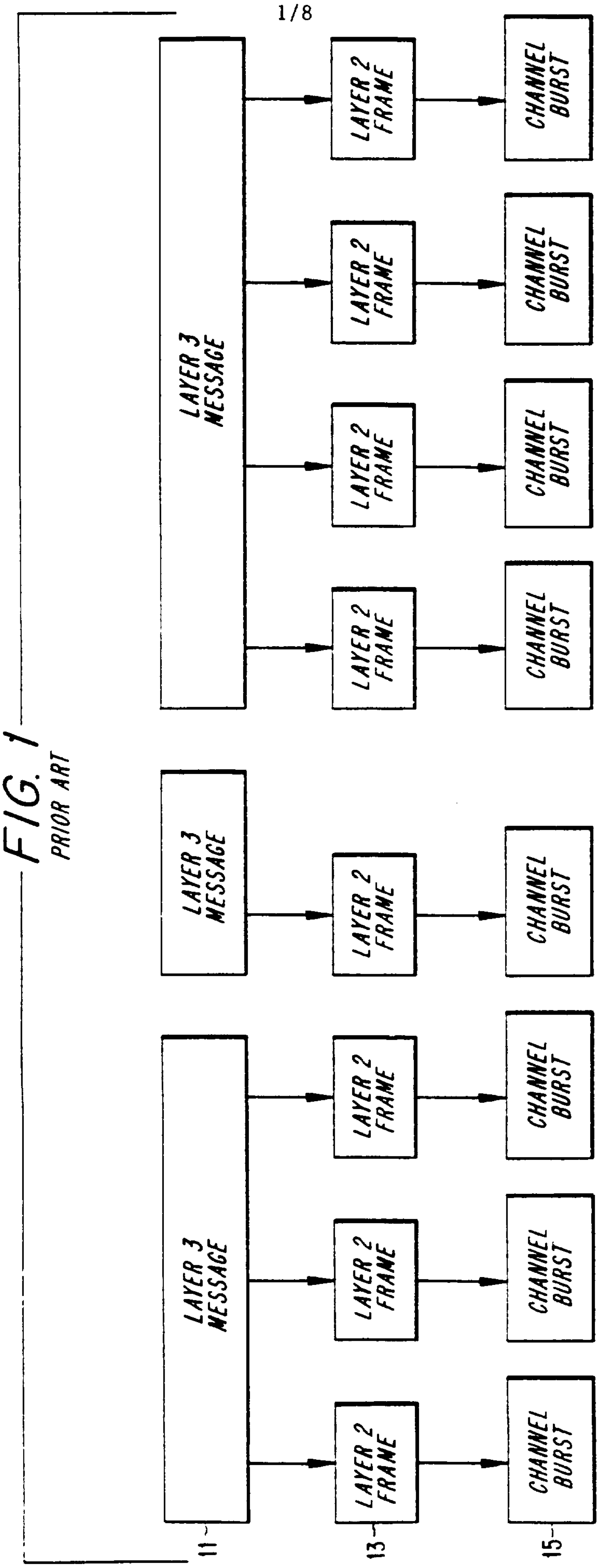


FIG. 1
PRIOR ART

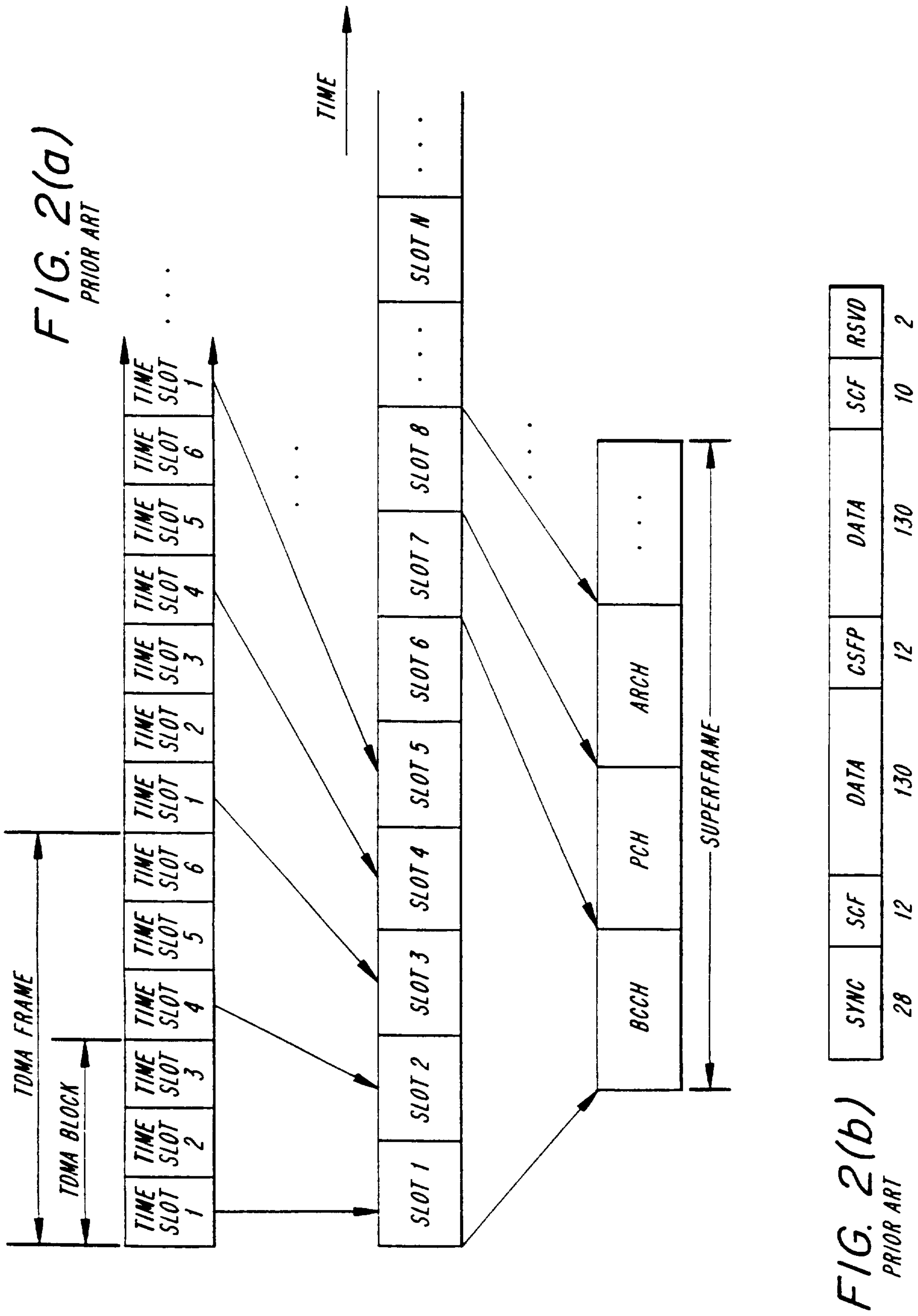


FIG. 2(a)
PRIOR ART

FIG. 2(b)
PRIOR ART

FIG. 3
PRIOR ART

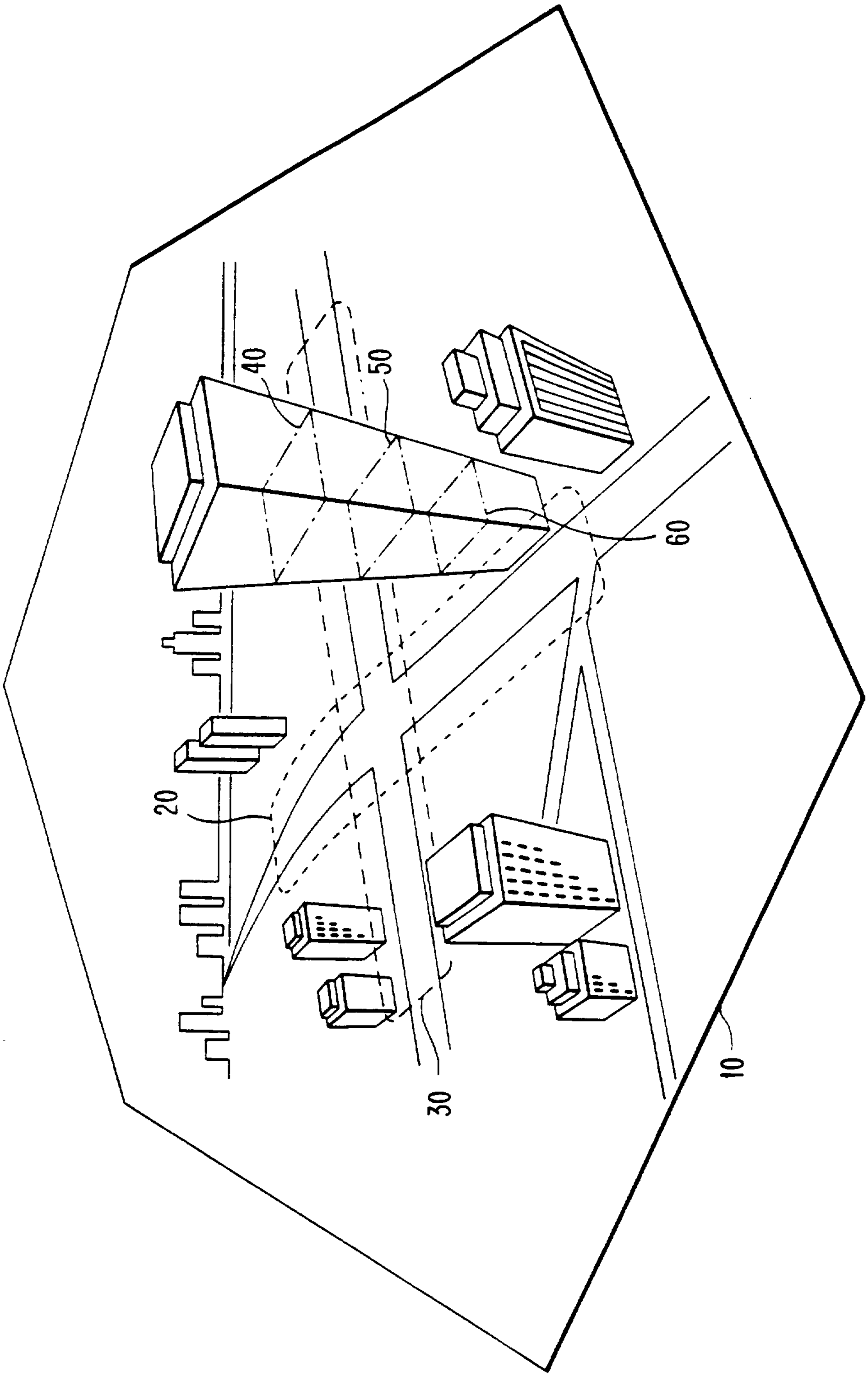
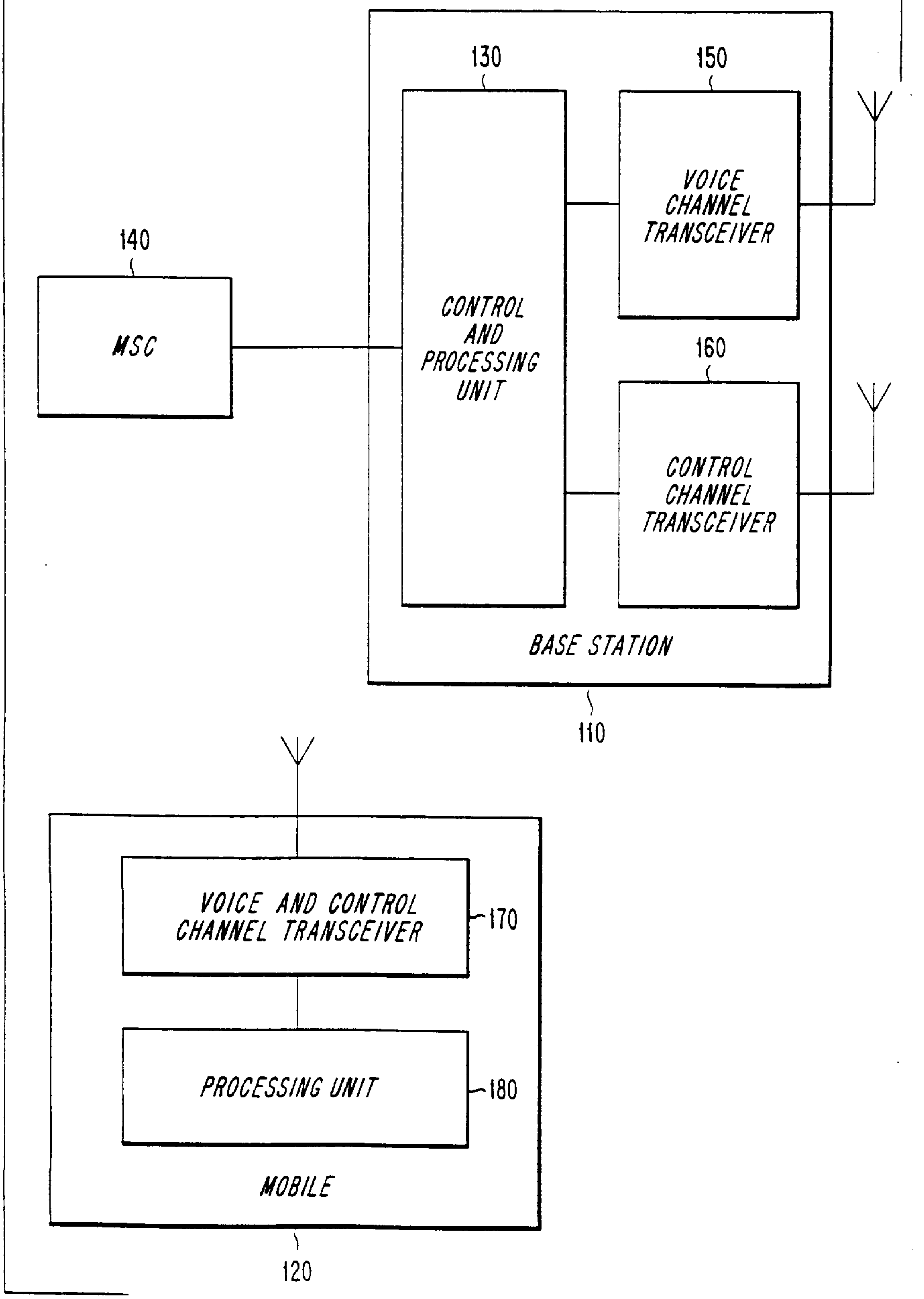


FIG. 4
PRIOR ART



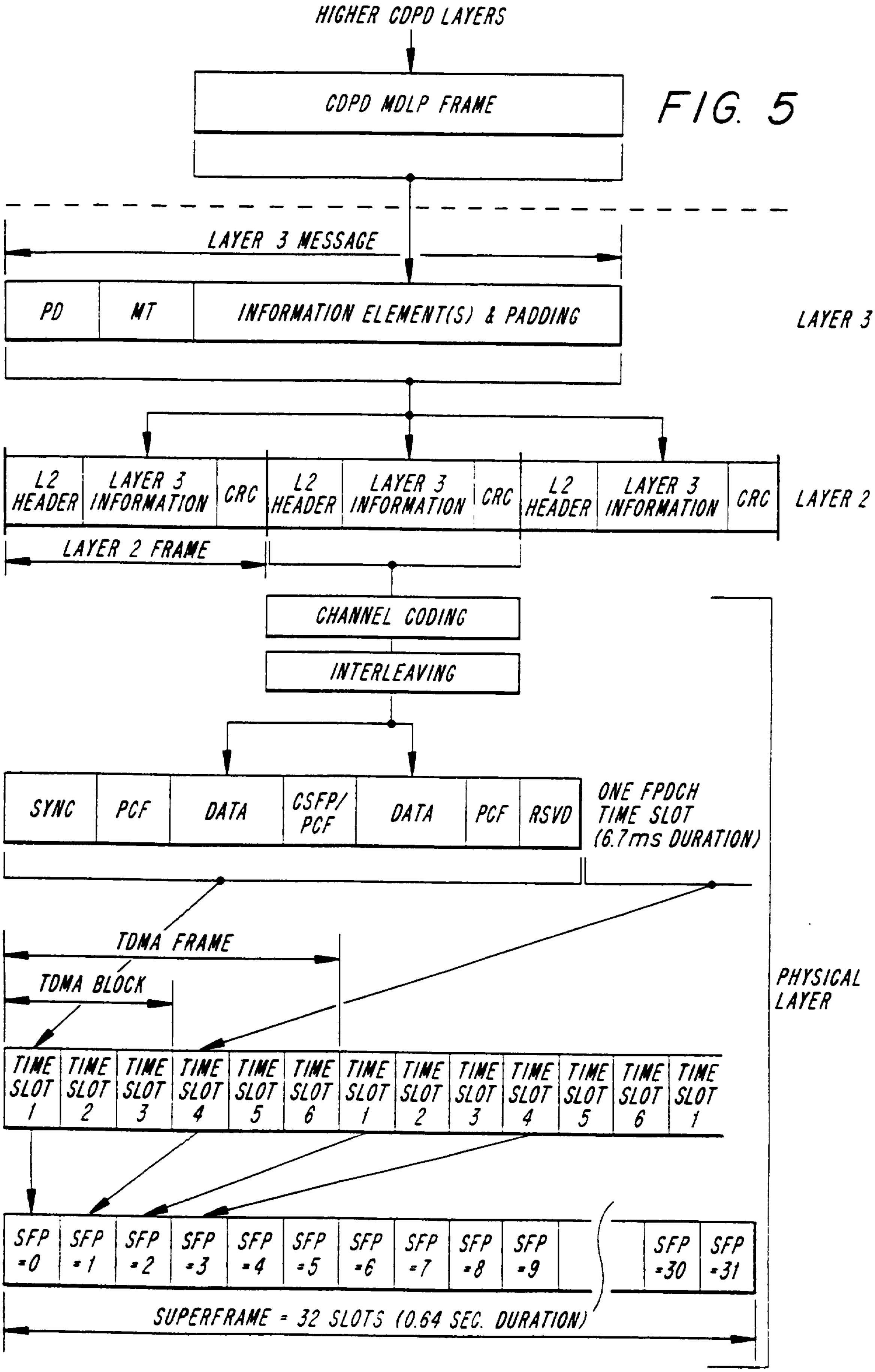
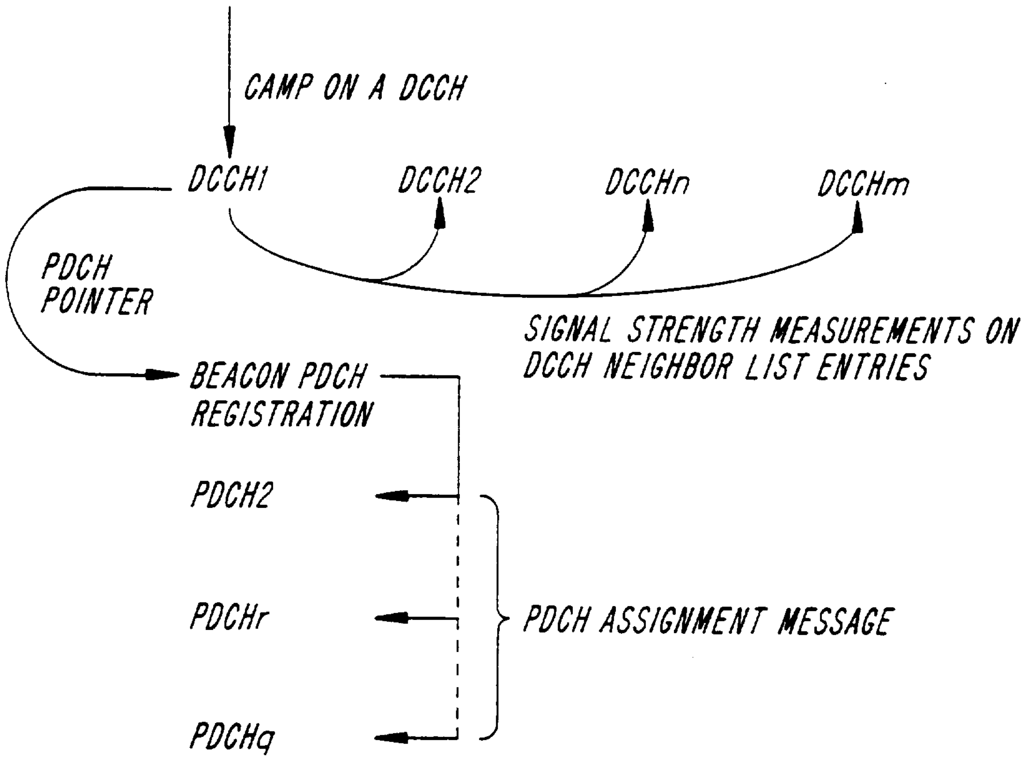

HIGHER CDPD LAYERS
CDPD MDLP FRAME
LAYER 3 MESSAGE
PD
MT
INFORMATION ELEMENT(S) & PADDING
LAYER 3
L2 HEADER
LAYER 3 INFORMATION
CRC
LAYER 2
LAYER 2 FRAME
CHANNEL CODING
INTERLEAVING
SYNC
PCF
DATA
CSFP/ PCF
RSVD
ONE FPDCH TIME SLOT (6.7ms DURATION)
TDMA FRAME
TDMA BLOCK
TIME SLOT 1
TIME SLOT 2
TIME SLOT 3
TIME SLOT 4
TIME SLOT 5
TIME SLOT 6
PHYSICAL LAYER
SFP =0
SFP =1
SFP =2
SFP =3
SFP =4
SFP =5
SFP =6
SFP =7
SFP =8
SFP =9
SFP =30
SFP =31
SUPERFRAME = 32 SLOTS (0.64 SEC. DURATION)

FIG. 5

FIG. 6


CAMP ON A DCCH
DCCH1
DCCH2
DCCHn
DCCHm
PDCH POINTER
SIGNAL STRENGTH MEASUREMENTS ON DCCH NEIGHBOR LIST ENTRIES
BEACON PDCH REGISTRATION
PDCH2
PDCHr
PDCHq
PDCH ASSIGNMENT MESSAGE

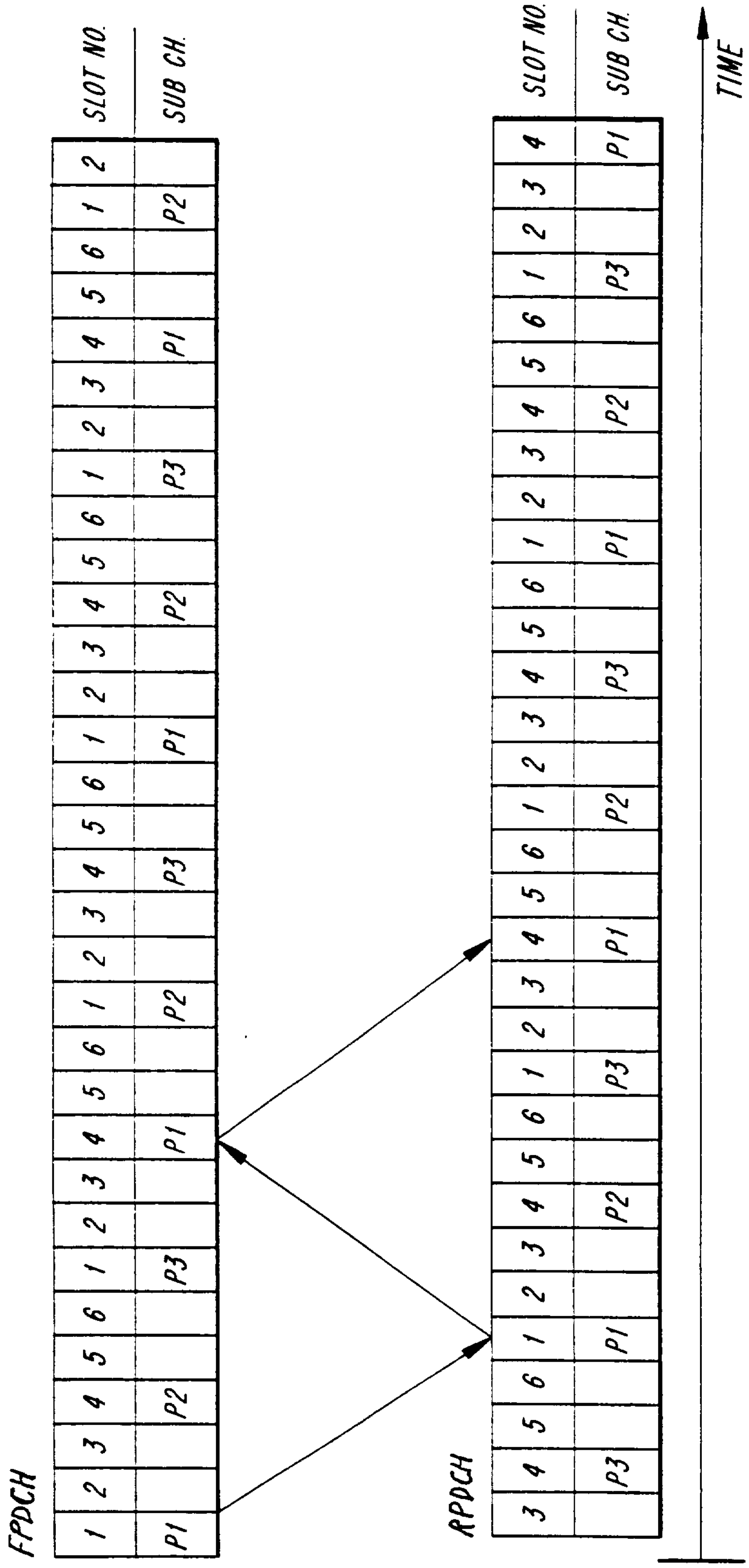
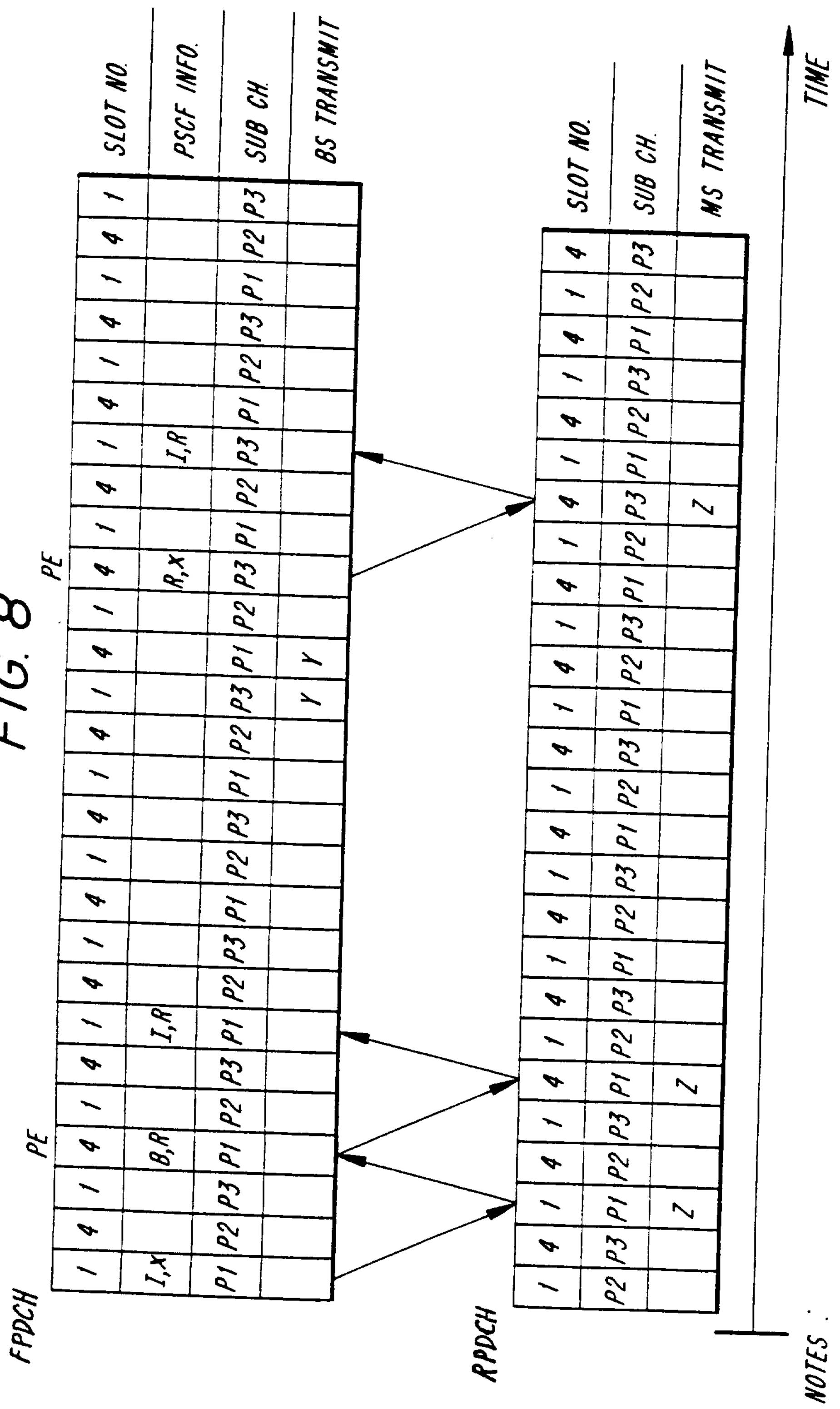


FIG. 7

FIG. 8



NOTES :

1. "X" MEANS "DON'T CARE".
2. "Z" MEANS "TRANSMIT OCCASIONS FOR THE MOBILE STATION".
3. "Y" MEANS "BASE STATION RESPONSE".
4. THE FIRST FIELD OF PCF INFO REPRESENTS THE BRI VALUE AND THE SECOND FIELD REPRESENTS THE R/N VALUE.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/16678

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/38 H04Q7/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 415 898 A (ERICSSON TELEFON AB L M) 6 March 1991 see column 4, line 30 - line 54 see column 5, line 30 - line 52 see column 6, line 14 - line 25 see column 8, line 30 - column 9, line 5 see column 11, line 55 - column 13, line 14 see column 18, line 47 - column 19, line 5 ---	1-4,19, 21,22,24
X	EP 0 594 458 A (NIPPON ELECTRIC CO) 27 April 1994	1,2,5,6, 11,12, 15,17
Y	see column 1, line 47 - column 2, line 33 see column 3, line 15 - line 41 see column 3, line 57 - column 4, line 37 see column 6, line 36 - column 9, line 13 ---	3

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
13 March 1997	20.03.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gerling, J.C.J.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/16678

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, vol. 42, no. 1, February 1993, NEW-YORK (US), pages 87-93, XP000363403 H. KAYAMA ET AL: "Adaptive Control for Random Access Traffic in Mobile Radio Systems"	19,22
Y	see page 87, right-hand column, line 4 - paragraph II. see page 89, left-hand column, paragraph III. - right-hand column, line 14 ---	3
A	EP 0 652 680 A (ERICSSON TELEFON AB L M) 10 May 1995 see page 24, line 30 - line 53 see page 38, line 1 - page 42, line 17 see page 59, line 28 - line 55 see page 82, line 1 - line 27 see page 41 ---	1,10,19
A	WO 94 10767 A (ERICSSON TELEFON AB L M) 11 May 1994 -----	

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 96/16678

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0415898 A	06-03-91	SE 464438 B	22-04-91
		AU 633148 B	21-01-93
		AU 6332790 A	03-04-91
		CA 2039162 A	26-02-91
		DE 69003915 D	18-11-93
		DE 69003915 T	10-02-94
		ES 2045892 T	16-01-94
		JP 4501497 T	12-03-92
		KR 9609456 B	19-07-96
		NO 177369 B	22-05-95
		SE 8902845 A	26-02-91
		WO 9103111 A	07-03-91
		US 5103445 A	07-04-92
EP 0594458 A	27-04-94	JP 6141362 A	20-05-94
		CA 2109169 A	24-04-94
		US 5412659 A	02-05-95
EP 0652680 A	10-05-95	US 5603081 A	11-02-97
		AU 1048095 A	23-05-95
		AU 1048395 A	23-05-95
		AU 1087495 A	23-05-95
		AU 1087695 A	23-05-95
		AU 7757094 A	18-05-95
		AU 8131394 A	23-05-95
		AU 8131494 A	23-05-95
		BR 9404316 A	04-07-95
		BR 9405702 A	28-11-95
		BR 9405703 A	28-11-95
		BR 9405704 A	28-11-95
		BR 9405705 A	28-11-95
		BR 9405743 A	05-12-95
		BR 9405927 A	05-12-95
		CA 2134695 A	02-05-95
		CA 2152942 A	11-05-95
		CA 2152943 A	11-05-95
		CA 2152944 A	11-05-95
		CA 2152945 A	11-05-95
		CA 2152946 A	11-05-95
		CA 2152947 A	11-05-95

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0652680 A		CN 1112345 A	22-11-95
		CN 1117329 A	21-02-96
		CN 1116888 A	14-02-96
		CN 1117330 A	21-02-96
		CN 1117331 A	21-02-96
		CN 1124074 A	05-06-96
		CN 1117332 A	21-02-96
		EP 0682829 A	22-11-95
		EP 0679304 A	02-11-95
		EP 0677222 A	18-10-95
		EP 0681766 A	15-11-95
		EP 0677223 A	18-10-95
		EP 0677224 A	18-10-95
		FI 953262 A	30-08-95
		FI 953263 A	30-06-95
		FI 953264 A	30-06-95
		FI 953265 A	30-06-95
		FI 953266 A	30-06-95
		FI 953267 A	22-08-95
		FI 953268 A	30-06-95
		JP 8510607 T	05-11-96
		JP 8508627 T	10-09-96
		JP 8508628 T	10-09-96
		JP 8508629 T	10-09-96
		JP 8508630 T	10-09-96
		JP 8508631 T	10-09-96
		JP 8509340 T	01-10-96
		SE 9403725 A	19-06-95
WO 9410767 A	11-05-94	SE 500565 C	18-07-94
		AU 4070695 A	04-04-96
		AU 667998 B	18-04-96
		AU 5379594 A	24-05-94
		BR 9305692 A	24-12-96
		CN 1088378 A	22-06-94
		EP 0623263 A	09-11-94
		FI 943052 A	23-06-94
		JP 7502874 T	23-03-95
		NZ 257411 A	24-02-97
		NZ 280819 A	24-02-97

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 96/16678

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9410767 A		SE 9203127 A	27-04-94
		US 5420864 A	30-05-95

Form PCT/ISA/210 (patent family annex) (July 1992)