INCREASED BANDWIDTH IN ALOHA-BASED FREQUENCY HOPPING TRANSMISSION SYSTEMS

A method and apparatus that increases bandwidth in Aloha-based frequency hopping transmission systems is disclosed.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
Increased Bandwidth in Aloha-based
Frequency Hopping Transmission Systems

BACKGROUND OF THE INVENTION

TECHNICAL FIELD

The invention relates to transmission systems. More particularly, the invention relates to a method and apparatus that provides increased bandwidth in Aloha-based frequency hopping transmission systems.

DESCRIPTION OF THE PRIOR ART

The installed base of cable television set-top boxes was designed for efficient downstream, i.e. cable plant to subscriber, information delivery. Upstream data transmission, i.e. from subscriber to cable plant, is much more restrictive, supporting only limited bandwidth. As new classes of interactive services become available, it becomes ever more important to increase the upstream transmission bandwidth. For example, if it is necessary to pass voice information from the subscriber to the cable headend (also known as the "headend"), sufficient upstream bandwidth must be made available.

One of the most popular digital set-top boxes, the General Instruments (now Motorola) DCT-2000, is a useful example. When the box was first deployed, upstream transmissions were restricted to user pay-per-view requests, and other infrequent transmissions. As a consequence, the transmission format
used for upstream transmissions was not required to be very efficient, and in fact, it is not very efficient.

In this set-top box, the transmit hardware is capable of selecting twenty different 256K bps channels, each of which uses QPSK transmission coding. While the hardware is capable of frequency-hopping to avoid channels which are subject to interference, the scheme used is fairly static, with typical deployments only using two active upstream communications channels, for an aggregate bandwidth of only 512K bps per cluster of set-top boxes. This cluster is called a node in cable television terms, and typically represents between 500 and 2000 subscribers.

Furthermore, the transmission control protocol used, referred to as Aloha, is one where an individual set-top box immediately transmits any pending request to the headend, without regard to whether or not the channel is already in use. This transmission is repeated at regular intervals until the box receives an acknowledgement command, indicating successful receipt of the transmission.

Downstream data transmission occurs in a separate frequency band from the upstream channels. As is well-understood, this transmission control protocol is quite inefficient due to the number of collisions which ensue, *e.g.* simultaneous transmissions from different set-top boxes which interfere with one another, forcing all of the transmitters to repeat their transmissions again. This leads to typical channel utilization on the order of just 30%. As a
consequence, the total bandwidth available for upstream transmission per
node is only about 30% * 512K bps = ~137K bps, on average.

Transporting voice across this limited bandwidth is not practical because an
individual voice stream requires a minimum of perhaps 4K bps, meaning that
at most (137K / 4K =) 34 people could use the link simultaneously, which is as
little as (34 / 2000 = ) 1.7% of the available households.

It would be advantageous to provide a method and apparatus that increases
bandwidth in Aloha-based frequency hopping transmission systems, for
example, thereby allowing voice transmission in such systems.

**SUMMARY OF THE INVENTION**

The preferred embodiment of the invention provides a method and apparatus
that increases bandwidth in Aloha-based frequency hopping transmission
systems, for example, thereby allowing voice transmission in such systems.

A first step in improving efficiency of known systems is to increase the number
of parallel upstream transmissions by changing known systems from
frequency hopping to a parallel transmission model. To increase upstream
bandwidth, the invention replaces the existing headend receiver with one that
is capable of simultaneously receiving data from all of the possible upstream
channels simultaneously.

Next, by treating the head-end receiver and the set-top boxes as an
integrated system, it is possible to use the existing transmission spectrum
much more efficiently. Instead of enabling each set-top box to perform
frequency hopping, it is much more effective if the head-end receiver is made
responsible for active frequency management of the upstream transmission
spectrum. To do this, when the system is first powered-up, the head-end
receiver examines the RF spectrum to determine which frequencies are
available, and which are not available due to interference from other sources.

After determining which frequencies are free of interference, the headend
receiver then polls the node to determine how many set-top boxes are active
in this node. Once this is complete, the headend receiver partitions the total
number of set-top boxes into an approximately equal number of set-top boxes
for each of the available upstream data channels. That is, the boxes are
assigned a transmission channel. The head-end receiver then commands
each set-top box to tune to the channel it has been assigned by sending the
channel selection information to each set-top box, i.e. using the separate
downstream transmission channel mentioned above.

A second major change to known systems revises the transmission control
protocol from an Aloha system to a slotted assignment system. To do this,
the head-end receiver is used not just to assign each set-top box a specific
transmission channel, but also a specific transmission time slot. By assigning
a specific set-top box to a particular slot, it becomes possible for multiple set-
top boxes to transmit in sequential slots, while assuring that the transmission
packets do not collide.

BRIEF DESCRIPTION OF THE DRAWINGS
Fig. 1 is a block diagram of a system architecture according to the invention;

Fig. 2 is a flow diagram showing a channel assignment scheme according to the invention;

Fig. 3 shows channel and status information and corresponding allocation table entries according to the invention;

Fig. 4 is a timing diagram showing slot assignments according to the invention; and

Fig. 5 shows a flow diagram that the provision of high resolution slot interrupts in a low resolution device.

DETAILED DESCRIPTION OF THE INVENTION

The preferred embodiment of the invention provides a method and apparatus that increases bandwidth in Aloha-based frequency hopping transmission systems thereby allowing, for example, voice transmission in such systems.

Fig. 1 is a block diagram of a system architecture according to the invention. Such systems with which the invention may be used can include, but are not limited to, a headend receiver 10 and one or more set-top boxes 11, 12 between which communication proceeds over a plurality of communications channels, e.g. Channel$_1$-Channel$_N$.

**Hopping-Parallel Transmission**

A first step in improving efficiency of known systems is to increase the number of parallel upstream transmissions. To do this, the nature of the transmission
system must be revised. However, replacing existing set-top boxes is a very expensive proposition, so it is extremely desirable to devise a method of accomplishing this task using existing set-top boxes. The invention achieves this goal by changing such systems from frequency hopping to a parallel transmission model.

To increase upstream bandwidth, the first step is to replace the existing headend receiver with one that is capable of simultaneously receiving data from all of the possible upstream channels simultaneously, i.e. twenty in the case of the DTC-2000 discussed above.

Next, by treating the head-end receiver and the set-top boxes as an integrated system, it is possible to use the existing transmission spectrum much more efficiently. Fig. 2 is a flow diagram showing a channel assignment scheme according to the invention.

Instead of enabling each set-top box to perform frequency hopping, it is much more effective if the head-end receiver is made responsible for active frequency management of the upstream transmission spectrum. To do this, when the system is first powered-up (100) and intermittently thereafter, the head-end receiver examines the RF spectrum to determine which frequencies are available (101), and which are not available due to interference from other sources. After determining which frequencies are free of interference, the headend receiver then polls the node to determine how many set-top boxes are active in this node (102). Once this is determined, the headend receiver partitions the set-top boxes into an approximately equal number of set-top
boxes for each of the available upstream data channels (103). That is, the boxes are assigned a transmission channel. The head-end receiver then commands each set-top box to tune to the channel it has been assigned by sending the channel selection information to each set-top box (104), i.e. using the separate downstream transmission channel mentioned above.

The headend receiver uses an allocation table 14 (Figs. 1 and 3) to keep track of the assignments of channels by storing a mapping between each channel and the set-top box to which the channel is assigned. An important element of the allocation table is that it keeps track of areas which are deemed to be busy. Thus, a key function of a headend receiver is in finding those frequencies which are not available, and eliminating them from the allocation table.

One reason for using frequency hopping is that it is relatively insensitive to interference by virtue of the fact that if there is an interfering carrier, such carrier only interferes with one step of the frequency hopping sequence. Therefore, only a minimal amount of information is lost and an error correction scheme can usually correct for this loss.

In the preferred embodiment of the invention, if there is interference on a channel, e.g. the channel is busy, then the channel is removed from the allocation table and is not allocated to any set-top box until it is no longer busy. Thus, the invention actively avoids interference instead of passively correcting for or responding to such interference because busy channels are actually removed from the allocation table. When there is a need to assign a channel to a set-top box, the headend receiver only sees the available channels, as listed
in the allocation table. When a busy channel becomes free, it is put back into the allocation table and can subsequently be assigned by the headend receiver.

By making this simple change, the number of upstream channels increases dramatically, from typically two upstream channels, to perhaps sixteen channels depending on the amount of interference which is actually present in the upstream transmission spectrum. In the case mentioned above, this provides eight times more upstream transmission bandwidth, allowing up to (1.7% * 8) = 13.6% of households to transmit voice information simultaneously.
Improving Channel Utilization

A second major change to known systems requires no hardware whatsoever, but revises the transmission control protocol from an Aloha system to a slotted assignment system. To do this, the head-end receiver is used not just to assign each set-top box a specific transmission channel, but also a specific transmission time slot (105; see Fig. 2).

For the purposes of this document, a "slot" (see Fig. 4) is a specific slice of time used to transmit information, typically a fraction of a second in length. Here, assume that each second on each channel is divided up into one thousand slots, for a slot length of one millisecond. By assigning a specific set-top box to a particular slot, which is stored in a time slot table 16 (see Fig. 1), it becomes possible for multiple set-top boxes to transmit in sequential slots, while assuring that the transmission packets do not collide.

It is known in time division multiple access systems which of many transmitters is allowed to transmit in a given time slot. One such method is referred to as a reservation protocol in which a talker who wants to talk requests, and is then assigned, one of the available time slots. When that time slot arrives, the talker talks, and then is quiet while others talk. The management and assignment of time slots comes from some central authority, which in the case of a cable modem system is the headend controller. A reserved time slot allows a modem to transmit a known amount of information in a known period. However, if the modem does not wish to use the time slot, the time slot is not available for use by anyone else until the
controller decides that the time slot is available and then assigns it to someone else. (see W. Ciciora, J. Farmer, D. Large, Modern Cable Television Technology, Ch. 4, pp. 199, Morgan Kaufman Publishers, Inc., San Francisco, (1999).

One general problem in known systems is that the assignment of slots normally requires very precise alignment of the timing of each device in the system, such that each transmitter knows precisely when its assigned slot time arrives.

One known technique is to define a guard band such that a worst case clock skew between different transmitters does not result in overlap from slot to slot. This guard band itself often requires a substantial portion of the bandwidth that is available. There are a number of factors that go into computing the optimal guard band, such as local oscillator inaccuracy multiplied by the duration of time between time synchronization, and uncertainty involved in the hardware transmission path, i.e. variation in latency between the various set top boxes for which it is difficult, if not impossible, to account.

The presently preferred method of assigning slots in the system herein is for the downstream data transmitter to broadcast a timestamp at a regular interval 106), e.g. every one second. This heartbeat is received by all set-top boxes in the network, forming a rigid timing standard for the boxes. By repeating the heartbeat at regular, e.g. one second, intervals the inherent timing inaccuracy of the individual set-top boxes is not given the opportunity to become significant because each box resets its slot timers when it receives
the broadcast time-stamp (114). In this manner, a consistent time is maintained throughout the network.

However, an additional problem arises in known cable systems. Because each of the set-top boxes may be at very different distances from the headend, and because each may have a different internal processing speed, the response time from the different set-top boxes is individually skewed, thereby preventing perfect alignment of the different transmission slots. To correct for this, the headend receiver requests that each individual set-top box echo a specific command (108) as rapidly as possible during system initialization (107), while polling the node for attached set-top boxes. At the instant the head-end receiver sends out the command, it begins running an internal timer (17; see Fig. 1). This timer is incremented (110) until a response is received from the set-top box (109). This response may be an echo of the timestamp. The value of the timer once the response has been received is an accurate measure of the propagation delay in the network, plus the processing delay in the particular set-top box. By applying this new knowledge, it becomes possible to align the timing for all set-top boxes in the system (111), so that the slot times are aligned.

Note that a timestamp is used to account for varying delays in downstream transmission. The timestamp which is transmitted contains a value indicating the actual moment in time when the transmitted packet hits the wire. By having the set-top box echo the received timestamp, it becomes possible to measure the precise time overhead or loss inherent in the network and the particular set-top box, even in the presence of varying transmit delay in the
downstream transmitter. Note that maximal accuracy may be obtained by repeating this process several times and averaging the time correction results.

To accomplish slot alignment, the head-end receiver transmits the time correction factor it computed while polling the set-top box back to the set-top box (112). Inside the set-top box, this timing correction factor is subtracted from the nominal slot time to find a corrected slot time (113). By doing so, the set-top box's processing time effectively becomes zero. As a consequence, by the time the set-top box actually begins transmission, its packet is aligned properly to the desired slot transmission point so that sequential transmissions do not interfere with one another.

As a final step, many set-top boxes do not have the hardware clock resolution to enable interrupts to occur at the desired slot frequency. To resolve this, a combination of interrupts and software counters are used to provide finer time granularity. Fig. 5 shows a flow diagram that shows the provision of high resolution slot interrupts in a low resolution device. In essence, a hardware timer interrupt 17 (Fig. 1) is programmed to awaken the CPU at the set-top box at the nearest hardware interrupt point preceding the desired slot interval (150, 151), then software counters 18 are used to count down the remaining time (152) until this set-top box's transmission slot (153, 154). By combining these methods, it becomes possible to have more slots available than the hardware interrupt would otherwise make possible because the slots may be subdivided into sub-slots that are finer than the resolution of the set-top box.
All told, this slotted approach to transmission can increase utilization of individual upstream channels from approximately 30%, to in excess of 80%. As a consequence, the number of simultaneous voice transmissions in the example system described here increases to \((13.6\% \times 80\% / 30\%) = 36\%\), \textit{i.e.} more than twenty times faster than the original installation. This substantial bandwidth increase is crucial because it enables entirely new classes of service to be delivered to subscriber's homes, without requiring expensive replacement of the installed base of set-top boxes.

Although the invention is described herein with reference to the preferred embodiment, one skilled in the art will readily appreciate that other applications may be substituted for those set forth herein without departing from the spirit and scope of the present invention. Accordingly, the invention should only be limited by the Claims included below.
CLAIMS

1. An apparatus for increasing bandwidth in a frequency hopping transmission system, comprising:

   a headend receiver responsible for active frequency management of an upstream transmission RF spectrum, wherein said headend receiver is capable of simultaneously receiving data from all possible upstream channels; and

   one or more set-top boxes, each of said set top boxes being associated with a particular one of one or more nodes;

   wherein communication between said headend receiver and said one or more set-top boxes proceeds via a parallel transmission model over said RF spectrum which comprises a plurality of communications channels.

2. The apparatus of Claim 1, wherein when said apparatus is first powered-up and optionally intermittently thereafter, said head-end receiver periodically examines said RF spectrum to determine which frequencies are available, and which are not available due to interference from other sources.

3. The apparatus of Claim 2, wherein said headend receiver polls said one or more nodes to determine how many of said one or more set-top boxes are active in each node after determining which frequencies are free of interference.

4. The apparatus of Claim 3, wherein said one or more set-top boxes are each assigned to a transmission channel by said headend receiver.
5. The apparatus of Claim 4, wherein said headend receiver partitions said one or more set-top boxes into an approximately equal number of set-top boxes for each of said available upstream data channels.

6. The apparatus of Claim 4, wherein said head-end receiver commands each of said one or more set-top boxes to tune to a channel to which it has been assigned by sending channel selection information to each of said one or more set-top boxes.

7. The apparatus of Claim 6, wherein said headend receiver uses a separate downstream transmission channel to send channel selection information to each of said one or more set-top boxes.

8. The apparatus of Claim 4, wherein headend receiver further comprises:
   an allocation table for keeping track of assignments of channels by storing a mapping between each channel and a set-top box to which said channel is assigned.

9. The apparatus of Claim 8, wherein said allocation table keeps track of areas which are deemed to be busy.

10. The apparatus of Claim 8, wherein said headend receiver finds those frequencies which are not available and eliminates them temporarily from said allocation table.
11. The apparatus of Claim 1, wherein said headend receiver further comprises:

    a slotted assignment system which assigns each of said one or more set-tops boxes a specific transmission slot, wherein each slot comprises a specific slice of time used to transmit information.

12. The apparatus of Claim 11, said slotted assignment system further comprising:

    a guard band such that a worst case clock skew between different transmitters does not result in overlap from slot to slot.

13. The apparatus of Claim 11, said slotted assignment system further comprising:

    a timestamp that is broadcast downstream to each of said one or more set-top boxes at a regular interval.

14. The apparatus of Claim 13, wherein said timestamp is repeated at regular intervals so that inherent timing inaccuracy of individual set-top boxes is not given an opportunity to become significant because each of said one or more set-top boxes resets a slot timer when it receives a broadcast time-stamp.

15. The apparatus of Claim 13, wherein said headend receiver requests that each of said one or more set-top boxes echos a specific command as rapidly as possible periodically, while polling each of said one or more nodes for attached set-top boxes.
16. The apparatus of Claim 15, wherein said headend receiver further comprises:

- a mechanism that begins running an internal timer at the instant said head-end receiver sends out said command to a particular one of said one or more set-top boxes;

- wherein said timer is incremented until a response is received from said particular one of said one or more set-top boxes;

- wherein said response is an echo of said timestamp;

- wherein a value of said timer is an accurate measure of propagation delay plus processing delay in said particular one of said one or more set-top boxes once a response has been received by said headend receiver; and

- wherein a value is generated for each of said one or more set-top boxes to align timing for said one or more set-top boxes.

17. The apparatus of Claim 16, wherein said headend receiver repeatedly operates said mechanism several times and averages time correction results obtained thereby.

18. The apparatus of Claim 16, wherein said head-end receiver transmits a particular time correction factor it computed while polling said one or more set-top boxes back to a corresponding one of said one or more set-top boxes;

- wherein said corresponding one or said one or more set-top boxes subtracts said timing correction factor from a nominal slot time to determine a corrected slot time; and
wherein a transmission packet is aligned properly to a desired slot transmission point by the time said particular one or said one or more set-top boxes actually begins transmission.

19. The apparatus of Claim 12, said slotted assignment system further comprising:
   a mechanism that enables interrupts to occur at a desired slot frequency.

20. The apparatus of Claim 19, said mechanism comprising:
   a timer interrupt programmed to awaken a CPU at each set-top box at
   a nearest hardware interrupt point preceding a desired slot interval; and
   a counter for counting down a remaining time until said set-top box's
   transmission slot is reached;
   wherein said slots are subdivided into sub-slots that are finer than the
   timing resolution of said set-top box.

21. A method for increasing bandwidth in a frequency hopping transmission system, comprising the steps of:
   providing a headend receiver responsible for active frequency management of an upstream transmission RF spectrum, wherein said headend receiver is capable of simultaneously receiving data from all possible upstream channels; and
   providing one or more set-top boxes, each of said set top boxes
   associated with a particular one of one or more nodes;
   wherein communication between said headend receiver and said one
   or more set-top boxes proceeds via a parallel transmission model over said
   RF spectrum which comprises a plurality of communications channels.

22. The method of Claim 21, further comprising the step of:
said head-end receiver examining said RF spectrum to determine which frequencies are available, and which are not available due to interference from other sources.

23. The method of Claim 22, further comprising the step of:

said headend receiver polling said one or more nodes to determine how many of said one or more set-top boxes are active in each node after determining which frequencies are free of interference.

24. The method of Claim 23, further comprising the step of:

said headend receiver assigning each of said one or more set-top boxes to a transmission channel.

25. The method of Claim 24, further comprising the step of:

said headend receiver partitioning said one or more set-top boxes into an approximately equal number of set-top boxes for each of said available upstream data channels

26. The method of Claim 24, further comprising the step of:

said head-end receiver commanding each of said one or more set-top boxes to tune to a channel to which it has been assigned by sending channel selection information to each of said one or more set-top boxes.

27. The method of Claim 26, further comprising the step of:
said headend receiver using a separate downstream transmission channel to send channel selection information to each of said one or more set-top boxes.

28. The method of Claim 24, further comprising the step of:
keeping track of assignments of channels by storing a mapping between each channel and a set-top box to which said channel is assigned in an allocation table associated with said headend receiver.

29. The method of Claim 28, further comprising the step of:
said allocation table keeping track of areas which are deemed to be busy.

30. The method of Claim 28, further comprising the step of:
said headend receiver finding those frequencies which are not available and eliminates them from said allocation table.

31. The method of Claim 21, further comprising the step of:
assigning each of said one or more set-tops boxes a specific transmission slot with a slotted assignment system associated with said headend receiver, wherein each slot comprises a specific slice of time used to transmit information.

32. The method of Claim 31, further comprising the step of:
said slotted assignment system providing a guard band such that a worst case clock skew between different transmitters does not result in overlap from slot to slot.
33. The method of Claim 31, further comprising the step of:
   said slotted assignment system providing a timestamp that is broadcast
downstream to each of said one or more set-top boxes at a regular interval.

34. The method of Claim 32, further comprising the step of:
   repeating said timestamp at regular intervals so that inherent timing
inaccuracy of individual set-top boxes is not given an opportunity to become
significant because each of said one or more set-top boxes resets a slot timer
when it receives a broadcast time-stamp.

35. The method of Claim 33, further comprising the step of:
   said headend receiver requesting that each of said one or more set-top
boxes echo a specific command as rapidly as possible during system
initialization, while polling each of said one or more nodes for attached set-top
boxes.

36. The method of Claim 35, further comprising the steps of:
   providing a mechanism running an internal timer in said headend
receiver at the instant said head-end receiver sends out said command to a
particular one of said one or more set-top boxes;
   incrementing said timer is until a response is received from said
particular one of said one or more set-top boxes;
   wherein said response is an echo of said timestamp;
wherein a value of said timer is an accurate measure of propagation delay plus processing delay in said particular one of said one or more set-top boxes once a response has been received by said headend receiver; and

wherein a value is generated for each of said one or more set-top boxes to align timing for said one or more set-top boxes.

37. The method of Claim 36, further comprising the step of:

said headend receiver repeatedly operating said mechanism several times and averaging time correction results obtained thereby.

38. The method of Claim 36, further comprising the step of:

said head-end receiver transmitting a particular time correction factor it computed while polling said one or more set-top boxes back to a corresponding one of said one or more set-top boxes;

wherein said corresponding one or said one or more set-top boxes subtracts said timing correction factor from a nominal slot time to determine a corrected slot time; and

wherein a transmission packet is aligned properly to a desired slot transmission point by the time said particular one or said one or more set-top boxes actually begins transmission.

39. The method of Claim 32, said slotted assignment system further comprising:

a mechanism that enables interrupts to occur at a desired slot frequency.
40. The method of Claim 39, further comprising the steps of:

   providing a timer interrupt programmed to awaken a CPU at each set-top box at a nearest hardware interrupt point preceding a desired slot interval; and

   providing a counter for counting down a remaining time until said set-top box’s transmission slot is reached;

   wherein said slots are subdivided into sub-slots that are finer that the resolution of said set-top box.

41. A method for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said method comprising the steps of:

   providing a headend receiver responsible for active frequency management of an upstream transmission RF spectrum, wherein said headend receiver is capable of simultaneously receiving data from all possible upstream channels;

   wherein communication between said headend receiver and said one or more set-top boxes proceeds via a parallel transmission model over said RF spectrum which comprises a plurality of communications channels.

42. A method for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said method comprising the steps of:
assigning each of said one or more set-tops boxes a specific transmission slot with a slotted assignment system associated with a headend receiver, wherein each slot comprises a specific slice of time used to transmit information;

providing a timer interrupt programmed to awaken a CPU at each set-top box at a nearest hardware interrupt point preceding a desired slot interval; and

providing a counter for counting down a remaining time until said set-top box's transmission slot is reached;

wherein said slots are subdivided into sub-slots that are finer that the resolution of said set-top box.

43. A method for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said method comprising the steps of:

assigning each of said one or more set-top boxes to a transmission channel with a headend receiver; and

keeping track of assignments of channels by storing a mapping between each channel and a set-top box to which said channel is assigned in an allocation table associated with said headend receiver.

44. An apparatus for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said apparatus comprising:
a headend receiver responsible for active frequency management of an upstream transmission RF spectrum;

wherein said headend receiver further comprises:

a mechanism for simultaneously receiving data from all possible upstream channels; and

a parallel transmission model, wherein communication between said headend receiver and said one or more set-top boxes proceeds over said RF spectrum which comprises a plurality of communications channels.

45. An apparatus for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said apparatus comprising:

means for assigning each of said one or more set-tops boxes a specific transmission slot with a slotted assignment system associated with a headend receiver, wherein each slot comprises a specific slice of time used to transmit information;

a timer interrupt programmed to awaken a CPU at each set-top box at a nearest hardware interrupt point preceding a desired slot interval; and

a counter for counting down a remaining time until said set-top box’s transmission slot is reached;

wherein said slots are subdivided into sub-slots that are finer that a resolution of said set-top box.
46. An apparatus for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said apparatus comprising:

means for assigning each of said one or more set-top boxes to a transmission channel with a headend receiver; and

an allocation table associated with said headend receiver for keeping track of assignments of channels by storing a mapping between each channel and a set-top box to which said channel is assigned.
FIG. 1
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HEAD RECEIVER POWERED UP

DETERMINE WHICH FREQUENCIES ARE AVAILABLE

POLL NODE TO DETERMINE NUMBER OF ACTIVE SET TOP BOXES IN NODE

PARTITION SET TOP

COMMAND SET TOP BOX TO TUNE TO ASSIGNED CHANNEL

ASSIGN SET TOP BOX TO TIME SLOT

BROADCAST TIME STAMP

YES

INITIALIZATION

RESPONSE

NO

INCREMENT TIMER

YES

ASSIGN TIMING TO SET TOP BOX

TRANSMIT CORRECTION FACTOR

NO

RETURN

RESET SET TOP BOX

SUBTRACT IN SET TOP BOX FROM SLOT TIME

CONTINUE

FIG. 2
<table>
<thead>
<tr>
<th>CHANNEL</th>
<th>STATUS</th>
<th>ALLOCATION TABLE</th>
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<tr>
<td>1</td>
<td>BUSY</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>AVAILABLE</td>
<td>2</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>...</td>
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<td>N</td>
<td>BUSY</td>
<td>N-1</td>
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**FIG. 3**

**FIG. 4**
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N7/173

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 7 H04N

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)
WPI Data, EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>Y</td>
<td>US 5 613 191 A (BURTON WILLIAM ET AL) 18 March 1997 (1997-03-18) the whole document</td>
<td>1,21, 41-46 2-20, 22-40</td>
</tr>
<tr>
<td>Y</td>
<td>WO 00 03542 A (PINNACLE VENTURES LTD ; ARDEMAGNI FIORENZO (IT)) 20 January 2000 (2000-01-20) page 15, line 28 - page 16, line 21</td>
<td>1,21, 41-46 2-20, 22-40</td>
</tr>
<tr>
<td>A</td>
<td>US 5 225 902 A (MCMULLAN JR JAY C) 6 July 1993 (1993-07-06) column 5, line 33 - column 7, line 64</td>
<td>1-46</td>
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Date of the actual completion of the international search

8 November 2001

Date of mailing of the international search report

16/11/2001

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Greve, M
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