

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
9 November 2006 (09.11.2006)

PCT

(10) International Publication Number  
WO 2006/117637 A2

(51) International Patent Classification:  
H04L 12/56 (2006.01) H04B 7/26 (2006.01)  
H04B 7/005 (2006.01)

(74) Agent: ALBERT, Peter, G., Jr.; Foley & Lardner LLP,  
11250 El Camino Real, Suite 200, San Diego, CA 92130  
(US).

(21) International Application Number:  
PCT/IB2006/001080

(81) Designated States (unless otherwise indicated, for every  
kind of national protection available): AE, AG, AL, AM,  
AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,  
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,  
GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,  
KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV,  
LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI,  
NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG,  
SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US,  
UZ, VC, VN, YU, ZA, ZM, ZW.

(22) International Filing Date: 1 May 2006 (01.05.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
11/119,550 2 May 2005 (02.05.2005) US

(71) Applicant (for all designated States except US): NOKIA  
CORPORATION [FI/FI]; Keilalahdentie 4, FIN-02150  
Espoo (FI).

(84) Designated States (unless otherwise indicated, for every  
kind of regional protection available): ARIPO (BW, GH,  
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,  
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),  
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,  
FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT,  
RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA,  
GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(71) Applicant (for LC only): NOKIA, INC. [US/US]; 6000  
Connection Drive, Irving, TX 75039 (US).

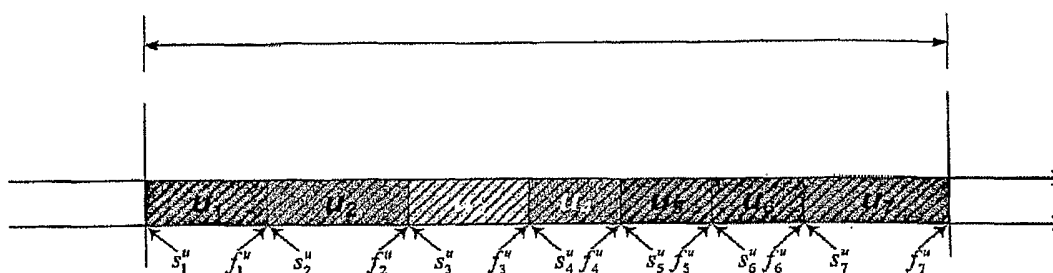
(72) Inventors; and

Published:  
— without international search report and to be republished  
upon receipt of that report

(75) Inventors/Applicants (for US only): LENZINI, Luciano  
[IT/IT]; Via delle Siepi, 45, I-57100 Livorno (IT). MIN-  
GOZZI, Enzo [IT/IT]; Via S. Stefano, 26, I-56123 Pisa  
(IT). BACIOCCOLA, Andrea [IT/IT]; Via A. Gram-  
sci 3, I-Paciano 06060 (IT). CICCONE, Claudio  
[IT/IT]; SP Calcesana 484, I-San Giuliano Terme (IT).  
ERTA, Alessandro [IT/IT]; Via Europa 23 bis, I-54012  
Barbarasco Tresana (IT).

For two-letter codes and other abbreviations, refer to the "Guid-  
ance Notes on Codes and Abbreviations" appearing at the begin-  
ning of each regular issue of the PCT Gazette.

(54) Title: SYSTEM AND METHOD FOR PROVIDING A FAST AND OPTIMIZED UPLINK AND DOWNLINK SCHEDULING ALGORITHM FOR USE IN FDD COMMUNICAION SYSTEMS WITH HALF-DUPLEX STATIONS



(57) Abstract: A system and method for scheduling uplink and downlink burst data transmissions for half-duplex terminals in a communication system. After the first half duplex terminal capacity allocation is scheduled for a plurality of half duplex terminals, all available second half duplex terminals are placed in the same relative order as that of the half duplex terminal first capacity allocation. An iterative process is used in order to determine a final second frame layout. Once a set of potential solutions are determined, one solution is selected, and a final second frame structure is determined.

WO 2006/117637 A2

**SYSTEM AND METHOD FOR PROVIDING A FAST AND  
OPTIMIZED UPLINK AND DOWNLINK SCHEDULING  
ALGORITHM FOR FDD COMMUNICATION SYSTEMS WITH  
HALF-DUPLEX STATIONS**

FIELD OF THE INVENTION

[0001] The present invention relates generally to communication systems. More particularly, the present invention relates to communication systems where a bandwidth controller is needed in order to define the downlink and the uplink allocations.

BACKGROUND OF THE INVENTION

[0002] Communication systems having both uplink and downlink capabilities are typically characterized by a number of constraints. First, in such a communication system, uplink and downlink transmissions use different frequencies but are typically simultaneous. Downlink and uplink transmissions are also centrally scheduled frame-by-frame by a central controller, also referred to as an Access Point (AP). Such communication systems also provide support for half duplex terminals, and half duplex terminals are allowed to transmit before receiving and/or vice-versa. A half-duplex terminal is a terminal that alternates between sending and receiving information. An example of such a system is the air interface for the Institute of Electrical and Electronics Engineers (IEEE) 802.16 fixed broadband wireless access system.

[0003] When half duplex terminals are used in a particular communication system, the bandwidth controller does not allocate uplink bandwidth to a half-duplex terminal at the same time that it is expected to receive data on the downlink channel, including allowance for the propagation delay, the terminal transmit/receive transition gap and the terminal receive/transmit transition gap. On the other hand, the bandwidth controller may have to determine which packets should be the next to be transmitted, i.e. how to allocate bandwidth, in order to meet a variety of system-defined

requirements. These requirements may include, for example, the provisioning of quality of service ("QoS") considerations.

#### SUMMARY OF THE INVENTION

**[0004]** The invention solves the problem of correctly allocating bandwidth in a communication system with half-duplex terminals. The present invention involves the use of an algorithm for scheduling uplink and downlink burst data transmissions for half-duplex terminals in a burst mode frequency division duplexing (FDD) system. The algorithm may be implemented in the devices which control the air interface. The algorithm assumes that data bursts to be transmitted in the frame are defined by a QoS scheduler according to a predetermined QoS model. The algorithm then finalizes the frame schedule by arranging the burst data transmission order in terms of both uplinking and downlinking, so that transmission and reception intervals (for each of the half-duplex terminals) do not overlap and the switching gaps constraints are satisfied.

**[0005]** The present invention provides a number of benefits not available under conventional systems. The algorithm of the present invention is optimal, in the sense that it is always successful, provided that the amount of capacity allocated in both uplinking and downlinking to half-duplex terminals does not exceed the frame length. Furthermore, the algorithm actually produces a set of valid solutions, among which it is possible to choose the solution that is optimal according to whatever optimum function is related to the communication system. The solutions presented by the present invention also are independent from any QoS scheduling design choice, and the set of feasible solutions permits to choose the best feasible solution among the others according to the optimum function related to the particular communication system. Furthermore, only a minimum level of achievable complexity is needed to solve the problems currently faced, and the solution is applicable in a wide variety of FDD networks.

**[0006]** With respect to prior attempted solutions to the problems discussed above, the present invention provides an increased number of potential solutions relative to prior innovations. Additionally, the present invention performs a fine grained

computation; it exhibits a complexity of  $O(n)$ , while the prior algorithm exhibits a complexity of  $O(n^2)$ .

[0007] These and other objects, advantages and features of the invention, together with the organization and manner of operation thereof, will become apparent from the following detailed description when taken in conjunction with the accompanying drawings, wherein like elements have like numerals throughout the several drawings described below.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figure 1 is a perspective view of a mobile telephone that can be used in the implementation of the present invention;

[0009] Figure 2 is a schematic representation of the telephone circuitry of the mobile telephone of Figure 1;

[0010] Figure 3 is a representation of a generic uplink and downlink capacity allocation for a terminal  $i$ ;

[0011] Figure 4 is a representation of an uplink capacity allocation according to one embodiment of the present invention;

[0012] Figure 5 is a representation of an unfeasible uplink and downlink capacity allocation order when the downlink allocations are placed in the same order as the respective uplink allocations;

[0013] Figure 6 is a representation of a feasible uplink and downlink capacity allocation order according to the principles of the present invention; and

[0014] Figure 7 is a flow chart depicting the steps involved in the implementation of one embodiment of the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Figures 1 and 2 show one representative electronic device 12 within which the present invention may be implemented. It should be understood, however, that the present invention is not intended to be limited to one particular type of electronic device 12 or other electronic device. For example, the present invention can be incorporated into a combination personal digital assistant (PDA) and mobile

telephone, a PDA, an integrated messaging device (IMD), a desktop computer, and a notebook computer. The present invention can be also incorporated into a combination of core network devices which have to control the air interface. The electronic device 12 of Figures 1 and 2 includes a housing 30, a display 32 in the form of a liquid crystal display, a keypad 34, a microphone 36, an ear-piece 38, a battery 40, an infrared port 42, an antenna 44, a smart card 46 in the form of a universal integrated circuit card (UICC) according to one embodiment of the invention, a card reader 48, radio interface circuitry 52, codec circuitry 54, a controller 56 and a memory 58. Individual circuits and elements are all of a type well known in the art.

[0016] The communication devices may communicate using various transmission technologies including, but not limited to, Code Division Multiple Access (CDMA), Global System for Mobile Communications (GSM), Universal Mobile Telecommunications System (UMTS), Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Transmission Control Protocol/Internet Protocol (TCP/IP), asynchronous transfer mode (ATM), Short Messaging Service (SMS), Multimedia Messaging Service (MMS), e-mail, Instant Messaging Service (IMS), Bluetooth, IEEE 802.11, IEEE 802.16, etc.

[0017] As discussed above, the present invention involves the use of an algorithm for scheduling uplink and downlink burst data transmission for half-duplex terminals in a burst mode FDD system. The algorithm assumes that data bursts to be transmitted in the frame are defined by a QoS scheduler according to a predetermined QoS model. The algorithm then finalizes the frame schedule by arranging the burst data transmission order in both terms of both uplinking and downlinking, so that transmission and reception intervals (for each of the half-duplex terminals) do not overlap and the switching gap constraints are satisfied.

[0018] As an example, if the algorithm is used in a base station (BS) controlling orthogonal frequency division multiplexing (OFDM) FDD air interface as defined according to IEEE 802.16, the optimum function may be aimed at minimizing the number of uplink and downlink bursts transmitted in a frame, thus minimizing the number of entries in the downlink map, while allowing to schedule transmissions according to the respective QoS model.

[0019] In terms of the implementation of the present invention as discussed herein, the following notations are adopted:

[0020]  $n$  is the overall number of half duplex terminals being allocated capacity in a frame.

[0021]  $u_i$  is the amount of uplink capacity, in time units, allocated for a terminal  $i$ .

[0022]  $d_i$  is the amount of downlink capacity, in time units, allocated for the terminal  $i$ .

[0023]  $T$  is the total amount of capacity, in time units, available in the frame, both for uplink and downlink.

[0024]  $s_i^u$  is the time offset, in time units, at which the uplink capacity allocation for the terminal  $i$  starts.

[0025]  $s_i^d$  is the time offset, in time units, at which the downlink capacity allocation for the terminal  $i$  starts.

[0026]  $f_i^u$  is the time offset, in time units, at which the uplink capacity allocation for the terminal  $i$  ends. It must be  $f_i^u = \lfloor s_i^u + u_i \rfloor_T$ , i.e.,  $s_i^u = \lfloor f_i^u - u_i \rfloor_T$ .

[0027]  $f_i^d$  is the time offset, in time units, at which the downlink capacity allocation for the terminal  $i$  ends. It must be  $f_i^d = \lfloor s_i^d + d_i \rfloor_T$ , i.e.,  $s_i^d = \lfloor f_i^d - d_i \rfloor_T$ .

[0028]  $(s_i^u, u_i)$  is the uplink capacity allocation for the terminal  $i$ .

[0029]  $(s_i^d, d_i)$  is the downlink capacity allocation for the terminal  $i$ .

[0030] With respect to the above defined notations, the following assumptions are used before applying the algorithm:

[0031] 1. A set  $U = \{(s_i^u, u_i)\}$  of uplink capacity allocations is defined. The set is feasible, meaning that capacity allocations for different terminals do not overlap in time. It should be noted that any suitable scheduling algorithm, tailored to the system specific uplink QoS requirements, can be used to define the uplink capacity allocations. One representative situation is depicted in Figure 4.

[0032] 2. Access terminals are identified by an index number ranging from 1 to  $n$ , such that  $i < j \Leftrightarrow s_i^u < s_j^u$ , i.e., by increasing the uplink capacity allocation start time.

[0033] 3. The amount of downlink capacity allocated for each terminal has been determined. In other words, the set of capacities  $\{d_i\}$  is defined. Any suitable scheduling algorithm tailored to the system specific downlink QoS requirements can be used to define the downlink capacity allocations.

[0034] 4. The set of capacities  $\{d_i\}$  is such that  $\sum d_i \leq T$ , and  $u_i + d_i \leq T$ ,  $\forall i$ .

[0035] Figure 3 represents a generic uplink capacity allocation. Each block represents the allocation of one terminal. The  $s_i^u$  and the  $f_i^u$  values are referred from the beginning of the frame. The greater the size of the block, the higher capacity is allocated to the terminal. In terms of the present invention, the goal is to find at least one set  $D = \{(s_i^d, d_i)\}$  of feasible downlink capacity allocations.

[0036] The next step in the implementation of the algorithm of the present invention is to initially place all the downlink half duplex terminals in the same relative order as that of the uplink capacity allocation, independent of the way it was determined. The result of this step is depicted in Figure 5. In general, the ordering may be determined depending on specific communication system constrains. As an example, in the standard IEEE 802.16 OFDM and SC FDD physical layers, a preferred choice is to order the uplink half duplex terminal capacity by decreasing robustness.

[0037] A solution to the allocation problem discussed herein is said to be "feasible" if and only if the blocks of the same terminals do not overlap, meaning that, in terms of Figure 5, blocks of the terminal are not above each other. Therefore, the situation depicted in Figure 5 is not a feasible solution to the allocation problem.

[0038] The next step involves the algorithm executing a sequence of  $n$  operations to determine the final downlink frame layout. Specifically, the algorithm finds a set  $X$  of suitable solutions to the allocation problem as follows:

$$X \triangleq \left\{ x \in \mathbb{R} \mid \max_i (f_i^d - s_i^u) \leq x \leq \min_i (s_i^d - f_i^u + T) \right\}$$

[0039] The algorithm's operations can be detailed step-by-step according to the following sequence of steps. This sequence is depicted in Figure 7. At step 500, the  $x1$  and  $x2$  variables are reset to zero, where  $x1$  and  $x2$  are two variables used to store the value of  $\max_i (f_i^d - s_i^u)$  and  $\min_i (s_i^d - f_i^u + T)$ , respectively. The next terminal  $i$  is then considered at step 510. At step 520, the quantities  $sum1$  and  $sum2$  are calculated

for the terminal  $i$ , where  $sum1$  is defined as  $f_i^d - s_i^u$  and  $sum2$  is defined as  $T + s_i^d - f_i^u$  for the terminal  $i$  under consideration. At step 530, the value of  $sum1$  obtained in step 520 is compared to  $x1$ . If  $sum1$  is greater than  $x1$ , then the  $sum1$  value is assigned to  $x1$  at step 540; otherwise, the system moves directly to step 550. At step 550, the value of  $sum2$  obtained in step 520 is compared to  $x2$ . If  $sum2$  is less than  $x2$ , then the  $sum2$  value is assigned to  $x2$  at step 560; otherwise, the system moves directly to step 570. At step 570, the system checks to determine whether there are half duplex terminals left to be processed. If so, then the system returns to step 510, and the next terminal is processed according to steps 520-560. At step 580, one solution  $x$  is selected from the set of solutions  $X$  according to the optimum function related to the communication system constraint. At step 590, the final downlink frame structure is computed according to the following: for each half duplex terminal, the final  $s_i^d$  and  $f_i^d$  is computed according to the formulas  $s_i^d = |s_i^d - x|_T$  and  $f_i^d = |f_i^d - x|_T$ . It should be noted that the actions discussed herein can also be reversed with respect to the uplink and downlink functions.

[0040] The formulas  $s_i^d = |s_i^d - x|_T$  and  $f_i^d = |f_i^d - x|_T$  are used to determine the final downlink allocation as shown. The mathematical modulus operation is defined as

$$|x|_T = \begin{cases} x & 0 \leq x < T \\ T - x & -T < x < 0 \end{cases}$$

[0041] The  $x$  value is defined as  $-T < x < T$ . The modulus operation is the mathematical formula to represent the idea of the shift in a circular way. Because the result of the formulas could be less than zero, the modulo operation  $| \cdot |_T$  is used. A negative result of the formula means that the computed value has to be referred to the end of the frame (i.e. the shift of the block continues from the end of the frame).

[0042] The resulting allocation is depicted in Figure 6. This allocation is obtained using the formula  $x=x1$ . In this allocation, there are no overlapping blocks, and the allocation is feasible.

[0043] The rationale behind the algorithm described above is to formalize the process of disposing uplink bursts, disposing downlink bursts, and moving the downlink bursts to the left (according to Figures 5 and 6) in a circular way, after a



feasible allocation is found. By a “circular way,” it is meant that each downlink burst is moved to the left, and when a block reaches the frame start while shifting to the left, it continues shifting but from the end of the frame. For example, in the allocation process depicted in Figures 4-6,  $d_1$  and  $d_2$  reaches the frame starting point and therefore continued shifting from the end of the frame. The  $x$  value computed by the algorithm represents the length of the respective shift.

[0044] The following is a generic code implementation for the present invention:

```

1.  $x1 = 0$ 
2.  $x2 = 0$ 
3.  $sum1 = 0;$ 
4.  $sum2 = 0;$ 
5. for ( $i = 1; i \leq n; i++$ ) {
6.  $sum1 = f\_d[i] - s\_u[i];$ 
7. if ( $sum1 \geq x1$ )  $x1 = sum1;$ 
8.  $sum2 = s\_d[i] - f\_u[i] + T;$ 
9. if ( $sum2 \leq x2$ )  $x2 = sum2;$ 
10. }
11.  $x = \text{select}(x1, x2);$ 
12. for ( $i = 1; i \leq n; i++$ ) {
13.  $s\_d[i] = \text{mod}(s\_d[i], T);$ 
14.  $f\_d[i] = \text{mod}(f\_d[i], T);$ 
15. }
```

[0045] An alternative implementation of the algorithm is shown below. It should be noted that the code below reports only a procedure for finding the set of suitable solutions  $X$  omitting the allocation part which remains the same among implementations.

```

1.  $x1 = 0, x2 = 0;$ 
2.  $sum1 = 0, sum2 = 0;$ 
3. for ( $i = 1; i \leq n; i++$ ) {
4.  $sum1 += d[i] - s\_u[i] + s\_u[i-1];$ 
5.  $sum2 += d[i-1] - f\_u[i] + f\_u[i-1] + T;$ 
```

6. **if** ( $sum1 \geq x1$ )  $x1 = sum1$ ;
7. **if** ( $sum2 \leq x2$ )  $x2 = sum2$ ;
8. **}**
9. **return** ( $x1, x2$ )

[0046] According to the IEEE 802.16 standard with both OFDM or SC FDD physical layers, the optimal choice that is computed is such that  $x$  is equal to  $x1$ . This choice, and the decreasing robustness ordering of half duplex terminals, permits one to achieve the goal of minimizing the numbers of preambles and the number of map entries, reducing the system's overhead and thus maximizing the channel utilization..

[0047] A generic code implementation is represented below for the cases of the standard IEEE 802.16 with OFDM and SC FDD physical layers, omitting the allocation portion. The code is more simplified than that discussed above due to the choice associated to the optimum function. In fact, in this case it is necessary to compute only  $x1$  because the chosen value  $x$  is simply  $x1$ .

1.  $x = 0$ ;
2.  $sum = 0$ ;
3. **for** ( $i=1; i \leq n; i++$ ) {
4.  $sum += d[i] - s[i] + s[i-1]$ ;
5. **if** ( $sum \geq x$ )  $x = sum$ ;
6. **}**
7. **return**  $x$ ;

[0048] The present invention is described in the general context of method steps, which may be implemented in one embodiment by a program product including computer-executable instructions, such as program code, executed by computers in networked environments.

[0049] Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. Computer-executable instructions, associated data structures, and program modules represent examples of program code for executing steps of the methods disclosed herein. The particular sequence of such executable instructions or

associated data structures represents examples of corresponding acts for implementing the functions described in such steps.

[0050] Software and web implementations of the present invention could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various database searching steps, correlation steps, comparison steps and decision steps. It should also be noted that the words “component” and “module” as used herein, and in the claims, are intended to encompass implementations using one or more lines of software code, and/or hardware implementations, and/or equipment for receiving manual inputs.

[0051] The foregoing description of embodiments of the present invention have been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the present invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the present invention. The embodiments were chosen and described in order to explain the principles of the present invention and its practical application to enable one skilled in the art to utilize the present invention in various embodiments and with various modifications as are suited to the particular use contemplated.

**WHAT IS CLAIMED IS:**

- 1           1.       A method of scheduling uplink and downlink burst data transmission  
2 for half-duplex terminals in a communication system, comprising:
  - 3                   ordering a half duplex terminal first capacity allocation for a plurality  
4 of half duplex terminals, the first capacity allocation being selected from an uplink  
5 capacity allocation and a downlink capacity allocation,  
6                   ordering a half duplex terminal second capacity allocation for a  
7 plurality of half duplex terminals according to the same ordering rules of the half  
8 duplex terminal first capacity allocation, the second capacity allocation being the  
9 other of the uplink capacity allocation and the downlink capacity allocation,  
10                  defining the final half duplex terminal first capacity allocation by  
11 performing an iterative process, the iterative process including arranging the first  
12 capacity allocation in the frame following the order of the half duplex first capacity  
13 allocation;  
14                  defining the final half duplex terminal second capacity allocation by  
15 performing an iterative process, the iterative process including:
    - 16                   determining for each terminal a first time interval representing  
17 the difference between terminal's second capacity allocation end time and terminal's  
18 first capacity allocation start time;  
19                   determining for each terminal a second time interval  
20 representing the total capacity in a transmission frame plus the terminal's second  
21 allocation start time excluding the terminal's first allocation end time;  
22                   forming a set of solutions to the capacity allocation by:
      - 23                    calculating the maximum among the terminals' first  
24 time interval,  
25                    calculating the minimum among the terminals' second  
26 time interval, and  
27                    determining the set of solutions as all values between  
28 the maximum first time interval and the minimum second time interval;

29 selecting a capacity allocation solution from the set of solutions using  
30 an optimum function related to the communication system used and calculating the  
31 final second allocations for each terminal; and

32 arranging the first capacity allocation in the frame following the final  
33 first allocations for each of the plurality of half duplex terminals.

1 2. The method of claim 1, wherein the communication system comprises  
2 a burst mode FDD system.

1 3. The method of claim 1, wherein the first half duplex terminal capacity  
2 allocation capacity is ordered by decreasing robustness.

1 4. The method of claim 1, wherein the selected capacity allocation  
2 solution is selected according to the optimum function related to the communication  
3 system constraint.

1 5. The method of claim 1, wherein formulas  $s_i^d = |s_i^d - x|_T$  and  $f_i^d = |f_i^d - x|_T$   
2 are used to determine the final second allocation for each terminal  $i$ , and wherein  $s_i^d$  is  
3 the time offset, in time units, at which the second capacity allocation for the terminal  
4  $i$  starts;  $f_i^d$  is the time offset, in time units, at which the second capacity allocation  
5 for the terminal  $i$  ends;  $T$  is the total amount of capacity, in time units, available in  
6 the frame, both for uplink and downlink; and  $x$  represents the selected capacity  
7 allocation solution.

1 6. A computer program product for scheduling uplink and downlink burst  
2 data transmission for half-duplex terminals in a communication system, comprising:  
3 computer code for ordering a half duplex terminal first capacity  
4 allocation for a plurality of half duplex terminals, the first capacity allocation being  
5 selected from an uplink capacity allocation and a downlink capacity allocation,  
6 computer code for ordering a half duplex terminal second capacity  
7 allocation for a plurality of half duplex terminals according to the same ordering rules  
8 of the half duplex terminal first capacity allocation, the second capacity allocation  
9 being the other of the uplink capacity allocation and the downlink capacity allocation,

10 computer code for defining the final half duplex terminal first capacity  
11 allocation by performing an iterative process, the iterative process including arranging  
12 the first capacity allocation in the frame following the order of the half duplex first  
13 capacity allocation;

14 computer code for defining the final half duplex terminal second  
15 capacity allocation by performing an iterative process, the iterative process including:  
16 determining for each terminal a first time interval representing  
17 the difference between terminal's second capacity allocation end time and terminal's  
18 first capacity allocation start time;

19 determining for each terminal a second time interval  
20 representing the total capacity in a transmission frame plus the terminal's second  
21 allocation start time excluding the terminal's first allocation end time;

22 forming a set of solutions to the capacity allocation by:

23 calculating the maximum among the terminals' first  
24 time interval,

25 calculating the minimum among the terminals' second  
26 time interval, and

27 determining the set of solutions as all values between  
28 the maximum first time interval and the minimum second time interval;

29 computer code for selecting a capacity allocation solution from the set  
30 of solutions using an optimum function related to the communication system used and  
31 calculating the final second allocations for each terminal; and

32 computer code for arranging the first capacity allocation in the frame  
33 following the final first allocations for each of the plurality of half duplex terminals.

1 7. The computer program product of claim 6, wherein the communication  
2 system comprises a burst mode FDD system.

1 8. The computer program product of claim 6, wherein the first half  
2 duplex terminal capacity allocation capacity is ordered by decreasing robustness.

1           9.       The computer program product of claim 6, wherein the selected  
2 capacity allocation solution is selected according to the optimum function related to  
3 the communication system constraint.

1           10.      The computer program product of claim 6, wherein formulas  
2  $s_i^d = |s_i^d - x|_T$  and  $f_i^d = |f_i^d - x|_T$  are used to determine the final second allocation for each  
3 terminal  $i$ , and wherein  $s_i^d$  is the time offset, in time units, at which the second  
4 capacity allocation for the terminal  $i$  starts;  $f_i^d$  is the time offset, in time units, at  
5 which the second capacity allocation for the terminal  $i$  ends;  $T$  is the total amount of  
6 capacity, in time units, available in the frame, both for uplink and downlink; and  $x$   
7 represents the selected capacity allocation solution.

1           11.      An electronic device, comprising:  
2                    a processor;  
3                    a memory unit operatively connected to the processor and including a  
4 computer program product for scheduling uplink and downlink burst data  
5 transmission for half-duplex terminals in a communication system, comprising:  
6                    computer code for ordering a half duplex terminal first capacity  
7 allocation for a plurality of half duplex terminals, the first capacity allocation being  
8 selected from an uplink capacity allocation and a downlink capacity allocation,  
9                    computer code for ordering a half duplex terminal second  
10 capacity allocation for a plurality of half duplex terminals according to the same  
11 ordering rules of the half duplex terminal first capacity allocation, the second capacity  
12 allocation being the other of the uplink capacity allocation and the downlink capacity  
13 allocation,  
14                    computer code for defining the final half duplex terminal first  
15 capacity allocation by performing an iterative process, the iterative process including  
16 arranging the first capacity allocation in the frame following the order of the half  
17 duplex first capacity allocation;

18 computer code for defining the final half duplex terminal  
19 second capacity allocation by performing an iterative process, the iterative process  
20 including:  
21 determining for each terminal a first time interval  
22 representing the difference between terminal's second capacity allocation end time  
23 and terminal's first capacity allocation start time;  
24 determining for each terminal a second time interval  
25 representing the total capacity in a transmission frame plus the terminal's second  
26 allocation start time excluding the terminal's first allocation end time;  
27 forming a set of solutions to the capacity allocation by:  
28 calculating the maximum among the terminals'  
29 first time interval,  
30 calculating the minimum among the terminals'  
31 second time interval, and  
32 determining the set of solutions as all values  
33 between the maximum first time interval and the minimum second time interval;  
34 computer code for selecting a capacity allocation solution from  
35 the set of solutions using an optimum function related to the communication system  
36 used and calculating the final second allocations for each terminal; and  
37 computer code for arranging the first capacity allocation in the  
38 frame following the final first allocations for each of the plurality of half duplex  
39 terminals.

1 12. The electronic device of claim 11, wherein the communication system  
2 comprises a burst mode FDD system.

1 13. The electronic device of claim 11, wherein the first half duplex  
2 terminal capacity allocation capacity is ordered by decreasing robustness.

1 14. The electronic device of claim 11, wherein the selected capacity  
2 allocation solution is selected according to the optimum function related to the  
3 communication system constraint.



1           15.     The electronic device of claim 11, wherein formulas  $s_i^d = |s_i^d - x|_T$  and  
2      $f_i^d = |f_i^d - x|_T$  are used to determine the final second allocation for each terminal  $i$ , and  
3     wherein  $s_i^d$  is the time offset, in time units, at which the second capacity allocation for  
4     the terminal  $i$  starts;  $f_i^d$  is the time offset, in time units, at which the second capacity  
5     allocation for the terminal  $i$  ends;  $T$  is the total amount of capacity, in time units,  
6     available in the frame, both for uplink and downlink; and  $x$  represents the selected  
7     capacity allocation solution.

1           16.     A module, comprising:  
2                     a processor;  
3                     a memory unit operatively connected to the processor and including a  
4     computer program product for scheduling uplink and downlink burst data  
5     transmission for half-duplex terminals in a communication system, comprising:  
6                     computer code for ordering a half duplex terminal first capacity  
7     allocation for a plurality of half duplex terminals, the first capacity allocation being  
8     selected from an uplink capacity allocation and a downlink capacity allocation,  
9                     computer code for ordering a half duplex terminal second  
10    capacity allocation for a plurality of half duplex terminals according to the same  
11    ordering rules of the half duplex terminal first capacity allocation, the second capacity  
12    allocation being the other of the uplink capacity allocation and the downlink capacity  
13    allocation,  
14                     computer code for defining the final half duplex terminal first  
15    capacity allocation by performing an iterative process, the iterative process including  
16    arranging the first capacity allocation in the frame following the order of the half  
17    duplex first capacity allocation;  
18                     computer code for defining the final half duplex terminal  
19    second capacity allocation by performing an iterative process, the iterative process  
20    including:

21 determining for each terminal a first time interval  
 22 representing the difference between terminal's second capacity allocation end time  
 23 and terminal's first capacity allocation start time;  
 24 determining for each terminal a second time interval  
 25 representing the total capacity in a transmission frame plus the terminal's second  
 26 allocation start time excluding the terminal's first allocation end time;  
 27 forming a set of solutions to the capacity allocation by:  
 28 calculating the maximum among the terminals'  
 29 first time interval,  
 30 calculating the minimum among the terminals'  
 31 second time interval, and  
 32 determining the set of solutions as all values  
 33 between the maximum first time interval and the minimum second time interval;  
 34 computer code for selecting a capacity allocation solution from  
 35 the set of solutions using an optimum function related to the communication system  
 36 used and calculating the final second allocations for each terminal; and  
 37 computer code for arranging the first capacity allocation in the  
 38 frame following the final first allocations for each of the plurality of half duplex  
 39 terminals.

1 17. The module of claim 16, wherein the communication system comprises  
 2 a burst mode FDD system.

3 18. The module of claim 16, wherein formulas  $s_i^d = |s_i^d - x|_T$  and  
 4  $f_i^d = |f_i^d - x|_T$  are used to determine the final second allocation for each terminal  $i$ , and  
 5 wherein  $s_i^d$  is the time offset, in time units, at which the second capacity allocation for  
 6 the terminal  $i$  starts;  $f_i^d$  is the time offset, in time units, at which the second capacity  
 7 allocation for the terminal  $i$  ends;  $T$  is the total amount of capacity, in time units,  
 8 available in the frame, both for uplink and downlink; and  $x$  represents the selected  
 9 capacity allocation solution.

1           19.    The module of claim 16, wherein the first half duplex terminal capacity  
2   allocation capacity is ordered by decreasing robustness.

1           20.    The module of claim 16, wherein the selected capacity allocation  
2   solution is selected according to the optimum function related to the communication  
3   system constraint.

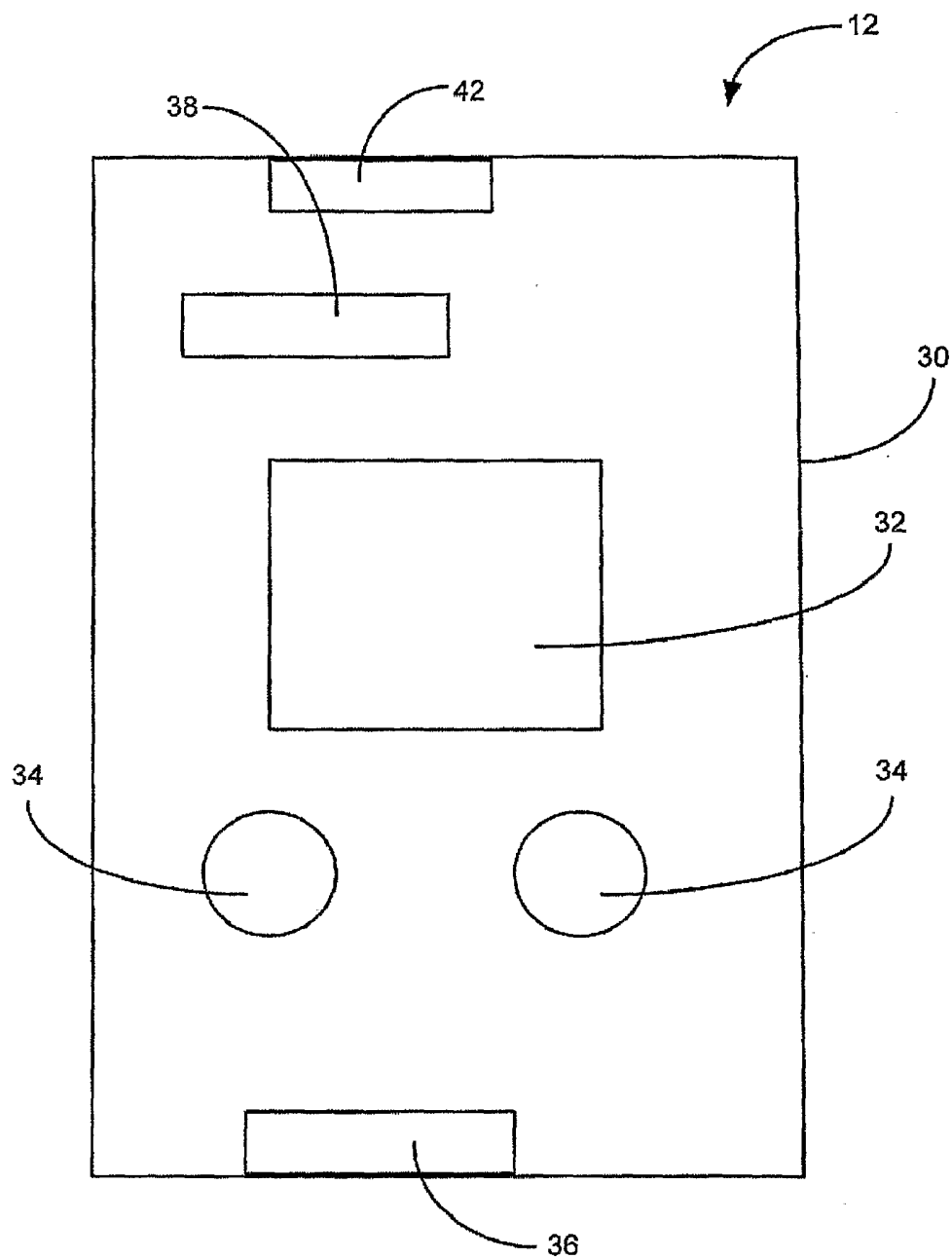


FIG. 1

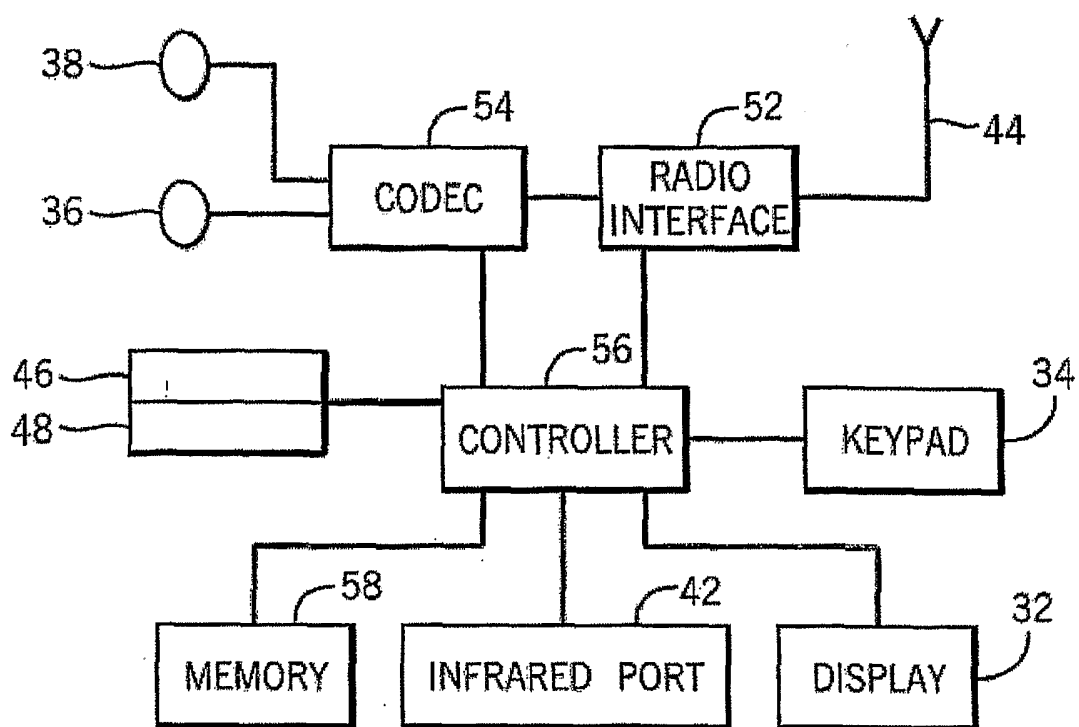


FIG. 2

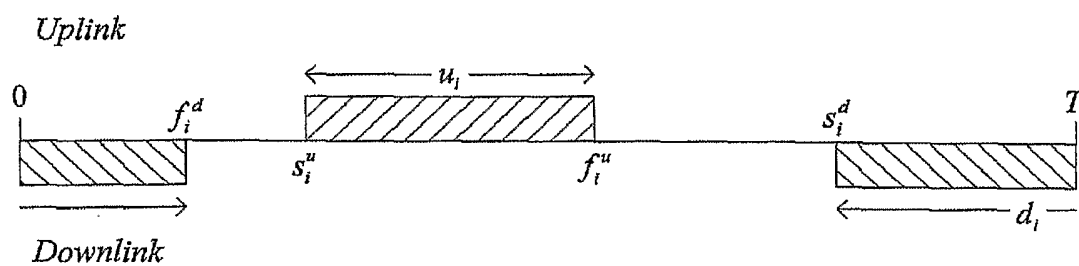


FIG. 3

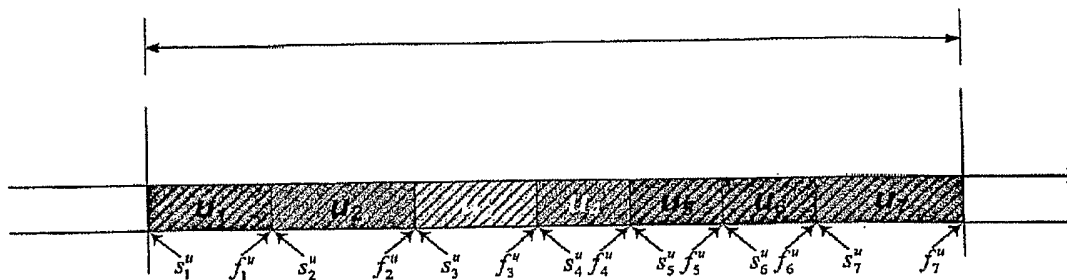


Figure 4

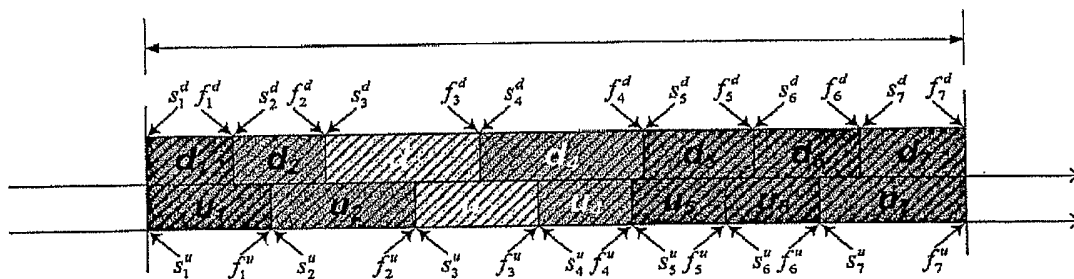


Figure 5

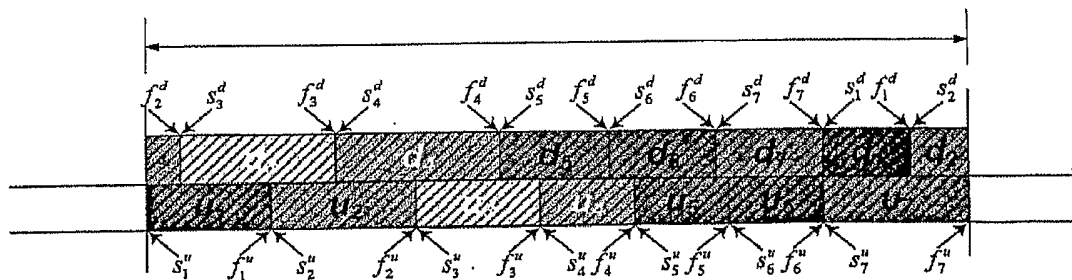


Figure 6

