US 20060064501A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0064501 A1**

Harris et al. (43) **Pub. Date: Mar. 23, 2006**

(54) **REDUCING LOSS IN TRANSMISSION QUALITY UNDER CHANGING NETWORK CONDITIONS**

(75) Inventors: **Ralph L. Harris**, Concord, OH (US); **Steffen Rasmussen**, Novelty, OH (US)

Correspondence Address:
FOGG AND ASSOCIATES, LLC
P.O. BOX 581339
MINNEAPOLIS, MN 55458-1339 (US)

(73) Assignee: **ADC Telecommunications, Inc.**, Eden Prairaie, MN (US)

(21) Appl. No.: **11/272,651**

(22) Filed: **Nov. 14, 2005**

Related U.S. Application Data

(63) Continuation of application No. 09/598,642, filed on Jun. 21, 2000, now Pat. No. 6,973,501.

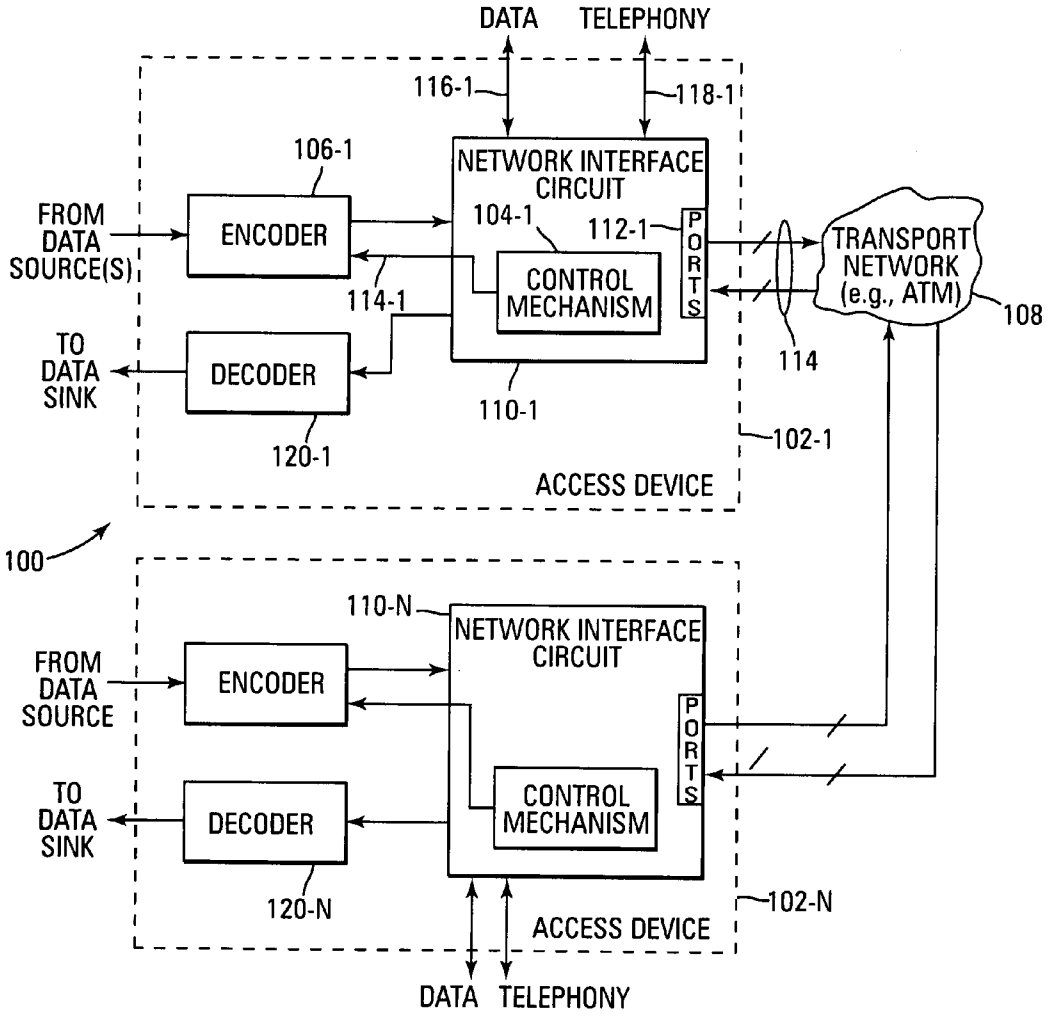
Publication Classification

(51) **Int. Cl.**
G06F 15/16 (2006.01)

(52) **U.S. Cl.** **709/232**

(57) **ABSTRACT**

An apparatus for dynamically controlling the delivery of data over a network is provided. The apparatus includes a network interface circuit with at least one communication port adapted to be coupled to a network. The apparatus further includes an encoder that is communicatively coupled to the network interface circuit. The encoder is adapted to receive data from a source and to encode the data with a selectable level of compression. The network interface circuit includes a control mechanism that provides a signal to select the level of compression for the encoder based on at least one parameter.



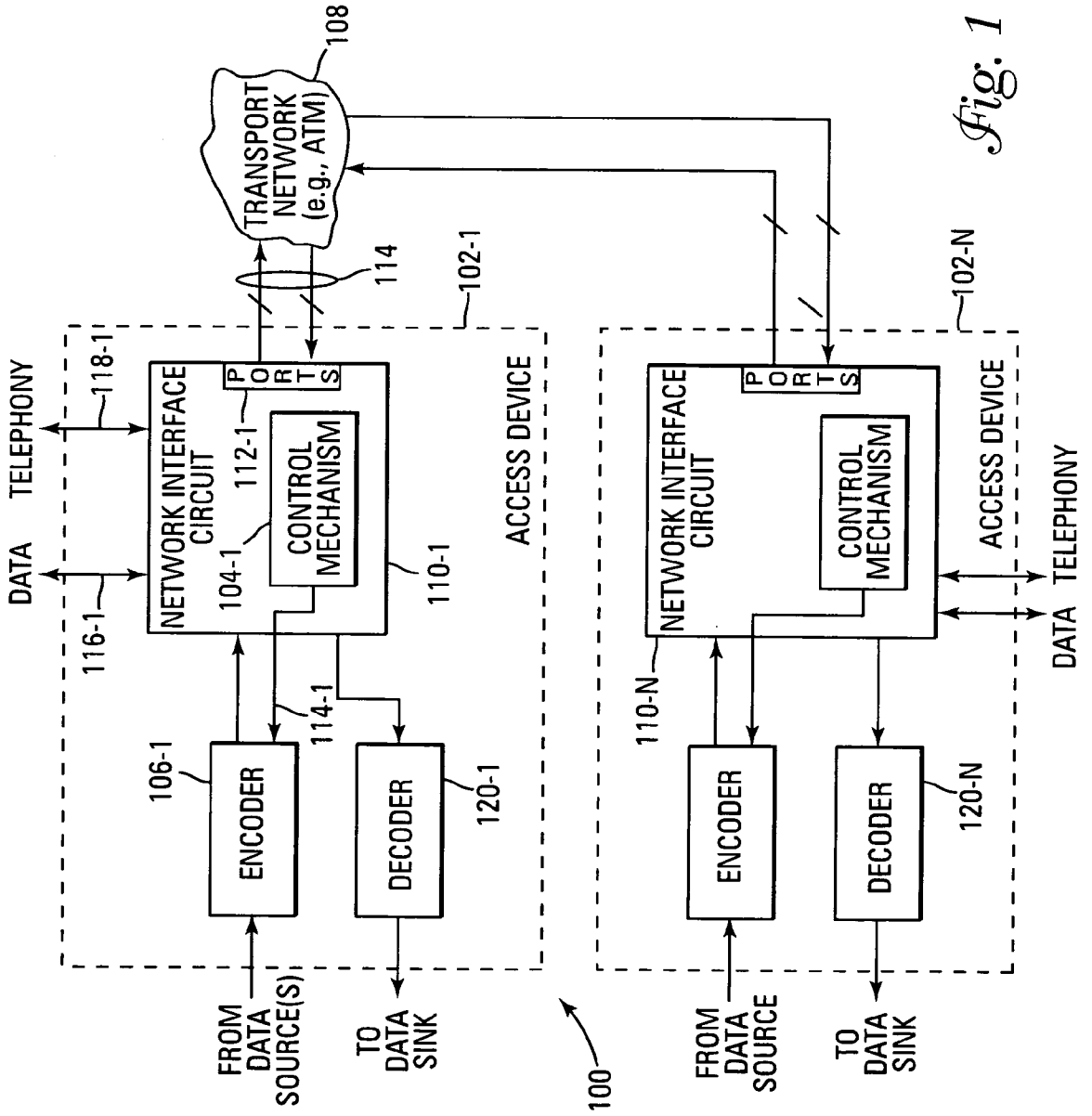

TRANSPORT NETWORK (e.g., ATM)
108
114
102-1
102-N
ACCESS DEVICE
ACCESS DEVICE
DATA
TELEPHONY
118-1
116-1
NETWORK INTERFACE CIRCUIT
104-1
PORTS
112-1
CONTROL MECHANISM
110-1
110-N
114-1
106-1
ENCODER
DECODER
120-1
120-N
FROM DATA SOURCE(S)
TO DATA SINK
FROM DATA SOURCE
TO DATA SINK
100

Fig. 1

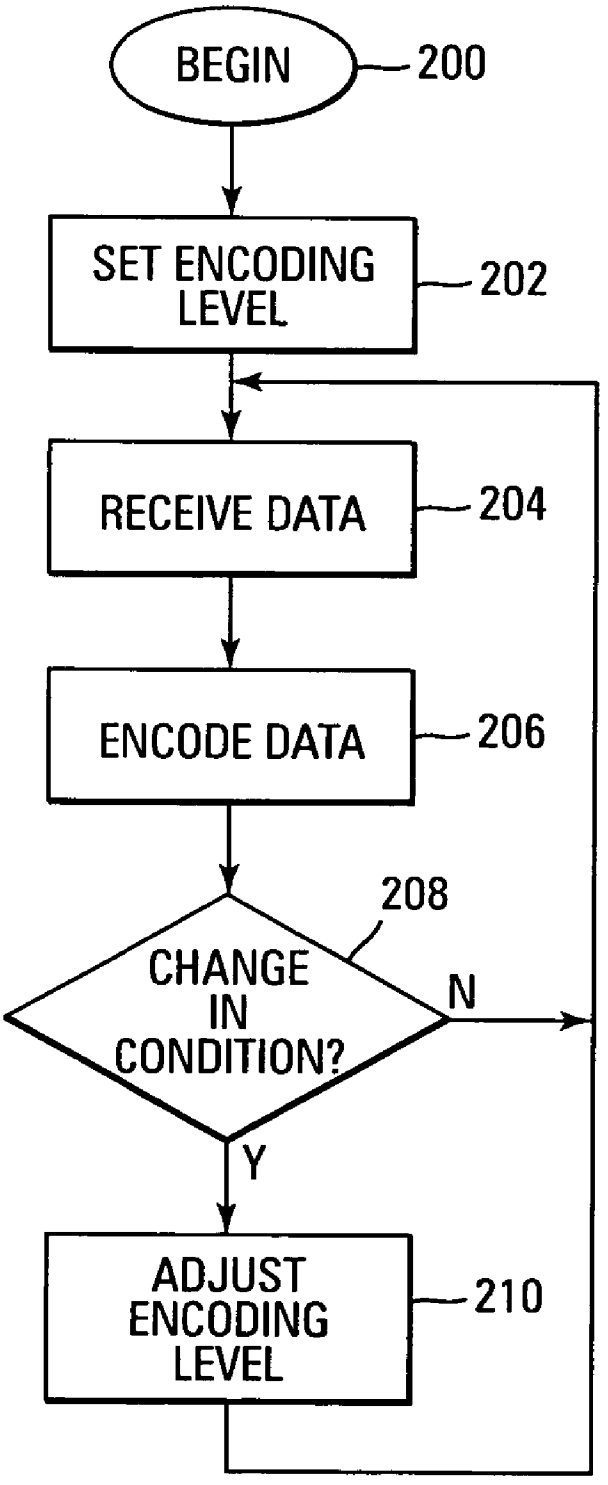

BEGIN
200
SET ENCODING LEVEL
202
RECEIVE DATA
204
ENCODE DATA
206
208
CHANGE IN CONDITION?
N
Y
ADJUST ENCODING LEVEL
210

Fig. 2

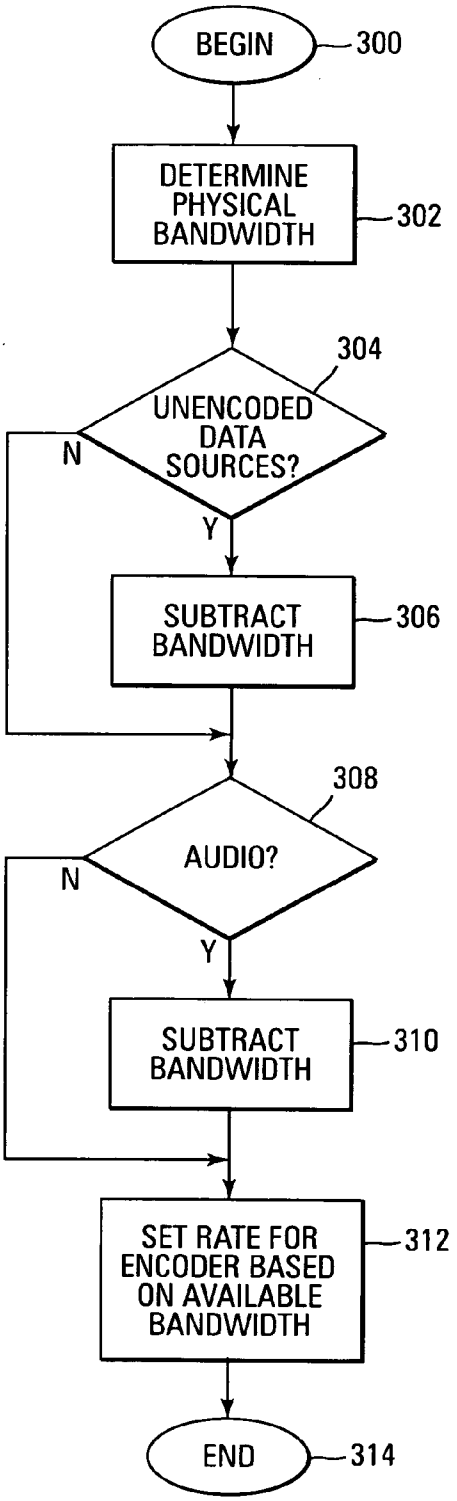

BEGIN
300
DETERMINE PHYSICAL BANDWIDTH
302
304
UNENCODED DATA SOURCES?
N
Y
SUBTRACT BANDWIDTH
306
308
AUDIO?
N
Y
SUBTRACT BANDWIDTH
310
SET RATE FOR ENCODER BASED ON AVAILABLE BANDWIDTH
312
END
314

Fig. 3

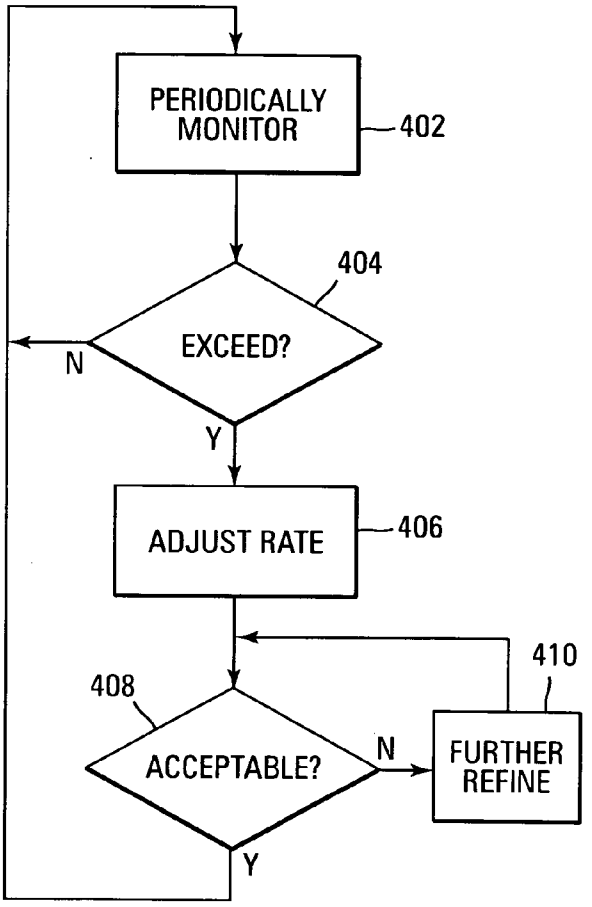

PERIODICALLY MONITOR
402
404
EXCEED?
N
Y
ADJUST RATE
406
410
408
ACCEPTABLE?
N
FURTHER REFINE
Y

Fig. 4

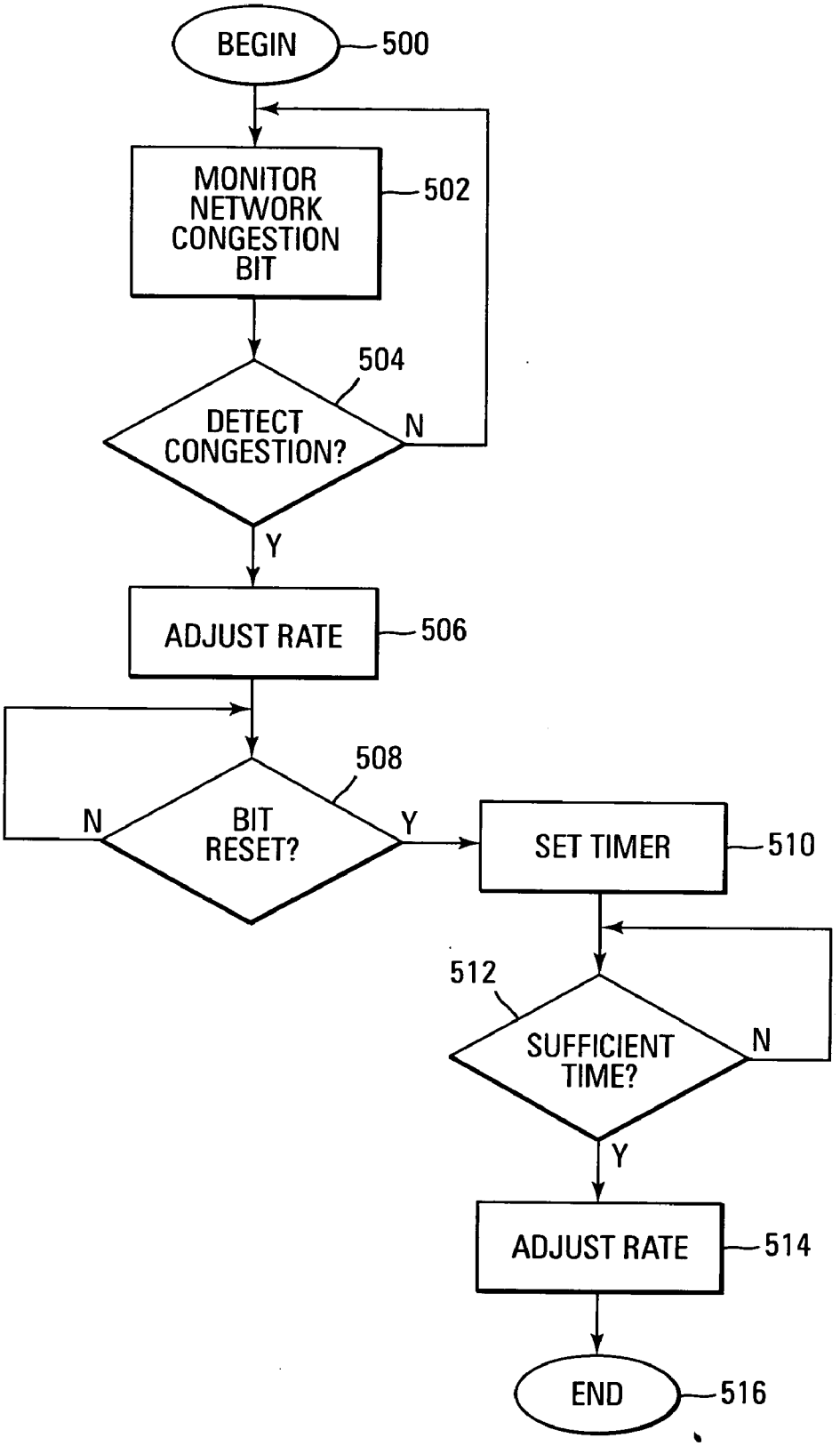

BEGIN
500
MONITOR NETWORK CONGESTION BIT
502
504
DETECT CONGESTION?
N
Y
ADJUST RATE
506
508
BIT RESET?
N
Y
SET TIMER
510
512
SUFFICIENT TIME?
N
Y
ADJUST RATE
514
END
516

Fig. 5

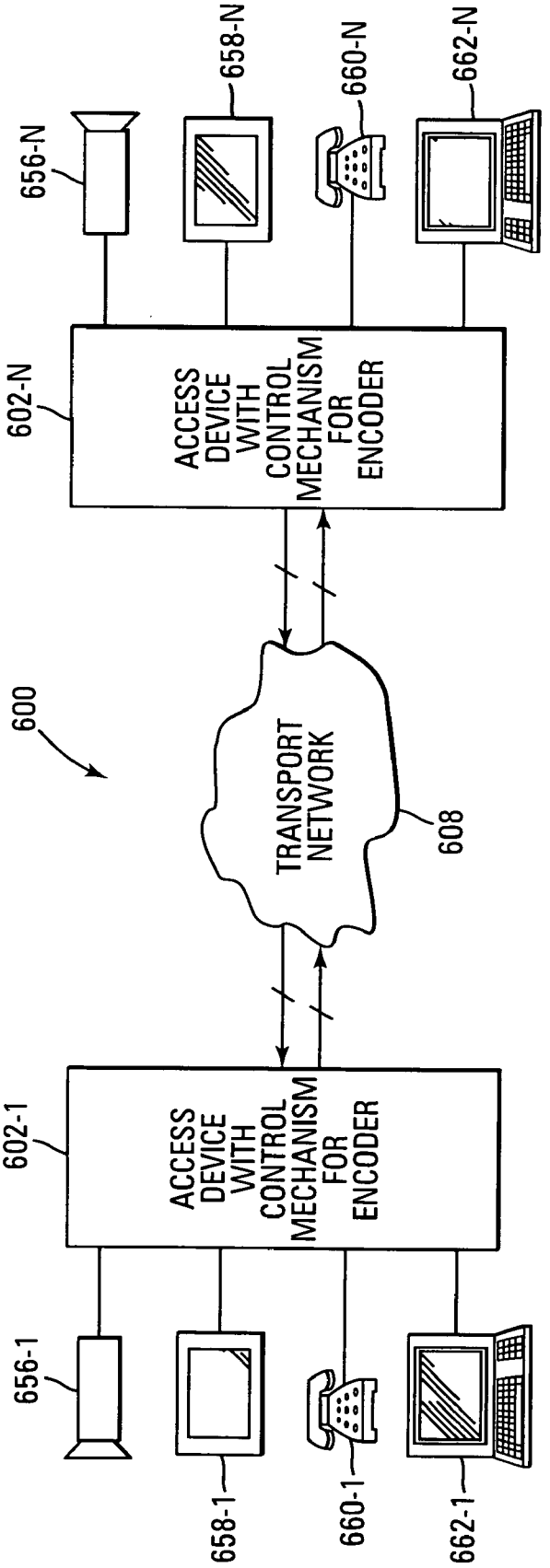

600
602-N
ACCESS DEVICE WITH CONTROL MECHANISM FOR ENCODER
656-N
658-N
660-N
662-N
TRANSPORT NETWORK
608
602-1
ACCESS DEVICE WITH CONTROL MECHANISM FOR ENCODER
656-1
658-1
660-1
662-1

Fig. 6

REDUCING LOSS IN TRANSMISSION QUALITY UNDER CHANGING NETWORK CONDITIONS

[0001] This application is a continuation of U.S. application Ser. No. 09/598,642, filed on Jun. 21, 2000.

TECHNICAL FIELD

[0002] The present invention relates generally to the field of telecommunications and, in particular, to reducing loss in transmission quality under changing network conditions.

BACKGROUND

[0003] Telecommunication networks transport signals between devices, e.g., telephones, computers, facsimile machines, televisions and other devices, at diverse locations. Originally, telecommunication networks were designed to carry primarily voice traffic. Thus, the telephone network was designed around frequency channels with a narrow frequency band, e.g., a low data rate.

[0004] With the introduction of computers, the telephone networks have been called on to carry additional types of traffic, e.g., video, and high-speed data. Further, new telecommunications networks have been developed, e.g., asynchronous transfer mode (ATM) networks, to respond to the need for transmitting higher volumes of data at higher speeds.

[0005] Video traffic typically is data intensive. To reduce the burden of the video traffic on the telecommunications network, it is common practice to compress the video data prior to transmission. Several standards exist for compressing video data. For example, the Motion Picture Expert Group has promulgated a family of standards for compression of video data referred to as the "MPEG" standards. Under these standards, the amount of data compression is selectable and can vary from application to application. With video compression, an encoder essentially transmits signals to a corresponding decoder that includes changes in the video image from frame-to-frame. The decoder reproduces the original video signal based on the transmitted changes.

[0006] Once compressed, video data is typically provided to a transport network, e.g., an ATM network, through a network interface card. The network interface card used in a specific embodiment depends on the type of connection to the network. For example, an inverse multiplexer (IMUX) is used in some systems to provide a connection to the network via a plurality of time division multiplexed connections, e.g., T1, and E1 connections. The ATM Forum has promulgated a specification for transport of ATM cells using an inverse multiplexer. The standard is titled "Inverse Multiplexing for ATM (IMA) Specification Version 1.1," AF-PHY-0086.001, March 1999 (the "IMA Specification"). The IMA specification is incorporated by reference. In other systems, the network interface card comprises an interface for a DS3 line or other appropriate interface card based on the type of connection to the network.

[0007] In current designs, a problem exists in delivering compressed video over a network via an IMUX network interface card such as an IMA compliant IMUX. The problem arises when one of the plurality of T1 or E1 connections carrying the video data to the network is lost. When the connection is lost, the available bandwidth that was used to deliver the video data is reduced. Eventually, some of the video data is lost during transmission over the network.

[0008] At the video decoder, the results of the loss of the connection can be catastrophic. The video decoder continues to attempt to reconstruct the video signal from the data received over the network. With portions of the data missing, the decoder begins to produce a lower quality video output since not all changes for a given frame are received. Due to the nature of compressed video, this problem is only compounded with each passing frame of video. Thus, it does not take long before the quality of the video output at the receiver is completely degraded.

[0009] For the reasons stated above, and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for a mechanism that reduces loss in transmission quality under changing network conditions.

SUMMARY

[0010] The above-mentioned problems with telecommunications networks and other problems are addressed by embodiments of the present invention and will be understood by reading and studying the following specification. Embodiments of the present invention provide a mechanism that assures quality of data transmission over a network by monitoring at least one parameter for the network and, when necessary, adjusting the compression of data to account for the changed condition. Advantageously, this mechanism operates on the fly and can account for changes on a frame-by-frame basis in video transmission.

[0011] More particularly, in one embodiment an apparatus for dynamically controlling the delivery of data over a network is provided. The apparatus includes a network interface circuit with at least one communication port adapted to be coupled to a network. The apparatus further includes an encoder that is communicatively coupled to the network interface circuit. The encoder is adapted to receive data from a source and to encode the data with a selectable level of compression. The network interface circuit includes a control mechanism that provides a signal to select the level of compression for the encoder based on at least one parameter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1** is a block diagram of an embodiment of a telecommunications network including an access device with a control mechanism that establishes a level of compression for an encoder for at least one data source according to the teachings of the present invention.

[0013] **FIG. 2** is a flowchart of an embodiment of a process for the operation of the network of **FIG. 1**.

[0014] **FIG. 3** is a flowchart of an embodiment of a process for generating a control signal to adjust a level of compression for an encoder in an access device according to the teachings of the present invention.

[0015] **FIG. 4** is a flowchart of an embodiment of a process for adjusting a level of compression for an encoder in an access device of a telecommunications network according to the teachings of present invention.

[0016] **FIG. 5** is a flowchart of another embodiment of a process for adjusting a level of compression for an encoder in an access device of a telecommunications network according to the teachings of the present invention.

[0017] **FIG. 6** is a block diagram of an embodiment of a distance learning system that includes a plurality of access devices each with a control mechanism that establishes a level of compression for an encoder for at least one data source according to the teachings of the present invention.

DETAILED DESCRIPTION

[0018] In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific illustrative embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

[0019] **FIG. 1** is a block diagram of an embodiment of a telecommunications network, indicated generally at **100**, including access devices **102-1**, . . . , **102**-N each with an associated control mechanism **104-1**, . . . , **104**-N that establishes a level of compression for an associated encoder **106-1**, . . . , **106**-N for at least one data source according to the teachings of the present invention. Network **100** further includes transport network **108** that couples access device **102-1**, . . . , **102**-N together. Due to the similarities between access device **102-1** and **102**-N, only access device **102-1** is described in detail. However, it is understood that the other access devices in network **100** are constructed in a similar manner. Further, although only two access devices are shown in **FIG. 1**, it is understood that any appropriate number of access devices may be included in a particular application.

[0020] Access device **102-1** is coupled to transport network **108** through network interface circuit **110-1**. In one embodiment, network interface circuit **110-1** comprises an inverse multiplexer (IMUX) that is compliant with the IMA Specification incorporated by reference above. In other embodiments, network interface circuit **110-1** comprises a network interface card that is compatible with a communication medium used to connect access device **102-1** with transport network **108**, e.g., an inverse multiplexer, a DS3 card, a network interface card for an optical link or the like.

[0021] Network interface circuit **110-1** includes a plurality of ports **112-1** for connection to transport network **108**. Ports **112-1** are coupled to transport network **108** over a plurality of communication links **114**. In one embodiment, transport network **108** comprises an asynchronous transfer mode (ATM) network. Further, in one embodiment, communication links **114** comprise a plurality of T1 or E1 communication links. In other embodiments, communication links **114** comprise a DS3 communication link, fiber-optic links or any other appropriate communication link that is adapted to carry data to transport network **108**.

[0022] Network interface circuit **110-1** further includes control mechanism **104-1**. Control mechanism **104-1** is coupled to encoder **106-1** over bus **114-1**. In one embodiment, bus **114-1** comprises a PCI bus. Further, in one embodiment, encoder **106-1** comprises an encoder that is compatible with at least one of the standards promulgated by the Motion Picture Expert Group (MPEG) for compression of video data. In other embodiments, encoder **106-1** uses any other appropriate compression algorithm for compressing data from the data source.

[0023] In one embodiment, network interface circuit **110-1** is co-located in a housing with encoder **106-1**. Advantageously this allows control mechanism **104-1** to communicate easily with encoder **106-1** to control its level of compression or data rate.

[0024] In one embodiment, network interface circuit **110-1** further includes data port **116-1** and telephony ports **118-1**. Data port **116-1** is adapted to be coupled to, for example, a 10BaseT Ethernet local area network (LAN), a 100BaseT Ethernet LAN, or other appropriate data network. Similarly, telephony port **118-1** is adapted to be coupled to any appropriate telephony communication line, e.g., a T1 or E1 line.

[0025] Access device **102-1** further includes decoder **120-1**. Decoder **120-1** is used to decode data received from an encoder located in another access device connected to transport network **108**. Thus, in some embodiments, a particular access device may include an encoder, a decoder, or both an encoder and a decoder. Therefore, although access device **102-1** and **102**-N each show an encoder and a decoder, it is understood that access devices in network **100** are not limited to including both an encoder and a decoder. The operation of system **100** is described in terms of the flowchart of **FIG. 2**.

[0026] In operation, network **100** transports data between access devices over transport network **108**. Advantageously, network **100** includes control mechanism **104-1** that adjusts a level of encoding in encoder **106-1** to reduce loss of transmission quality in response to changing network conditions. The method begins a block **200**. A block **202** control mechanism **104-1** sets a level of encoding for encoder **106-1**. For example, control mechanism **104-1** communicates a rate for encoder **106-1** over PCI bus **114-1**. In another embodiment, control mechanism **104-1** also provides further parameters to encoder **106-1** to control the encoding level of encoder **106-1**.

[0027] Access device **102-1** generates data for transmission over transport network **108**. At block **204**, encoder **106-1** receives data from at least one data source. In one embodiment, the at least one data source comprises a source of video data, e.g., a camera, video player, or other appropriate source of video data. At block **206**, encoder **106-1** encodes the data received from the data source using the level of compression specified at block **206**. Encoder **106-1** provides the encoded data to network interface circuit **110-1**. Network interface circuit **110-1** passes the encoded data over connections **114** to transport network **108**. Transport network **108** routes the data to, for example, access device **102**-N. In access device **102**-N, network interface circuit **110**-N passes the encoded data to decoder **120**-N. Decoder **120**-N decodes the data and provides the data to the data sink, for example, a television, a monitor, a computer, or other appropriate data sink.

[0028] At block **208**, control mechanism **104-1** determines whether a change in condition has been detected on network

100. For example, control mechanism **104-1** determines whether one or more of communication links **114** has become unusable, e.g., the link is cut or disconnected. Alternatively, control mechanism **104-1** monitors a congestion bit for transport network **108** or other diagnostic mechanism for monitoring the capacity of transport network **108**, e.g., buffer levels, statistics on cell loss, cyclic redundancy check at the ATM layer, cyclic redundancy check at the MPEG layer, or other appropriate statistic. In one embodiment, the end-to-end channel of an IMA Control Protocol (ICP) cell, specified in the IMA Specification, is used to communicate a changed condition between access devices. For example, the state of buffers at a decoder requiring a change in the rate of the encoder or a lost connection detected at the decoder is communicated over the end-to-end channel to the access device and encoder associated with transmission to the decoder.

[**0029**] When a change in network conditions is detected, control mechanism **104-1** provides a signal to encoder **106-1** to adjust its level of encoding. For example, when a communication link is lost, control mechanism **104-1** calculates a new rate of encoding for encoder **106-1** and transmits the new rate to encoder **106-1** over bus **114-1** at block **210**. Further, control mechanism **104-1** may also provide information on the rate change to the associated decoder over, for example, the end-to-end channel of an ICP cell.

[**0030**] In one embodiment, control mechanism **104-1** controls the rate of encoding for a plurality of sources. In some embodiments, control mechanism **104-1** reduces data rates for all sources proportionately. In other embodiments, control mechanism **104-1** reduces data rates for each source selectively based on a set algorithm or criteria. In other embodiments, control mechanism **104-1** adjusts other inputs to encoder **106-1** to adapt the output of encoder **106-1** to the changed condition. These other inputs can be used as a primary control of encoder **106-1** or as a secondary adjustment implemented after an initial rate change. The other inputs include, but are not limited to, settings for quantizers, buffer sizes, on/off padding, coefficients, video resolution, and any other appropriate adjustments or inputs acceptable to the encoder.

[**0031**] **FIG. 3** is a flowchart of an embodiment of a process for generating a control signal to adjust a level of encoding for an encoder in an access device according to the teachings of the present invention. This method is implemented, for example, in control mechanism **104-1** of access device **102-1** in system **100** during a synchronization process. The synchronization process may be accomplished either when a connection for a data stream is initialized, or during a resynchronization process after a change in bandwidth.

[**0032**] The method begins a block **300**. At block **302**, the method determines the physical bandwidth available for the access device. For example, when a number of physical links are used, the method calculates the available bandwidth by multiplying the number of links times the link rate. At block **304**, the method determines whether any unencoded data sources are provided to the access device. If unencoded data sources are provided to the access device, the method subtracts out bandwidth associated with the unencoded data sources at block **306** from the physical bandwidth determined at block **302**. If there are no unencoded data sources, the method proceeds directly to block **308**.

[**0033**] At block **308**, the method determines whether the access device receives any audio data. If the access device receives audio data, the method subtracts out bandwidth associated with the audio data at block **310**. If, however, the access device does not receive audio data, the method proceeds directly to block **312**.

[**0034**] At block **312**, the method sets the rate for the encoder of the access device based on the available bandwidth. The method ends at block **314**.

[**0035**] **FIG. 4** is a flowchart of an embodiment of a process for adjusting a level of encoding for an encoder in an access device of a telecommunications network according to the teachings of present invention. This method is implemented, for example, in control mechanism **104-1** of access device **102-1** in system **100**. In one embodiment, the method of **FIG. 4** is implemented as part of diagnostic routines that periodically monitor aspects of access device **102-1** as indicated at block **402**. This monitoring includes, for example, monitoring of buffer levels, loss of cells, error levels as indicated based on cyclic redundancy checks based on cells at the ATM layer or at the MPEG layer or other appropriate parameters or conditions of the network.

[**0036**] At block **404**, the method determines whether a threshold in the monitored condition has been exceeded. If the threshold has been exceeded, the method adjusts the rate of the encoder at block **406**, e.g., reduces the level of encoding to compensate for the excess in errors in the system.

[**0037**] At block **408**, the method determines whether the monitored condition is acceptable after adjusting the rate. If not, the method proceeds to refine the rate at block **410** and returns to block **408**. If, however, the method determines that the monitored condition is acceptable, the method returns to block **402**. Similarly, if the method determines a block **404** that the threshold has not been exceeded, the method also returns to block **402**.

[**0038**] **FIG. 5** is a flowchart of another embodiment of a process for adjusting a level of compression for an encoder in an access device of a telecommunications network according to the teachings of the present invention. This method is implemented, for example, in control mechanism **104-1** of access device **102-1** in system **100**. In one embodiment, the method of **FIG. 5** is implemented as part of a diagnostic routine that periodically monitors a network congestion bit.

[**0039**] The method begins at block **500** and monitors a network congestion bit at block **502**. At block **504**, the method determines whether the network congestion bit indicates congestion in the network. If not, the method returns to block **502**. If, however, the method determines that there is network congestion, the method proceeds to block **506**. At block **506**, the method adjusts the rate of the encoder, e.g., reduces the output rate of the encoder, to compensate for the network congestion.

[**0040**] At block **508**, the method determines whether the congestion bit has been reset. If not, the method returns to block **508**. If, however, the congestion bit has been reset, the

method proceeds to block **510**. At block **510**, the method sets a timer. At block **512**, the method determines whether sufficient time has elapsed since the reset of the congestion bit to allow the encoder to return to a higher data rate. If not, the method returns to block **512**. If, however, sufficient time has elapsed, the method proceeds to block **514** and adjusts the rate of the encoder, e.g., returns the encoder to the original rate.

[**0041**] **FIG. 6** is a block diagram of an embodiment of a distance learning system, indicated generally at **600**, that includes a plurality of access devices **602-1**, . . . , **602**-N each with a control mechanism that establishes a level of compression for an encoder for at least one data source according to the teachings of the present invention. In one embodiment, each of access devices **602-1**, . . . , **602**-N is constructed as shown and described above with respect to **FIG. 1**. Further, each of access devices **602-1**, . . . , **602**-N implements one or more of the functions described above with respect to **FIGS. 1 through 5**. Access devices **602-1**, . . . , **602**-N are coupled together over transport network **608**. In one embodiment, transport network **608** comprises an ATM network coupled to the access devices over a plurality of T1 or E1 lines.

[**0042**] Distance learning system **600** includes a plurality of data sources coupled to each access device. For example, access device **602-1** is coupled to receive data from camera/microphone **656-1**, telephone **661**, and computer or network **662-1**. Access device **602-1** is similarly coupled to a plurality of data sources. Further, each access device also includes one or more data sinks, e.g., monitor/speakers **658-1**, telephone **661**, and computer or network **662-1**. It is understood, however, that each access device may be coupled to any appropriate combination or subcombination of data sources and data sinks.

[**0043**] In operation, distance learning system **600** transport data between access devices over transport network **608**. Advantageously, access devices **602-1**, . . . , **602**-N each include a control mechanism that controls an encoder based on conditions in the network as described above with respect to one or more of **FIGS. 1 through 5**.

CONCLUSION

[**0044**] Embodiments of the present invention have been described. The embodiments provide a mechanism for reducing loss in quality transmission over a network with changing network conditions. Specifically, embodiments of the present invention utilize a control mechanism that adjusts the level of encoding for an encoder based on a monitored condition or parameter of a network. For example, the control mechanism may adjust the encoding level based on the monitored bandwidth availability, network congestion bit, or other statistical information relating to the quality of transmission over a network.

[**0045**] Although specific embodiments have been illustrated and described in this specification, it will be appreciated by those of ordinary skill in the art that any arrangement that is calculated to achieve the same purpose may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. For example, the transport network in other embodiments comprises other packet-based networks. Further, the control mechanism of an access device provides control data to an associated encoder over any appropriate communications mechanism. An access device in other embodiments includes one or more encoders and one or more decoders. Further, in some embodiments, an access device includes no decoders. Further, in other embodiments, other parameters or statistics that indicate the quality of transmission in the network may be used by a control mechanism to adjust the rate of an encoder.

what is claimed is:

1. A method for controlling delivery of video over an asynchronous transfer mode (ATM) network, the method comprising:

establishing a first encoding level for a video encoder;

receiving video data from at least one video source;

encoding the video data with the first encoding level;

transmitting the encoded video data over a plurality of communication lines to the ATM network via an inverse multiplexer; and

when at least one of the plurality of communication lines becomes unusable, modifying the encoding level to encode with a second, different rate.

2. The method of claim 1, wherein establishing a first encoding level comprises establishing a data rate for an MPEG encoder.

3. The method of claim 1, wherein receiving video data comprises receiving video data from a plurality of video sources.

4. The method of claim 1, wherein transmitting the encoded video data over a plurality of communication lines comprises transmitting the encoded video data over a plurality of T1 or E1 lines.

5. The method of claim 1, wherein modifying the encoding level comprises reducing the data rate.

6. The method of claim 5, and further comprising:

when at least one of the plurality of connections becomes unusable:

calculating an available bandwidth for delivering the video data; and

establishing a second, different data rate for a video encoder used to deliver the video data based on the currently available bandwidth.

7. An access device, comprising:

an inverse multiplexer having a plurality of network ports adapted to couple to a plurality of communication lines for an asynchronous transfer mode (ATM) network;

an encoder, communicatively coupled to the inverse multiplexer, that is adapted to receive data from at least one audio/video source;

a control mechanism, communicatively coupled with the inverse multiplexer and the encoder, the control mechanism producing at least one control signal to control the rate of the encoder based on a condition of the ATM network; and

wherein the encoder, the control mechanism, and the inverse multiplexer are located in a common housing.

8. The access device of claim 7, wherein the inverse multiplexer includes a data port adapted to couple to at least

one data source, and at least one telephony port adapted to couple to at least one telephony line.

9. The access device of claim 7, wherein the encoder and the control mechanism are communicatively coupled over a bus.

10. The access device of claim 7, wherein the encoder comprises an MPEG encoder.

11. The access device of claim 7, wherein the control mechanism reduces the rate of the encoder when one of the plurality of connections to the ATM network is unusable.

12. An apparatus for dynamically controlling the delivery of data over a network, the apparatus comprising:

a network interface circuit with at least one communication port adapted to be coupled to a network;

an encoder, communicatively coupled to the network interface circuit, the encoder adapted to receive data from a source and to encode the data with a selectable level of compression; and

wherein the network interface circuit includes a control mechanism that provides a signal to select the level of compression for the encoder based on one parameter;

wherein the network interface circuit comprises an inverse multiplexer (IMUX) with a plurality of network ports, each network port adapted to be coupled to a selected communication link of the network.

13. The apparatus of claim 12, wherein the encoder is adapted to receive data from at least one of a video source, and an audio source.

14. The apparatus of claim 12, wherein the network interface circuit further is adapted to receive at least one of high-speed data and telephony data.

15. The apparatus of claim 12, wherein the encoder comprises an encoder that is adapted to receive input from a plurality of data sources.

16. The apparatus of claim 12, wherein each port is adapted to be coupled to at least one of a T1 and an E1 communication link.

17. The apparatus of claim 12, and further comprising a bus, communicatively coupling the network interface circuit and the encoder, the bus being adapted to carry commands from the control mechanism of the network interface circuit to the encoder.

18. The apparatus of claim 12, wherein the control mechanism generates signals to control the rate of the encoder based on at least one of available bandwidth, buffer levels and signals over an end-to-end channel of the network.

* * * * *