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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(54) Title: SYSTEM, DEVICE, AND METHOD FOR PROVIDING LOW ACCESS DELAY FOR TIME-SENSITIVE APPLICATIONS IN A SHARED MEDIUM NETWORK
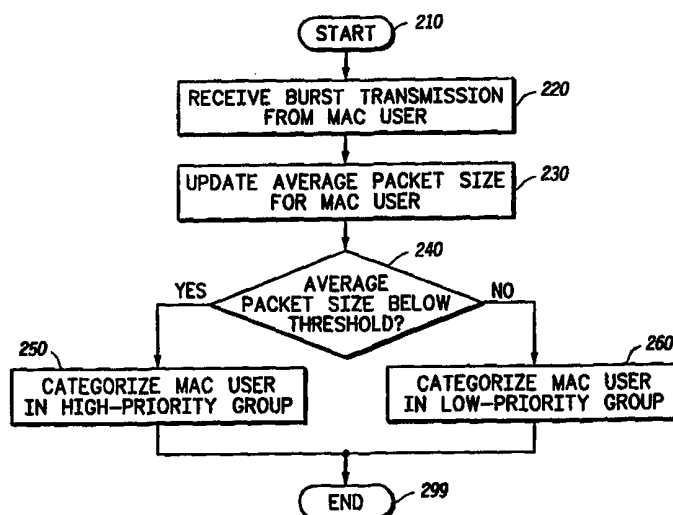
(57) Abstract

A system, device, and method for providing low access delay for time-sensitive applications in a shared medium network segregates MAC Users into a high-priority group and a low-priority group. Where the MAC User priorities are not known *a priori*, the MAC User priorities are inferred from the size of the data packets transmitted by the MAC Users. MAC Users transmitting small packets are placed in the high-priority group, while MAC Users transmitting large packets are placed in the low-priority group. The headend unit first polls all of the high-priority MAC Users, and then polls low-priority MAC Users until either all low-priority MAC Users have been polled or the low-priority MAC Users have been serviced for a predetermined maximum polling time. The headend unit repeats this polling sequence in sequential polling cycles to provide the high-priority MAC Users with expedited access to the shared channel.

System, Device, And Method For Providing Low Access Delay For Time-Sensitive Applications In A Shared Medium Network

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Background

1.   Field of the Invention

The invention relates generally to communication systems and, more particularly, to multiple access protocols for use over a shared communications medium

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2.   Discussion of Related Art

In today's information age, there is an increasing need for high speed communications that provides guaranteed quality of service (QoS) for an ever-increasing number of communications consumers. To that end, communications

15   networks and technologies are evolving to meet current and future demands. Specifically, new networks are being deployed which reach a larger number of end users, and protocols are being developed to utilize the added bandwidth of these networks efficiently.

One technology that will be employed increasingly in the future is the

20   shared-medium network. A shared medium network is one in which a single communications channel (the shared channel) is shared by a number of end users such that uncoordinated transmissions from different end users may interfere with each other. In modern broadband communications networks, the shared communications channel is typically one of a number of frequency bands carried

25   over a shared physical medium, such as a hybrid fiber-optic/coaxial cable (HFC) network or by electromagnetic waves in free space. Since communications networks typically have a limited number of communications channels, the shared medium network allows many end users to gain access to the network over a single communications channel, thereby allowing the remaining communications

30   channels to be used for other purposes. However, the shared medium network is only feasible when each end user only transmits data intermittently, allowing other end users to transmit during periods of silence.

In the shared medium network, each end user interfaces to the shared channel by means of an Access Interface Unit (AIU) which allows the end user to

35   transmit and receive information via the shared channel. A single AIU may support

one or a number of end users. Each end user wishing to utilize the shared channel participates in a Medium Access Control (MAC) protocol which provides a set of rules and procedures for accessing the shared channel. For convenience, each participant in the MAC protocol is referred to as a MAC User.

5   FIG. 1 is a logical representation of a shared medium network 100 as is known in the art. As illustrated in FIG. 1, a headend unit 110 is coupled to a plurality of AIUs 120_a through 120_n (collectively referred to as AIUs 120) via a shared channel 130. In the preferred embodiment, the shared channel 130 is one of a number of communications channels carried by a shared physical medium
10   such as an HFC or wireless network. In other embodiments, the shared physical medium may be coaxial cable, fiber-optic cable, twisted pair wires, and so on, and may also include air, atmosphere, or space for wireless and satellite communication. The headend unit 110 is also coupled to a communications network 140, which may include networks such as the Internet, on-line services,
15   telephone and cable networks, and other communication systems.

Continuing to refer to FIG. 1, in the preferred embodiment, the shared physical medium, such as an HFC or wireless network, has or supports a plurality of communications channels. For ease of reference, the communications channels in which a headend unit, such as the headend unit 110, transmits
20   information, signals, or other data to an AIU, such as AIU 120_n, are referred to as downstream channels. Also for ease of reference, the communications channels in which an AIU, such as AIU 120_n, transmits information, signals, or other data to a headend unit, such as headend unit 110, are referred to as upstream channels. These various upstream and downstream channels may, of course, be the same
25   physical channel or may be separate physical channels, for example, through time-division multiplexing or frequency-division multiplexing. These various channels may also be logically divided in other ways, in addition to upstream and downstream directions. In the preferred embodiment, the communications medium is an HFC network, with downstream channels in the frequency spectrum
30   (band) typically 50 - 750 MHz (and up to 1 GHz), and with upstream channels in the frequency spectrum typically 5 - 42 MHz.

In a simple model of an exemplary HFC network, the headend unit uses a single downstream channel to send information, including poll messages, to the MAC Users, and a single upstream channel is used by the MAC Users to send
35   information to the headend unit. Since the headend unit is the only device which

transmits on the downstream channel, the downstream channel is not a "shared channel" as that term is applied to the present invention. However, since multiple MAC Users transmit on the upstream channel, the upstream channel is a shared channel, and the MAC protocol must provide for orderly access to the channel so

5   as to maximize the data throughput over the channel.

A number of different access techniques have been developed for use over a shared channel. These techniques can generally be categorized as contention-free, which avoid collisions on the shared channel by means of various scheduling methods, and contention-based, which do not avoid collisions but instead resolve

10   any collisions that do occur on the shared channel. Contention-free protocols, such as time-division multiple access (TDMA) and round-robin polling protocols, are typically less efficient than contention-based protocols under light loads because the contention-free protocols generally allocate some amount of bandwidth to each MAC User whether or not the MAC User has information to

15   send. On the other hand, contention-based protocols only allocate bandwidth to those MAC Users that have information to send, although some amount of bandwidth is wasted whenever collision resolution is required. Hybrid protocols, utilizing both contention-free and contention-based access, have been developed in an attempt to gain the advantages of both techniques.

20   In many multiple access protocols, some form of round-robin polling is used. In the round-robin polling technique, a list of MAC Users is maintained, and the MAC Users on the list are polled sequentially, one after the other, to provide each MAC User with an opportunity to transmit data on the shared channel. In straight round-robin polling, each MAC User is provided equal access to the shared

25   channel whether the MAC User is "active" (i.e., is actively generating data) or "inactive" (i.e., infrequency has data to transmit).

Some round-robin polling protocols attempt to improve the effectiveness and efficiency of polling by segregating the MAC Users into multiple lists according to the frequency with which the MAC User has data to transmit. The "active" MAC

30   Users are typically placed on a "fast poll" list, and are polled at a relatively high frequency, while the "inactive" MAC Users are typically placed on a "slow poll" list, and are poll at a relatively low frequency. An alternative approach maintains a list of "recently active" MAC Users (i.e., MAC Users that are currently "inactive" but had recently been "active") which are polled less frequently than the MAC Users on the

35   fast poll list but more frequently than the MAC Users on the slow poll list. By

polling a MAC User at a frequency commensurate with its likelihood of having data to transmit, bandwidth efficiency may be improved.

Hybrid protocols go one step further and replace the round-robin polling of "inactive" MAC Users with contention-based access. The "inactive" MAC Users

5   are provided opportunities to contend for access to the shared channel along with other "inactive" MAC Users. In this way, individual poll messages are not wasted on "inactive" MAC Users that have no data to transmit.

One problem with round-robin polling is that the MAC Users on each poll list are treated as having equal priority and are provided equal access to the shared

10   channel, even if the MAC Users have different priorities. For example, an "active" MAC User having high-priority, time-sensitive data is polled in the same manner, and at the same frequency, as an "active" user having low-priority, time-insensitive data. In that case, the data from the high-priority MAC User may be delayed while data from low-priority MAC Users is being transmitted. Clearly, segregating MAC

15   Users according to data availability alone does not adequately address the issue of prioritizing MAC User transmissions. A knowledge of the MAC User priority *a priori* would allow the polling sequence to account for MAC User priority. However, the MAC User priority is typically not known at the time the MAC User enters the system, and may change over time as the MAC User accesses various

20   services over the network. Therefore, a need remains for a system, device, and method for providing low access delay for time-sensitive applications in a shared medium network.

25   *Brief Description of the Drawing*

In the Drawing,

FIG. 1 is a block diagram of a shared medium network as is known in the art;

FIG. 2 is a logic flow diagram for processing an upstream burst transmission; and

30   FIG. 3 is a logic flow diagram for a polling cycle.

Detailed Description

As discussed above, the need remains for a system, device, and method for providing low access delay for time-sensitive applications in a shared medium

35   network. The present invention provides such low access delay by having the

headend unit segregate MAC Users into a high-priority group and a low-priority group. The headend unit first polls all of the high-priority MAC Users, and then polls low-priority MAC Users until either all low-priority MAC Users have been polled or the low-priority MAC Users have been serviced for a predetermined

5   maximum polling time. The headend unit repeats this polling sequence in sequential polling cycles to provide the high-priority MAC Users with expedited access to the shared channel.

In order for the headend unit to segregate the MAC Users into the high-priority group and the low-priority group, the headend unit must be able to

10   determine the relative priority of each MAC User. In some networks, the MAC User priorities may be known a priori, for example, through configuration by a network administrator or by service class designations in an ATM or other network. In other networks, the MAC User priorities may not be known a priori, and, in fact, may change over time as the end users access different applications over the network.

15   In networks where the MAC User priorities are not explicitly known, the headend unit must determine the MAC User priorities by other means.

In the preferred embodiment, the MAC User priority is not known a priori and is instead inferred from the characteristics of the upstream transmissions generated by the MAC User. The headend unit monitors the MAC User

20   transmissions and determines the delay requirements of the MAC User according to a predetermined set of parameters such as the burst/packet sizes transmitted by the MAC User, the packet types included in the MAC User transmissions, the applications accessed by the MAC User, and any of a number of other parameters that will be apparent to the skilled artisan. The headend unit may use one or more

25   parameters to determine the relative priority of the MAC User, and may use a different set of parameters for each MAC User.

In the preferred embodiment, the MAC User priority is inferred solely from the size of the data packets transmitted by the MAC User. It has been observed that time-sensitive, low-latency applications typically generate small data packets

30   while time-insensitive applications typically generate larger data packets. For example, in a typical shared medium network carrying TCP/IP traffic, much of the upstream traffic for a TCP/IP application will be TCP acknowledgement packets which are transmitted over the upstream channel to allow TCP/IP traffic to continue flowing over the downstream channel. Web surfing and gaming applications will

35   likewise typically generate small data packets in the upstream direction. These

small data packets transmitted over the upstream channel are time-sensitive, since a delay in their delivery may result in noticeably unacceptable performance of the application. Upstream file transfers, on the other hand, will typically be characterized by large data packets transmitted over the upstream channel. These

5   large data packets transmitted over the upstream channel are considered time-insensitive, since a delay in their delivery will typically go unnoticed. While it is not universally true that time-sensitive applications transmit small packets over the upstream channel and that time-insensitive applications transmit large packets over the upstream channel, the size of the packets is used by the headend unit to

10 make an assumption as to the delay requirements of the application and therefore to categorize the MAC Users as either high-priority or low-priority.

    Since transmit packet sizes may vary between transmissions, the preferred embodiment utilizes an exponential weighted average of the received burst size for each MAC User. The headend unit calculates the exponential weighted

15 average for each MAC User as bursts are received over the upstream channel. MAC Users having an average packet size below a predetermined threshold packet size are placed in the high-priority group, while the remaining MAC Users are placed in the low-priority group. The exponential weighted average for a MAC User is calculated according to the following formula:

20      $avg\_packet\_size = \alpha * avg\_packet\_size + (1 - \alpha) * received\_burst\_size$

    where α is a predetermined weighting factor and received_burst_size is the size of the most recent burst received from the MAC User.

    Each time an upstream burst transmission is received from a MAC User, the headend unit updates the average packet size calculation for the MAC User and

25 re-categorizes the MAC User into either the high-priority group or the low-priority group. A logic flow diagram for processing an upstream burst transmission is shown in FIG. 2. The logic begins in step 210, and upon receiving a burst transmission from the MAC User in step 220, the logic updates the average packet size for the MAC User, in step 230. The logic then determines whether the

30 average packet size is below the predetermined threshold packet size, in step 240. If the average packet size for the MAC User is below the predetermined threshold packet size (YES in step 240), then the logic categorizes the MAC User in the high-priority group, in step 250; otherwise, the logic categorizes the MAC User in the low-priority group, in step 260. The logic terminates in step 299.

　　　　　Because the categorization of a MAC User represents an assumption as to the delay requirements of the MAC User, the values selected for the predetermined weighting factor α and the predetermined threshold packet size affect whether or not a valid categorization is made. The selection of the

5　　predetermined weighting factor α is a policy-based determination as to the weight placed on the most recently received burst relative to the historical average calculated over prior bursts. In the preferred embodiment, the predetermined weighting factor α is selected to be 0.5, which places equal weight on the most recently received burst and the historical average. The selection of the

10　　predetermined threshold packet size is based on observed traffic characteristics. In the preferred embodiment, the predetermined threshold packet size is selected to be 200 bytes.

　　　　　A logic flow diagram for a polling cycle is shown in FIG. 3. The logic for each polling cycle begins in step 310 and proceeds to poll the next high-priority

15　　MAC User in the high-priority round-robin polling list, in step 320. After polling the MAC User in step 320, the logic proceeds to step 330 where it determines if all of the high-priority MAC Users have been polled during the polling cycle. If all of the high-priority MAC Users have not been polled during the polling cycle (NO in step 330), then the logic recycles to step 320 to poll the next high-priority MAC User.

20　　However, if all of the high-priority MAC Users have been polled during the polling cycle (YES in step 330), then the logic proceeds to step 340 where it polls the next low-priority MAC User in the low-priority round-robin polling list. After polling the next low-priority MAC User in step 340, the logic determines if all of the low-priority MAC Users have been polled during the polling cycle, in step 350. If all of the low-

25　　priority MAC Users have been polled during the polling cycle (YES in step 350), then the logic recycles to step 310 to begin a new polling cycle. However, if all of the low-priority MAC Users have not been polled during the polling cycle (NO in step 350), then the logic determines whether the low-priority MAC Users have been serviced for a predetermined maximum polling time, in step 360. If the low-

30　　priority MAC Users have not been serviced for the predetermined maximum polling time (NO in step 360), then the logic recycles to step 340 to poll the next low-priority MAC User. However, if the predetermined maximum polling time has been reached (YES in step 360), then the logic recycles to step 310 to begin a new polling cycle.

If the headend unit terminates a polling cycle before polling all of the low-priority MAC Users (i.e., by reaching the predetermined maximum polling time in step 360), then polling of the low-priority MAC Users in step 340 during the next polling cycle begins with the next low-priority MAC User in the list following the last low-priority MAC User polled. As a result, the low-priority MAC Users may be round-robin polled over a number of polling cycles.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive.

What is claimed is:

1.   A method for segregating a plurality of MAC Users into a high-priority group and a low-priority group, the method comprising the steps of:

calculating the average packet size for each MAC User; and

for each MAC User:

5   categorizing the MAC User in the high-priority group, if the average packet size for the MAC User is below a predetermined threshold packet size; and

categorizing the MAC User in the low-priority group otherwise.

2.   The method of claim 1 wherein the average packet size for a MAC User is

10   determined according to an exponential weighted average of the sizes of bursts received from the MAC User calculated according the formula:

average packet size = α * average packet size + (1 - α) * received burst

size;

where α is a predetermined weighting factor and the received burst size is

15   the size of the most recently received burst from the MAC User.

3.   A method for providing low access delay for time-sensitive applications in a shared medium network wherein each application accesses the shared medium network by way of a MAC User, the method comprising the steps of:

20   segregating the MAC Users into a high-priority group and a low-priority group; and

polling the MAC Users in a series of polling cycles, where each polling cycle comprises the steps of:

polling each of the high-priority MAC Users; and

25   subsequent to polling each of the high-priority MAC Users, polling a number of the low-priority MAC Users until one of:

all low-priority MAC Users have been polled; and

the low-priority MAC Users have been serviced for a predetermined maximum polling time.

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4.   The method of claim 3 wherein the step of segregating the MAC Users comprises the steps of:

monitoring the transmissions of each MAC User; and

for each MAC User:

determining the access delay requirements of the MAC User from said transmissions;

placing the MAC User in the high-priority group, if the MAC User requires low access delay; and

5   placing the MAC User in the low-priority group otherwise.

5.   The method of claim 4 wherein the step of determining the access delay requirements of the MAC User comprises the steps of:

calculating the average packet size for the MAC User; and

10   determining that the MAC User requires low access delay, if the average packet size for the MAC User is below a predetermined threshold packet size.

6.   The method of claim 3 wherein each polling cycle comprises the steps of:

(a) polling a next high-priority MAC User;

15   (b) determining if all of the high-priority MAC Users have been polled during the polling cycle;

(c) if at least one high-priority MAC User remains to be polled during the polling cycle, recycling to step (a);

(d) if all of the high-priority MAC Users have been polled during the

20 contention cycle, polling a next low-priority MAC User;

(e) determining if all of the low-priority MAC Users have been polled during the polling cycle;

(f) if all of the low-priority MAC Users have been polled during the contention cycle, recycling to step (a) to begin a next polling cycle;

25   (g) if at least one of the low-priority MAC Users remains to be polled during the contention cycle, determining whether the low-priority MAC Users have been serviced for the predetermined maximum polling time;

(h) if the low-priority MAC Users have not been serviced for the predetermined maximum polling time, recycling to step (d); and

30   (i) if the low-priority MAC Users have been serviced for the predetermined maximum polling time, recycling to step (a) to begin the next polling cycle.

7.   A device for providing low access delay for time-sensitive applications in a shared medium network wherein each application accesses the shared medium

35 network by way of a MAC User, the device comprising:

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logic for segregating the MAC Users into a high priority group and a low-priority group; and

logic for polling the MAC Users in a series of polling cycles, where each polling cycle comprises:

5   polling each of the high-priority MAC Users; and

subsequent to polling each of the high-priority MAC Users, polling a number of the low-priority MAC Users until one of:

all low-priority MAC Users have been polled; and

the low-priority MAC Users have been serviced for a

10   predetermined maximum polling time.

8.   The device of claim 7 wherein the logic for segregating the MAC Users into a high priority group and a low-priority group comprises:

logic for calculating the average packet size for each MAC User;

15   logic for categorizing the MAC User in the high-priority group, if the average packet size for the MAC User is below a predetermined threshold packet size; and

logic for categorizing the MAC User in the low-priority group otherwise.

9.   The device of claim 8 wherein the average packet size for a MAC User is

20   determined according to an exponential weighted average of the sizes of bursts received from the MAC User calculated according the formula:

average packet size = α * average packet size + (1 - α) * received burst

size;

where α is predetermined weighting factor and the received burst size is the

25   size of the most recently received burst from the MAC User.

10.   A system comprising a headend unit for controlling access by a plurality of MAC Users to a shared transmission medium, wherein the headend unit includes:

logic for segregating the MAC Users into a high priority group and a low-

30   priority group; and

logic for polling the MAC Users in a series of polling cycles, where each polling cycle comprises:

polling each of the high-priority MAC Users; and

subsequent to polling each of the high-priority MAC Users, polling a number of the low-priority MAC Users until one of:

all low-priority MAC Users have been polled; and

the low-priority MAC Users have been serviced for a

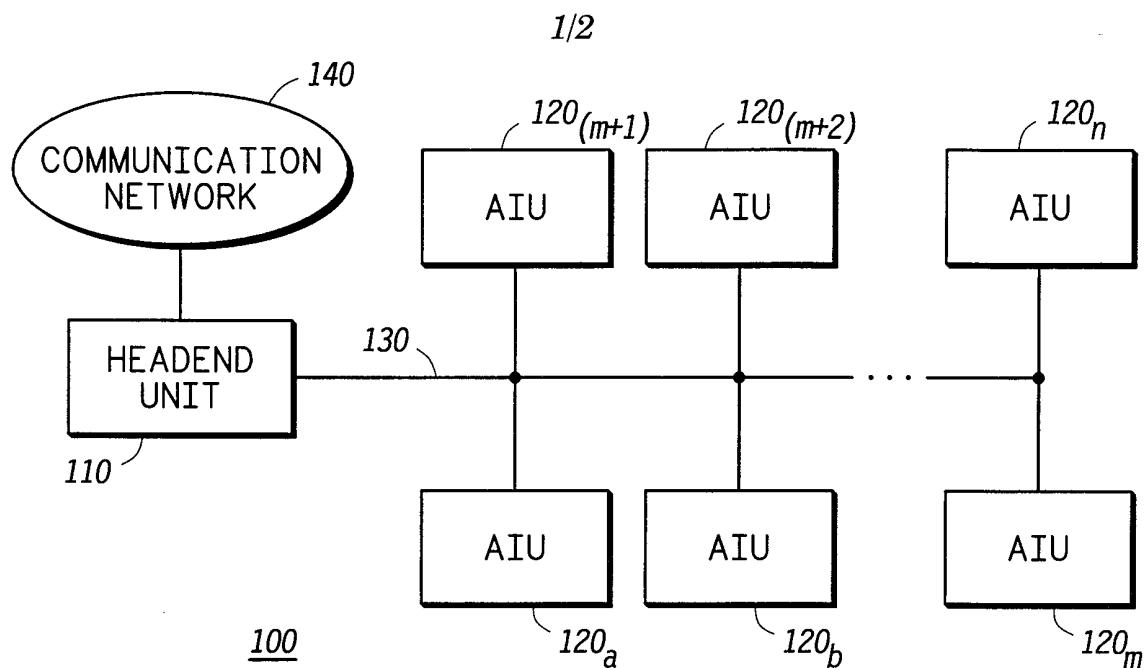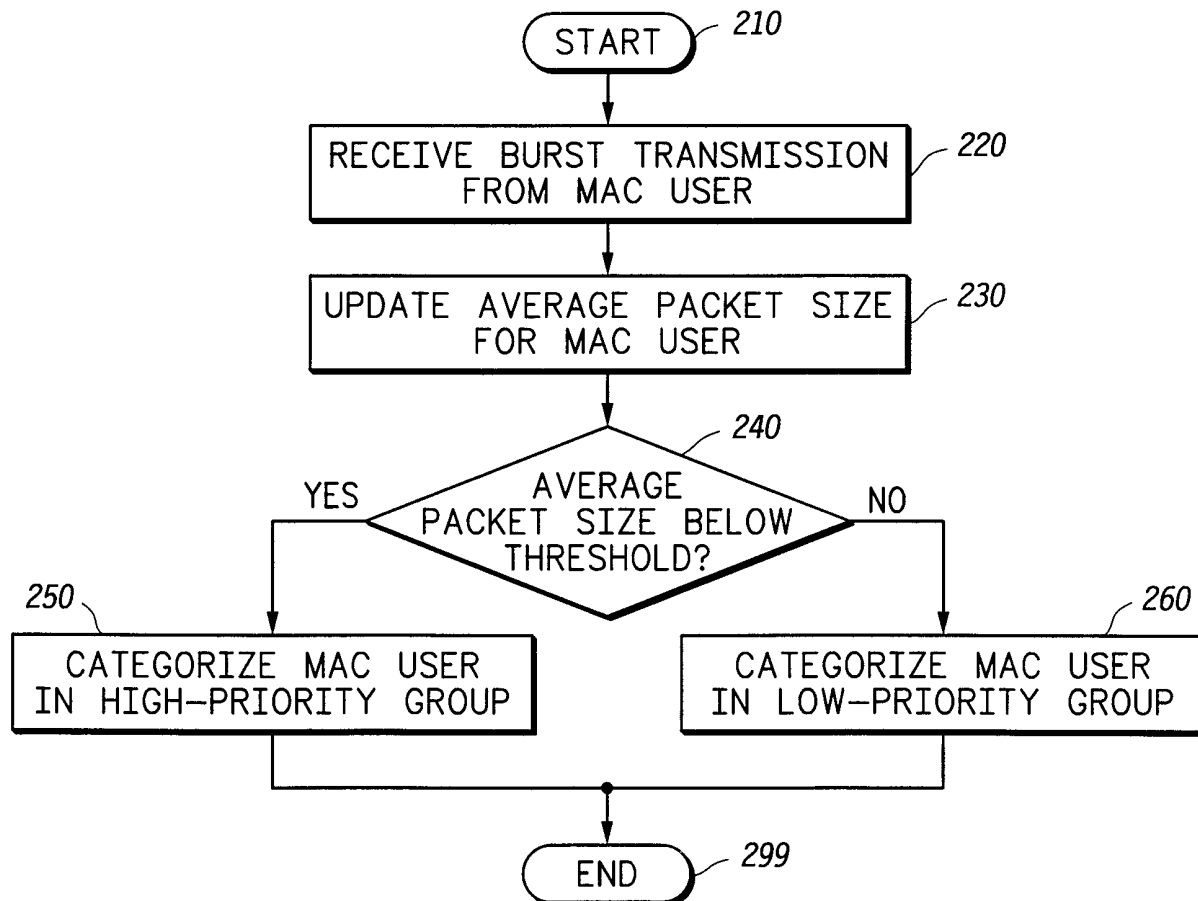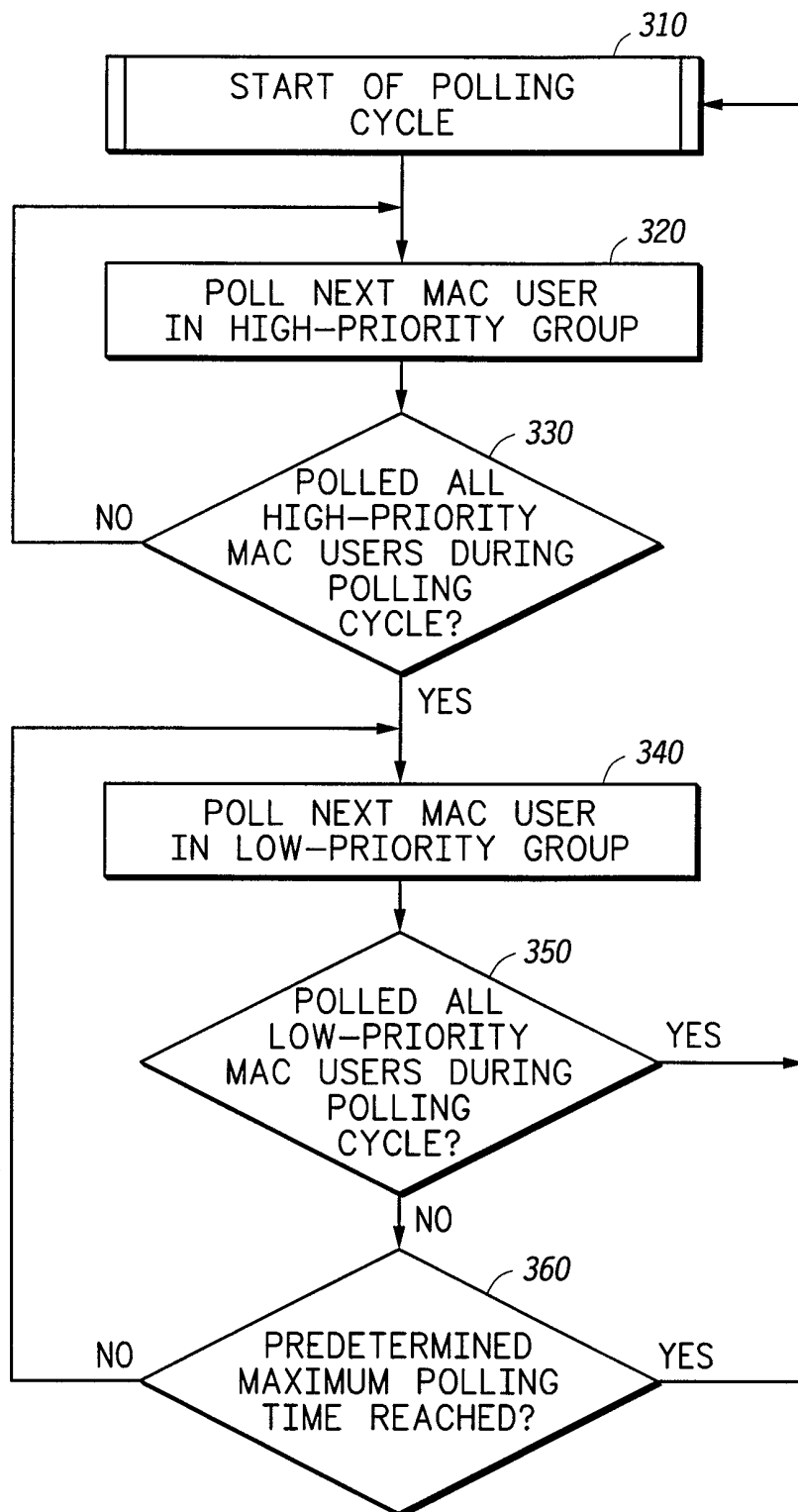5   predetermined maximum polling time.

FIG.1
−PRIOR ART−

FIG.2

2/2

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                                                                 ┌ 310
                    ┌─────────────────────────────────┐
                    │        START OF POLLING          │◄──────┐
                    │             CYCLE                │       │
                    └─────────────────────────────────┘       │
                                      │                        │
        ┌─────────────────────────────┤                        │
        │                             ▼                 ┌ 320   │
        │            ┌─────────────────────────────────┐        │
        │            │       POLL NEXT MAC USER         │        │
        │            │     IN HIGH-PRIORITY GROUP       │        │
        │            └─────────────────────────────────┘        │
        │                             │                          │
        │                             ▼        ┌ 330             │
        │                         ╱       ╲                      │
        │                       ╱  POLLED ALL ╲                  │
        │    NO               ╱   HIGH-PRIORITY  ╲                │
        └────────────────────◄   MAC USERS DURING  ►             │
                               ╲     POLLING     ╱               │
                                 ╲    CYCLE?   ╱                 │
                                   ╲       ╱                     │
                                     ╲   ╱                       │
                                      │ YES                      │
        ┌─────────────────────────────┤                          │
        │                             ▼                 ┌ 340     │
        │            ┌─────────────────────────────────┐          │
        │            │       POLL NEXT MAC USER         │          │
        │            │     IN LOW-PRIORITY GROUP        │          │
        │            └─────────────────────────────────┘          │
        │                             │                            │
        │                             ▼        ┌ 350               │
        │                         ╱       ╲                        │
        │                       ╱  POLLED ALL ╲        YES          │
        │                     ╱   LOW-PRIORITY  ╲──────────────►    │
        │                    ◄   MAC USERS DURING  ►                │
        │                     ╲     POLLING     ╱                   │
        │                       ╲    CYCLE?   ╱                     │
        │                         ╲       ╱                         │
        │                           ╲   ╱                           │
        │                            │ NO                           │
        │                            ▼        ┌ 360                 │
        │                         ╱       ╲                         │
        │   NO                  ╱ PREDETERMINED ╲     YES            │
        └──────────────────────◄ MAXIMUM POLLING  ►────────────────┘
                                ╲  TIME REACHED? ╱
                                  ╲           ╱
                                    ╲       ╱
                                      ╲   ╱
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FIG.3

INTERNATIONAL SEARCH REPORT

A.	CLASSIFICATION OF SUBJECT MATTER

IPC(6)   :H04L 12/403
US CL   :Please See Extra Sheet.

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)

U.S. : 370/449, 442, 443, 444, 445, 450, 451, 454, 455, 458, 462, 463

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 practicable, 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.
Y	US 5,185,737 A (NASSEHI et al) 09 Frebraury 1993, see Figs. 1, 1B, 11, 14, col. 1, lines 59-67, col. 2, lines 1-14, and col. 16, lines 5-46.	1, 3, 7, 8, and 10
Y	US 5,572,517 A (SAFADI) 05 November 1996, see Figs. 1, 3, 4, 7, col. 19, lines 10-49.	1, 3, 7, 8, and 10.

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family 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 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

Date of the actual completion of the international search	Date of mailing of the international search report
09 SEPTEMBER 1998	16 OCT 1998

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer PHIRIN SAM Telephone No. (703) 308-9294

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

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

370/449, 346, 389, 400, 401, 442, 443, 444, 445, 447, 450, 451, 452, 454, 455, 458, 462, 463, 517; 340/825.5, 825.51, 825.2, 825.08