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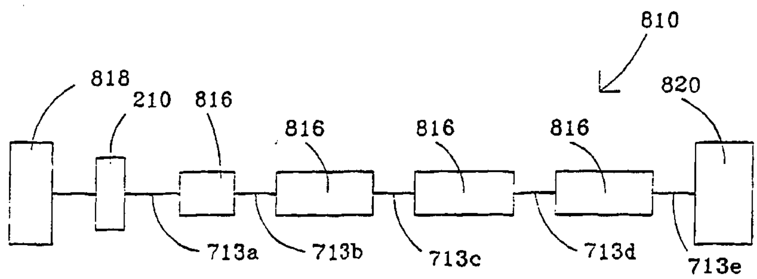

(57) Abstract

A variable latency cut through bridge (210) for selectively forwarding data packets (10) within a network (310) of computers (312), the variable latency cut through bridge (210) employing a variable latency bridging method wherein the latency factor of the variable latency cut through bridge (210) is set according to the position of a variable threshold point (428). The variable threshold point (428) is optionally set to within a rapid drop off portion (520) of a probability line (514) describing the probability that the data packet (10) is bad as a function of the amount of the packet (10) which has been examined within the variable latency cut through bridge (210).

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VARIABLE LATENCY CUT-THROUGH BRIDGING

TECHNICAL FIELD

The present invention relates generally to the field of computer science and more particularly to an improved device and method for communicating between computers. The predominant current usage of the variable threshold network packeting method is in computer networks wherein a number of individual computers are interconnected for the sharing of programs and data.

BACKGROUND ART

The interconnection of computers such that programs and data can be shared among a network of computers is presently a subject of much interest. A number of different methods and means for communicating program and/or file data between computers have been devised, and some of these have developed into standards which allow for the interconnection of computer devices which are in compliance with such standards. A specification for one such convention is found in the Institute of Electrical and Electronic Engineers ("IEEE") standard 802.3. This standard specifies the protocol for a Local Area Network ("LAN") communications method which is commonly referred to as "Ethernet" or, more descriptively as "carrier sense, multiple access with collision detection" ("CSMA/CD").

Groups of computers connected via LANs in general and Ethernet in particular can be broken into segments or separate LANs on an application and/or a geographical basis. Each segment or LAN can consist of one or more computers. The segments and LANs may be connected together in a topology by switching elements employing a variety of information forwarding schemes. Each segment of an interconnected LAN is electrically distinct but logically continuous in that information transmitted from one computer to another appears on all segments of a network. Connected LANs are not only electrically distinct but are also logically separate in that information is selectively forwarded from one LAN of an interconnected network to some subset of the other LANs of the network, depending upon the topology of the segments and information forwarding schemes of the network switching elements.

In Ethernet, as in several other computer intercommunication methods, information is communicated in units sometimes referred to as "packets". An Ethernet packet is depicted in Fig. 1 and is designated therein by the general reference character **10**. The standardized Ethernet packet **10** has a preamble **12** which is 64 bits in length, a destination address **14** which is 48 bits in length, a source address **16** which is 48 bits in length, a length/type field **18** which is 16 bits in length and a data field **20** which is variable in length from a minimum of 46 eight bit bytes to a maximum of 1500 bytes. Following the data field **20** in the packet **10** is a 4 byte (32 bit) frame sequence check ("FCS") **22**. The packet **10** is transmitted serially beginning at a "head" **24** and ending at a "tail" **26** thereof.

In CSMA/CD (Ethernet), computers and switching elements having a packet **10** destined for a particular computer of the network "listen" for the appropriate segment of a LAN to be quiet before transmitting the packet **10**. This feature is to avoid interference on the segment and is the "carrier sense" aspect of CSMA/CD. "Multiple access" relates to the distributed nature of the decision making among the computers and switching elements that access a particular LAN.

Despite the carrier sense function it is, nevertheless, possible for more than one computer or switching element to have a packet **10** ready to send to a LAN at precisely the same time. In such an instance, when both units sense quiet on the segment, both begin to transmit at the same time. Each of these transmitting computers and/or switching elements will then detect that a "collision" has occurred and will abort its respective transmission. The resulting incomplete (improperly formed) packets **10** are known as "runts".

Various different types of switching elements have been utilized to electrically interconnect LANs and segments of LANs. For example a "repeater" is a simple switching element which interconnects segments of a LAN. The function of a repeater is merely to receive a data stream from one segment of the LAN and forward it on to the other connected segments of the LAN. The carrier sense and collision detect functions of CSMA/CD take place on all segments of a LAN simultaneously with all computers and switching elements listening for quiet and/or detecting collisions in parallel. All the segments of a LAN interconnected by repeaters are said to be in the same "collision domain", since only one packet **10** can traverse a LAN at a time no matter what is the arrangement of the segments of the LAN. Multiple repeaters can connect numerous segments into a single LAN.

A "bridge" is a somewhat more sophisticated switching element in that it directs data streams between LANs and can, in fact, forward more than one packet **10** at a time with the restriction, discussed above, that only one packet **10** at a time is allowed on each of the connected LANs whether it be transmitting or receiving. Packets received from LANs are directed to their intended destinations by selecting which of the LAN(s) are to receive a particular packet **10**. Given the description of the packet **10** previously discussed herein, it can be appreciated that a bridge must have some buffering capability, as it cannot ascertain the intended destination of a packet **10** at least until the destination address **14** is received and interpreted. A so called "standard bridge" receives the packet **10** into its buffer before forwarding it. A "cut through bridge" attempts to speed up the process by beginning to forward the packet **10** before it is fully received (typically, as soon as the destination address **14** is received at the bridge). However, it may not be possible to forward the packet **10** as soon as the destination address **14** is received, since the destination LAN may not be quiet (for example, because another computer or switching element of the destination LAN is transmitting, or for any of various other reasons). Therefore, a bridge should have the capability of buffering substantially more than one packet **10** so that packets **10** can be queued for subsequent sending therefrom. Furthermore, a bridge may be required to retransmit a packet **10** if there is a collision in the destination LAN. This "buffering" in the bridge is required so as to avoid "reflecting" the collision to the source LAN.

The scheme discussed above may seem to be rather simple in description, but it becomes somewhat more complicated in practice. For example, since a number of devices may be competing for access to a particular network LAN there will, as previously mentioned, occur collisions of data resulting in the creation of incomplete packets **10** known as runts. Under heavy load conditions or in a large network, runts can occupy a significant portion of the available network traffic capability. A runt occurs because each device involved in a collision stops transmitting when the collision is detected, generally after only a portion of its packet **10** is transmitted.

A "dumb" bridge attempts to forward all packets **10** which it receives. A "filtering" bridge, on the other hand, attempts to identify packets **10** which, for one reason or another, should not be forwarded to a particular segment. Not forwarding ("filtering out") those packets **10** which should not be forwarded from one LAN to another reduces the traffic overhead in the network leaving more bandwidth available for the complete packets **10** which should be forwarded. This filtering also affects the delay a packet **10** faces in being forwarded to a particular LAN in that the lesser amount of the bandwidth which is being consumed by unwanted packets **10**, the more often a packet **10** can be forwarded from a source LAN to a destination LAN immediately (without being queued).

Bridges may "choose" which packets **10** to forward to a particular LAN based on a comparison of the destination address **14** of each packet **10** with some accumulated history data relating to the source addresses **16** of packets **10** previously seen from that LAN. Thus, in the case of a bridge, a packet is (generally) forwarded only to the LAN where the destination address **14** of a packet **10** matches a source address **16** of previous packets **10** seen on that LAN. This "destination address filtering" also reduces traffic on various segments of the network, thus increasing overall performance. Another of the several potential reasons why a packet should not be forwarded is that it is a runt. U.S. Patent No. 4,679,193 issued to Jensen et al. discloses a Runt Packet Filter for filtering out such runts in particular applications.

It can be appreciated in light of the prior discussion that there exist a number of "trade offs" in the operation of prior art network systems. How much of a packet **10** the bridge must receive prior to beginning to forward the packet **10** is known as the "latency" of the bridge. The longer the latency, the longer is the time delay involved in forwarding a packet **10** and, of course, it is desirable to reduce this delay as much as possible in order to speed up communications. On the other hand, to attempt to reduce this delay by allowing a bridge to begin transmission before an entire packet **10** is received, and thus before the packet **10** can be verified as being a complete packet **10** that should indeed be forwarded, will result in the improper forwarding of at least some packets **10**. This, of course, will only slow down the system in that not only is time taken in improperly forwarding a packet **10**, but also other packets **10** may be queued behind the improper packet **10** which other packets **10** should and could have been immediately forwarded were the bridge not occupied in forwarding the improper packet **10**.

Because of these conflicting considerations, prior art cut through bridges have been designed to provide a latency which allows the bridge to filter out only a relatively small percentage of the improper packets **10**. Such prior art filtering, as discussed above, has been accomplished primarily based on characteristics of the packets **10** found in the preamble **12** and/or the destination address **14**. Since the preamble **12** and the destination address **14** occur early in the packets **10**, the simple prior art filtering scheme does have the advantage that filtering packets **10** based upon these characteristics prevents a significant amount of clogging of the system because many unwanted packets **10** can be quickly and easily rejected for forwarding. However, even after such prior art filtering as is described herein, there remain a great many packets **10** which according to prior art methods are, but should not be, forwarded.

Clearly, it would be desirable to eliminate the forwarding of as many improper packets as possible without increasing latency in the bridge to be longer than is absolutely necessary. However, to the inventors' knowledge, no prior art method has succeeded in optimizing throughput of bridges by providing an optimal bridge latency. Moreover, this problem is exacerbated by the fact that what might be an optimal latency in one application of a bridge might well not be optimal in another application. Indeed, the "optimal" latency may even change in a fixed application as changes are made in the structure or usage of the system.

DISCLOSURE OF INVENTION

Accordingly, it is an object of the present invention to provide a method and means for optimizing the latency period within a bridge.

It is another object of the present invention to provide a method and means which can adapt a bridge for maximum throughput in a variety of different network configurations.

It is still another object of the present invention to provide a method and means by which network communication among computer devices is maximized.

It is yet another object of the present invention to provide a method and means for eliminating as many improper data packets as is practical without unduly delaying the forwarding of proper data packets.

Briefly, the preferred embodiment of the present invention is a cut through bridge with a variable latency. Since a large percentage of the improper packets **10** are runts, and since runts can be identified after only a small portion of the packet **10** is received at the bridge (given that a collision, if one has occurred, will be detected soon after the relevant packet **10** has begun to be forwarded), the inventive bridge begins sending after the threshold of most runts. However, there are a number of other improper packets **10** in addition to the runts which should also not be forwarded. In the worst case, a packet **10** may not be identified as being improper until the FCS **22** is encountered. It should be noted that the solution of filtering out only runts, while it eliminates a high percentage of improper packets **10**, eliminates only the shortest packets **10**, while the greatest time delay is involved in the forwarding of longer improper packets **10**. According to the inventive method, after a determination is made as to a threshold cut off point for the network in which a bridge is installed, provision is made for varying the latency of the bridge, from time to time, to optimize throughput on the network for the existing circumstances.

An advantage of the present invention is that throughput on a network is improved.

Yet another advantage of the present invention is that a bridge can operate at optimal efficiency even as the requirements of the application vary.

Still another advantage of the present invention is that a proper balance can be achieved between delays caused by bridge latency and delays caused by the forwarding of improper packets.

Yet another advantage of the present invention is that a network is not clogged with an excess of improper packets, nor does the network unnecessarily delay packets in order to minimize such improper packets.

These and other objects and advantages of the present invention will become clear to those skilled in the art in view of the description of the best presently known modes of carrying out the invention and the industrial applicability of the preferred embodiments as described herein and as illustrated in the several figures of the drawing.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a block diagram of a standard Ethernet packet;

Fig. 2 is a block diagram of a variable latency bridge according to the present invention;

Fig. 3 is block diagram of a simple computer network having therein the variable latency bridge of Fig. 2;

Fig. 4 is a block diagram of an Ethernet packet, similar to that shown in Fig. 1, showing a variable threshold point;

Fig. 5 is a graph showing the probability that an Ethernet packet is bad charted against the amount of the packet which has been analyzed;

Fig. 6 is an equally preferred alternate embodiment of the inventive variable latency bridge;

Fig. 7 is an example of the inventive variable latency bridge in use in a single link segment Ethernet; and

Fig. 8 is an example of the inventive variable latency bridge in use in a maximally configured Ethernet.

BEST MODE FOR CARRYING OUT INVENTION

The best presently known mode for carrying out the invention is a variable latency cut through bridge. The predominant expected usage of the inventive variable latency cut through bridge is in the interconnection LANs of computer devices, particularly in local area networks wherein the maximization of throughput of data packets is desirable. The variable latency cut through bridge connects LANs making up the overall network.

The variable latency bridge of the presently preferred embodiment of the present invention is illustrated in a functional block diagram in Fig. 2 and is designated therein by the general reference character **210**. The variable latency cut through bridge **210** described herein is adapted for use with the standardized Ethernet communications packet **10** described in Fig. 1 herein, although the invention is equally application to other communications protocols that use data packets or "frames".

The variable latency cut through bridge **210** has a buffer **212**, a controller **214**, an input port ("receiver") **216** and an output port ("transmitter") **218**. The variable latency cut through bridge **210** described herein is a simplified unit in that it has only the single receiver **216** and the single transmitter **218**. Further, the variable latency cut through bridge **210** described herein provides for the forwarding of the packets **10** (Fig. 1) in one direction only. One skilled in the art will recognize that the principles described herein could easily be utilized to build a more complex bridge by the provision of additional receivers **216** and/or transmitters **218** (with appropriate buffers **212** between them, as required), and that bidirectional communications could be accomplished using two iterations of the variable latency cut through bridge **210**.

As can be appreciated by a practitioner in the field, an invention such as the one described herein can be accomplished primarily in hardware, in software, or in some combination thereof, the distinction between hardware and software in this context being more a matter of convenience and efficiency than of a critical aspect of the inventive method of the variable latency cut through bridge **210**. In the best presently known embodiment **210** of the present invention, handling, forwarding and filtering of the packets **10** is done in the hardware of the variable latency cut through bridge **210** with monitoring and associated functions in software. One skilled in the art, given an understanding of the inventive method as described herein, can readily accomplish a hardware/software combination for accomplishing the inventive method.

Fig. 3 is a block diagram of a computer network **310** having therein the variable latency cut through bridge **210** of Fig. 2. A plurality of computers **312** are connected to the variable latency cut through bridge **210** via a plurality of interconnecting cables **314**. In the example of Fig. 3, a first computer **312a** is indicated as transmitting to the variable latency cut through bridge **210** and the variable latency cut through bridge **210** is, in turn, shown forwarding data to a second computer **312b** and a third computer **312c**. In accordance with the present inventive method, data transmitted over the interconnecting cables **314** is in the form of the Ethernet packets **10** of Fig. 1.

Fig. 4 is a block diagram of the Ethernet packet **10** showing a variable threshold point **428**. The variable threshold point **428** is that point in the Ethernet packet **10** at which the variable latency cut through bridge **210** (Fig. 2) begins to forward the Ethernet packet **10**. According to the present inventive method, when a determination is made as to a proper location for a threshold point **428** the controller **214** causes the threshold point **428** to move to that location.

Fig. 5 is a graph representing the probability that an Ethernet packet **10** (Fig. 1) is a "bad" or improper packet on the Y axis **510** plotted against the amount of the Ethernet packet **10** that has been examined at the variable latency bridge **210** on the X axis **511**. In this sense, "bad" Ethernet packets **10** are those that the variable latency bridge **210** should automatically filter out and not forward. As has been previously discussed herein, in Ethernet many bad packets **10** will be runts. However, bad Ethernet packets **10** also include those with errors in the FCS **22** and other locations within the Ethernet packet **10**. The probability that a packet transmission will be involved in a collision, resulting in a runt, depends on what is referred to as the acquisition time for the transmitting station (the first computer **312a** in the example of Fig. 3). This will be discussed in greater detail hereinafter in relation to the industrial applicability of the invention. The acquisition time will vary for each application.

As can be seen in the view of Fig. 5, a probability line **512** is highest at an initial point **513** which is a function of the specific acquisition time for the application. The initial point **513** corresponds to the head **24** of the Ethernet packet **10** (Fig. 1). This can be understood as being a reflection of the fact that, since the variable latency cut through bridge **210** (Fig. 2) will reject any Ethernet packet **10** that is "bad" once such condition is discovered, the highest probability that the particular Ethernet packet **10** being examined is "bad" exists at the inception of the process, before the variable latency cut through bridge **210** has had an opportunity to examine any of the Ethernet packet **10**. In such a case, no potential flaw locations have been eliminated and the maximum possible flaw locations remain, thus the maximum probability of errors exists.

Since in Ethernet collision processing all runts will be at least of a certain fixed length (such length varying with the application), a first portion **514** of the probability line **512** will be generally flat up to a minimum fragment size point **515** (which minimum fragment size point **515** corresponds to the minimum length of a runt). After the minimum fragment size point **515**, the probability line **512** decreases continuously as more stations see the transmitted packet **10** until a transmitting station's network acquisition time which is represented in the graph of Fig. 5 by an acquisition time point **516**. Thereafter, the variable latency bridge **210** can no longer be assured that the received packet **10** is a collision fragment and cannot filter it for that reason. However, other errors (such as errors in the FCS **12**) may be detected that would ideally cause filtering and the resulting probability does not go to zero until the packet is fully received (probability line end point **517**. It can be readily understood that at the end point **517** of the probability line **512** the probability that the Ethernet packet **10** is "bad" is essentially zero for the present purposes, the entire Ethernet packet having been examined within the variable latency cut through bridge **210**. That is, were an error (or other reason for not forwarding it) discovered within the Ethernet packet **10**, the variable latency cut through bridge **210** would have rejected the Ethernet packet **10** and examination would not have progressed to the tail **26**. Since some reasons for not forwarding a packet **10** may not be discoverable until the entire packet **10** is examined, there will be a distinct drop off of the probability line **512** at the end point **517**.

Note that the initial point **513**, the acquisition time point **516** and the end point **517** will be different for different transmitting stations and that the position of the end point **517** will also depend upon the size of the particular packet **10** being received. The shape of the graph of Fig. 5 is only an example, with specific values of the points **513**, **515**, **516** and **517** thereof being a function of the particular application. Indeed, the shape of the declining probability line **512** may well not even be linear (at least in portions) although it is assuredly monotonically decreasing.

Of particular significance is that, regardless of there application, there will be three points (the minimum fragment size point **515**, the acquisition time point **516** and the end point **517**) at which the probability line **512** drops off markedly. These are shown in the graph of Fig. 5 as rapid drop off portions **520** of the probability line **512**. Since an object of the variable latency bridge **210** is to position the variable threshold point **428** (Fig. 4) which balance overall latency (the X axis **511** of Fig. 5) with minimization of forwarded junk (the Y axis **510** of Fig. 5), the rapid drop off points **520** are good candidates for the variable threshold point **428**. It should be noted that the minimum fragment size point **515** will always occur before the destination address **14** (Fig. 1) is received and cannot, therefore, be used as a position for the variable threshold point **428** where filtering based upon the destination address **14** is desired. Nevertheless, the minimum fragment size point **515** could be useful where the variable latency bridge **210** is not required to filter based upon the destination address **14**.

As will be discussed in more detail hereinafter in relation to the industrial applicability of the invention, determination of the values of the points **513**, **515**, **516** and **517** of the probability line **512** can be achieved either analytically or empirically and either statically or dynamically. Analytically, the worst case values for a network of maximum size with the variable latency bridge **210** at one extreme thereof can be calculated. Empirically, network traffic may be monitored at the point in which the variable latency bridge **210** is (or would be) operating to establish the values. In a more sophisticated future version, the variable latency bridge **210** may itself monitor its received traffic and determine the values empirically and adjusting its values in a dynamic fashion.

It should be noted that, while the example of Fig. 5 is drawn in relation to an Ethernet packet **10**, the principles illustrated are applicable to any packet network in which the probability of a packet's being filtered varies over the packet's length.

It should be noted that the rapid drop off portion **520** is by no means the only position to which the variable threshold point **428** might be set. It should further be noted it is a feature of the present inventive variable latency bridge **210** that the variable threshold point **428** may be set according to criteria established to maximize the efficiency of any type of network **310** in which the variable latency bridge **210** might be employed. The setting of the variable threshold point **428** to correspond to the rapid drop off portion **520** is, in the best presently known embodiment **210** of the present invention, an initial "best guess" as to what might be an optimal setting for the variable threshold point **428**. As stated previously, the actual location of the rapid drop off portion **520** can readily be empirically determined for a particular application or, more generally, for applications of particular types. It is anticipated that the present inventors, as well as others, will develop improved methods and means for determining the optimal location for the variable threshold point **428**. The actual method currently employed by the inventors to set the variable threshold point **428** will be presented in more detail hereinafter in relation to the industrial applicability of the invention.

It will be of interest to those practicing the present invention to note that while the probability of the generation of "junk" - that is, improper packets - is a function of the sending unit (the first computer **312a** in the example of Fig. 3), the sensitivity to such "junk" - that is, the amount of harm to efficient throughput that is caused when such junk gets into the network **310** - is generally a function of the receiving equipment (the second computer **312b** and/or the third computer **312c** in the example of Fig. 3). That being the case, it is anticipated that the determination of an "optimal" variable threshold point **428** may require some feedback from the receiving equipment (the second computer **312b** and/or the third computer **312c** in the example of Fig. 3).

As stated previously herein, the variable latency cut through bridge **210** described herein is a "bare bones" example intended to illustrate the invention. For example, one skilled in the art will recognize that the variable latency cut through bridge **210** might also be equipped to include a buffer clearing means (not shown) for clearing the buffer **212** between iterations of the packet **10**, additional buffers (not shown) for buffering several of the packets **10** (as discussed previously herein in relation to the prior art) and/or other conventional appurtenances and features.

Fig. 6 is a block diagram of an equally preferred alternate embodiment **610** of the inventive variable latency cut through bridge. While the first preferred embodiment **210**, as previously stated, is a very simple example to best illustrate the principle of the invention, the equally preferred alternate embodiment **610** of Fig. 6 is somewhat more complex in order to illustrate the movement of a data packet **10** within the variable latency bridge **210** according to the present inventive method. In the example of Fig. 6, the variable latency bridge has a plurality (two in the present example) of receivers **216** and a plurality (two in the present example) of transmitters **218**. Like the first preferred embodiment **210**, the equally preferred alternate embodiment **610** of the present invention also has a buffer **212** and a controller **214**. The data packets **210** travel between the various aspects of the equally preferred alternate embodiment **610** of the invention on a data bus **612**. The buffer **212** is divided into a plurality (six, in the example of Fig. 6) of packet buffer slots **614**. The controller also has associated therewith a plurality (one for each transmitter **218**) of first-in-first-out ("FIFOs") **616** memories. The FIFOs **616** are configured to contain packet buffer numbers or pointers to the packet buffer slots **614** of the buffer **212**.

A packet **10** received by a receiver **216** from a source LAN (not shown in the view of Fig. 6) is assigned by the controller **214** to a particular packet buffer slot **614** in the buffer **212**. As the bytes of the packet **10** (not including preamble the preamble **12**) are received by the receiver **216** they are transferred over the data bus **612** and stored sequentially in their assigned packet buffer slot **614**. Other packets **10** being received by other receivers **216** will have their bytes of data stored in other assigned packet buffer slots **614** using the controller **214** and the data bus **612** on an interleaved or "time division multiplexed" basis. Each entire packet **10**, whether a full packet **10** or a "runt" will be stored in a packet buffer slot **614** of the buffer **212**.

The controller **214** monitors the various received packets **10** as they are transferred on the data bus **612** and examines the relevant portions with respect to making a decision as to where and when to forward the packet **10**. For example, the destination address **14** will generally be of interest to the controller **214** as will be the number of bytes of the packet **10** which have been transferred at any point in time. When the number of bytes determined by the current position of the variable threshold point **428** has been transferred on the data bus **612**, the controller **214** will attempt to begin transmission of the packet **10** through the one or more of the transmitters **218** selected by the controller **214** (for example that transmitter **218** which is associated with the packet's destination address **14**). The controller **214** will examine the FIFOs **616** associated with each of the transmitters **218** selected to forward the packet **10** and, if it is empty, the transmission can be started on that transmitter **218** immediately. If the FIFO **516** of a selected transmitter **218** is not empty, the number of the packet buffer slot **614** assigned to the incoming packet **10** will be entered into the appropriate FIFO **616** to enable later transmission. Indeed, the number of the packet buffer slot **614** is entered into the FIFO **616** even if that FIFO **616** <u>is</u> empty (and transmission can begin immediately) so that in the case of a transmit collision the packet **10** can be retransmitted. It should be noted that, in some occurrences, a valid position for the variable threshold point **428** may be such that the entire packet **10** is received before any attempt is made to transmit. When a transmission is successfully completed, the number of the packet buffer slot **614** is removed from the FIFO **616** and that packet buffer slot **614** can be used to store yet another incoming packet **10**.

As is shown above, in great part, the variable latency cut through bridge **210** according to the present invention resembles prior art conventional cut through bridges in many respects. Among the substantial differences are the inclusion of a variable threshold point for adjusting the latency of the bridge. No significant changes of materials are envisioned nor are any special constructions required.

Various modifications may be made to the invention without altering its value or scope. For example, although the variable latency cut through bridge **210** described herein, is relatively simple in structure, the inventive method can be used in combination with most features of existing prior art network systems. Also, as previously mentioned herein, although the best presently known embodiment **210** of the present invention is adapted for use with standard Ethernet, one skilled in the art could readily adapt the invention for use with essentially any type of communications means which utilizes data packets and for which the probability of a bad packet varies with the amount of the packet received.

All of the above are only some of the examples of available embodiments of the present invention. Those skilled in the art will readily observe that numerous other modifications and alterations may be made without departing from the spirit and scope of the invention. Accordingly, the above disclosure is not intended as limiting and the appended claims are to be interpreted as encompassing the entire scope of the invention.

INDUSTRIAL APPLICABILITY

The variable latency cut through bridge is adapted to be widely used in computer network communications. The predominant current usages are for the interconnection of computers and computer peripheral devices within networks and for the interconnection of several computer networks.

The variable latency cut through bridges of the present invention may be utilized in any application wherein conventional computer interconnection bridging devices are used. A significant area of improvement is in the inclusion of the variable threshold point **428** and associated aspects of the invention as described herein.

The inventive variable latency bridge **210** is used in a network in much the same manner as have been conventional prior art cut through bridges, with a potentially significant increase in efficiency in almost all applications. The position of the variable threshold point **428** may be made either statically or dynamically. In the static setting case, a setting is made through a user configuration of the variable latency bridge **210**. In this case, the setting would remain unchanged during the operation of the variable latency bridge **210**, or until the setting is modified through an explicit action of a user reconfiguring the variable latency bridge **210**.

In the case of dynamically setting the variable threshold point **428**, decision making logic within the variable latency bridge **210** (heuristic based learning) will be applied, as will be discussed in more detail hereinafter, to modify the setting of the variable threshold point **428** over time to accomplish tuning to minimize errors or to maximize throughput, or to maximize responsiveness to changing conditions of the application within which the variable latency bridge **210** is running.

The inventors have found that static assignment of the variable threshold point **428** may effectively be based on characteristics of the network segments attached to the bridge and on characteristics of the network controllers of devices on those segments. For example, if all controllers on those segments are such that unwanted packets ("junk") is readily discarded without impact on the computer containing the controller (as is the case with many Ethernet controllers in personal computers and workstations today), then the impact of junk is purely loss of bandwidth on the segment. In this case, and where segment bandwidth utilization is generally low, a very low threshold setting may be considered to be highly effective.

On segments where junk has a more negative impact, or where bandwidth is at a premium, more effective settings may require consideration of the rapid drop off portion **520** of the probability line **514** of Fig. 4. The location of the rapid drop off portion **520** is predictable based on the fact that proper deference behavior on an Ethernet precludes collisions outside the so called "collision window", which is the period of time beginning with the start of packet transmission and continuing for a period equal to the maximum round trip signal propagation time from end to end of a maximally configured network segment. It is reasonable to expect the vast majority of junk to be collision fragments whose length will not exceed this collision window length.

An example of the use of the rapid drop off portion **520** of the probability line **514** to set the variable threshold point **428** in a point-to-point ("private channel") Ethernet is as follows: A private channel Ethernet is one comprised of only two controllers; one at a station and one at a hub. When a variable latency cut-through bridge is employed as the hub for such a segment, collision fragments can arise only from collisions occurring when both the bridge and the station begin transmission at around the same time. In such cases, the reception (and possible forwarding) by the variable latency bridge **210** of the fragment can be precluded by the knowledge possessed by the variable latency bridge **210** of its own participation in the collision. Thus, the collision fragments which cause the high initial probabilities of receiving junk (illustrated by the high initial point **516** of the probability line **514** of Fig. 5) will not be present. This suggests use of a very low cut-through latency threshold for such connections.

An example of the use of the rapid drop off portion **520** of the probability line **514** to set the variable threshold point **428** in a single link segment thin coax Ethernet **710** as depicted in Fig 7. For an attachment from the variable latency bridge to the single segment thin coax Ethernet **710**, it can reasonably be expected that an effective threshold setting will be just past the collision window indicated by the maximum round trip propagation time on such a segment. The latest such collision would arise when a first station **712** located very near the variable latency bridge **210**, and very near one end of a (185 meter maximum length) cable **713**, experiences a last possible moment collision with a second station **714** located at the far end of the cable **713**. The time calculation would be as follows: (Note that for a 10 Megabits per second Ethernet, 1 bit time=100 nanoseconds {100ns}) At time=T0, signal from the first station **712** is on the cable **713** at the first station **712** and (for all practical purposes as this example has been defined) at the variable latency bridge **210**. At time=T1, the signal has propagated the full length of the cable **713** to the second station **714**. At time=T1+T2 the second station **714** controller senses the signal and has just released the first bit of its own packet **10** onto the cable **713**, causing a collision condition. At time=T1+T2+T3, the collision combination of signals first arrives back at the first station **712** and at the variable latency bridge **210**. At time=T1+T2+T3+T4 the last of the collided signal from the second station **714** reaches the first station **712** and the variable latency bridge **714**, at which time the variable latency bridge **210** may determine that the packet **10** transmitted from the second station **714** is a runt.

Given the above maximum error time scenario, calculation of T1 (which is also equal to T3) may be made from the cable length, the speed of light, and the specified cable light speed factor (0.65) of the cable **713** as follows:

T1=T3=((185m/0.65c))=9.5 bit times

(where c is the speed of light in meters per second.)

Calculation of worst case times for T2 have been made based on IEEE 802.3 Ethernet standard worst case delay values. This is T2=22.14 bit times.

Calculation of T4 is based on the specified minimum collision fragment, which is 64 bits of preamble **12** and start of frame delimiter, followed by a 32 bit jam pattern, for a total of 96 bit times.

Thus, the worst case collision window is:

T1+T2+T3+T4=9.5+22.14+9.5+96=137.14 bit times (or 13.714 microseconds)

For the example of Fig. 7, a good candidate for the setting of the variable threshold point **428** (which begins measuring only after the 64 bits of preamble **12**) is:

137.14-64=73.14 bit times, or between 9 and 10 bytes into the received packet.

For an attachment from the variable latency bridge **10** to a maximally configured Ethernet segment **810** as depicted in Fig. 8, it is again assumed (at least initially) that an effective position for the variable threshold point **428** would be just past the collision window indicated by the maximum round trip propagation time on such a segment. This maximal configuration **810** has 5 full length cable runs **713a** through

713b attached with a plurality (four, in the case of the maximally configured Ethernet segment **810**) of maximally delaying repeaters **816**. In this case, the "latest" collision detection would arise when a first end station **818** located very near one end of the first cable **713a** and very near the variable latency bridge **210** experiences a last possible moment collision with a second end station **820** located at the far end of the fifth cable **713e** through all four repeaters **816**. Given the general practice, it can be assumed in the example of Fig. 8 that the interior cables **713b**, **713c** and **713d** are "thick coax" cabling, and the "end run" cables **713a** and **713e** are "thin coax". The time calculation for this example is much the same as in the example of Fig. 7, except that the propagation times (T1 and T3) are quite a bit larger. Also the propagation back of the collision is subject to potentially larger delays within the repeaters **816** than is the propagation forward, so T3 will be larger than T1. Again using 802.3 worst case delay specifications, these propagation delays are calculated to be T1=182.48 bit times and T3=222.48 bit times.

The other components of this calculation remain as in the example of Fig. 7, revealing the worst case window to be:

T1+T2+T3+T4=182.48+22.14+222.48+96=523.1 bit times (or 52.3 microseconds)

A good candidate for the setting of the variable threshold point **428** in the example of Fig. 8 would be 523.1-64=459.1 bit times, or between 57 and 58 bytes into the received packet.

As previously mentioned, the variable threshold point **428** of the variable latency bridge **210** certainly need not remain fixed during operation of the variable latency bridge **210**. In order to maximize overall data throughput, a small percentage of errors being forwarded may be preferable to overly delaying the cut through operation. The specific acceptable percentage of errors may be employed using simple heuristic logic to periodically adjust the variable threshold point **428** based on the number of packets **10** which the variable latency bridge **210** has been forwarding and the amount of "junk" packets among the good packets. More specifically, if

PE is the maximum acceptable percentage of errors which it is decided will be tolerated in forwarding the packets **10**, and the variable latency bridge **210** maintains counts of packets **10** forwarded (PF) and the number of those forwarded which, subsequent to forwarding, were found to be errored packets (EP), then every time PF reaches some sample size (such as 10,000) the variable latency bridge **210** could (in hardware or software) compute EP divided by PF, and compare the resulting percentage to PE. If the ratio is greater than PE, the threshold position would be increased, to seek to reduce the forwarded error rate. If the ratio is less than PE, the threshold value would be decreased, since a higher error rate is considered acceptable. The two counts would then be reset for the next sample period.

Since the variable latency cut through bridges of the present invention may be readily constructed and are compatible with existing computer equipment it is expected that they will be acceptable in the industry as substitutes for conventional bridges. For these and other reasons, it is expected that the utility and industrial applicability of the invention will be both significant in scope and long-lasting in duration.

In the Claims:

1. A bridge for a computer network system, the network having a plurality of computer devices interconnected by a plurality of data cables wherein data packets are transmitted over the data cables, the bridge comprising:

a buffer for temporarily holding the data packets, and;

a controller for controlling said buffer such that the data packets are forwarded out of said buffer upon command from said controller, wherein;

said controller variably sets a latency threshold of the buffer, the latency threshold being that portion of each data packet which is received by the buffer prior to said controller commanding said buffer to forward that data packet.

2. The bridge of claim 1, wherein:

the latency threshold is set to be within a rapid drop off portion of a probability function, the probability function describing the probability that a data packet is bad as a function of the amount of the data packet which has been examined.

3. The bridge of claim 2, wherein:

the probability function is empirically determined.

4. A method for improving the efficiency of a computer network having a plurality of network segments therein, wherein data is communicated in the form of data packets, the method comprising:

providing a bridge between the segments of the network, said bridge being configured to attempt to begin forwarding each data packet when that data packet is received by the bridge and verified as being one which should be forwarded up to a variable threshold point of that data packet; and

setting the variable threshold point such that said bridge begins to forward each data packet after at least a portion of that data packet has been verified as being one which should be forwarded and before all of the data packet has been verified as being one which should be forwarded.

5. The method of claim 4, wherein:

the variable threshold point is varied as said bridge is used.

6. The method of claim 4, wherein:

the variable threshold point is set at a point such that any runts will have been rejected as being bad before the variable threshold point is reached.

7. The method of claim 4, wherein:

the variable threshold point is set according to empirically gathered data.

8. The method of claim 4, wherein:

the variable threshold point is set such as a function of a probability line, the probability line being represented by a graph plotting a probability value that the data packet should not be forwarded against an amount of the data packet that has been examined within said bridge.

9. The method of claim 8, wherein:

the variable threshold point is set to within a rapid drop off portion of the probability line, the rapid drop off portion being a portion of the probability line wherein the probability value of the probability line drops markedly toward zero.

10. A method for forwarding data packets within a bridge of a computer network, comprising:

setting a variable latency point within the bridge such that an amount of each data packet which is received at the bridge before the bridge attempts to forward that data packet is variable according to the position of the variable latency point.

11. The method of claim 10, wherein:

said variable latency point is set after a preamble of the data packet.

12. The method of claim 10, wherein:

said variable latency point is set such that essentially all runts will be rejected before said variable latency point is reached in each data packet, a runt being an incomplete data packet resulting from an aborted attempt to transmit that data packet.

13. The method of claim 10, wherein:

said variable latency point is adjustable according to data obtained during the operation of the bridge.

14. The method of claim 10, wherein:

said variable latency point is set by software from a computer.

15. The method of claim 14, wherein:

the computer is connected to the computer network through the bridge.

16. The method of claim 14, wherein:

the computer retains information concerning the packets for optimizing the position of said variable latency point.

17. The method of claim 10, wherein:

said variable latency point is reset from time to time as the demands of the computer network vary.

18. The method of claim 10, wherein:

said variable latency point is set according to a calculation of an acquisition time of the application.

19. The method of claim 10, wherein:

the variable latency point is set according to empirically determined data gather during the operation of the bridge.

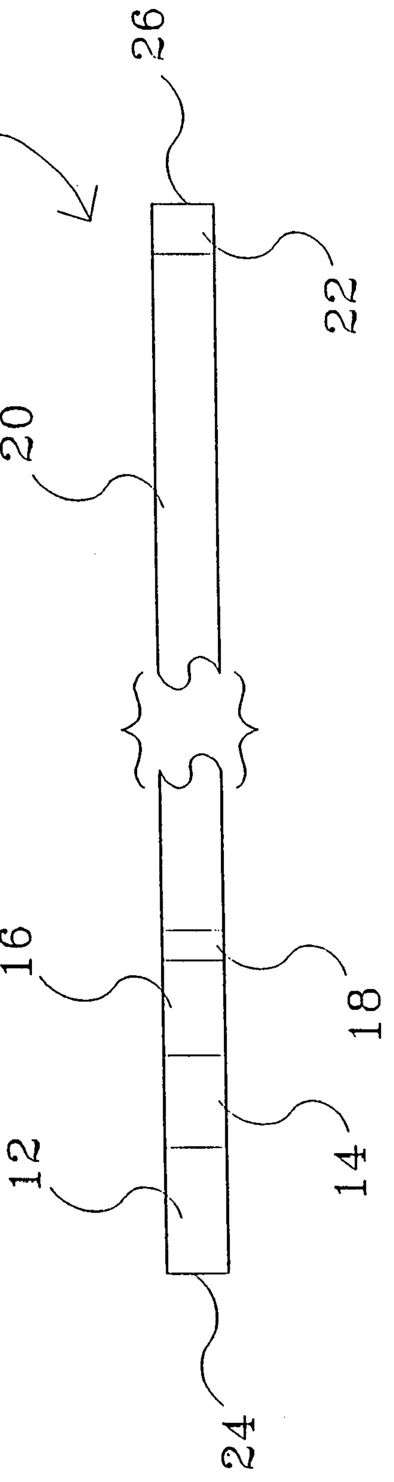


Fig. 1

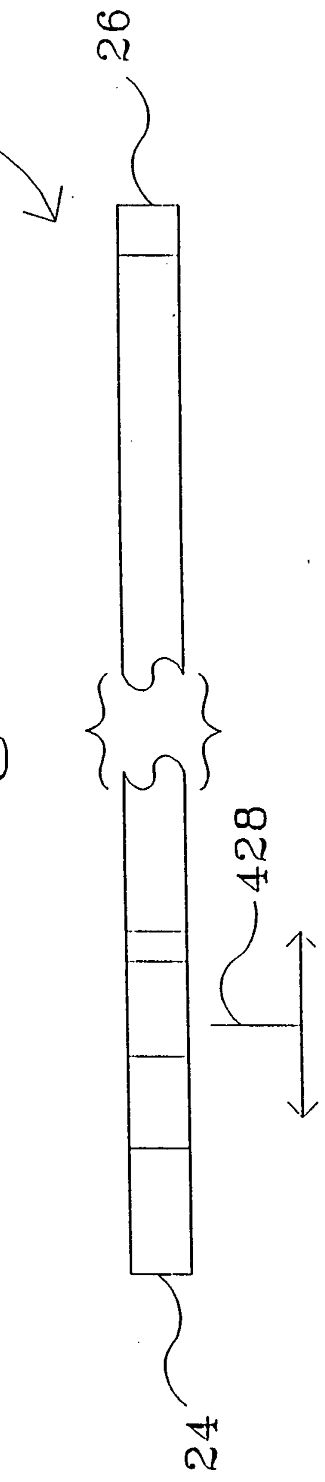


Fig. 4

Fig. 2

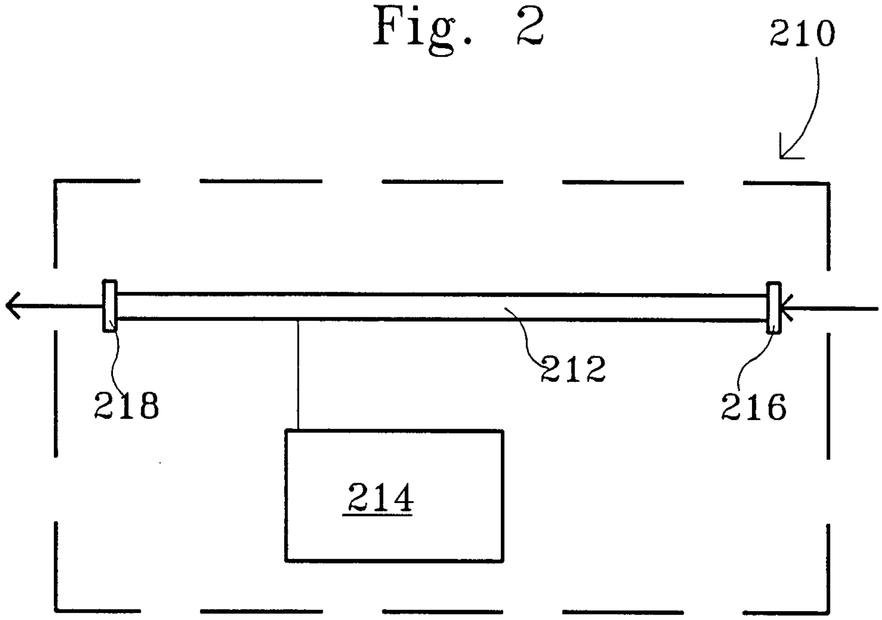


Fig. 3

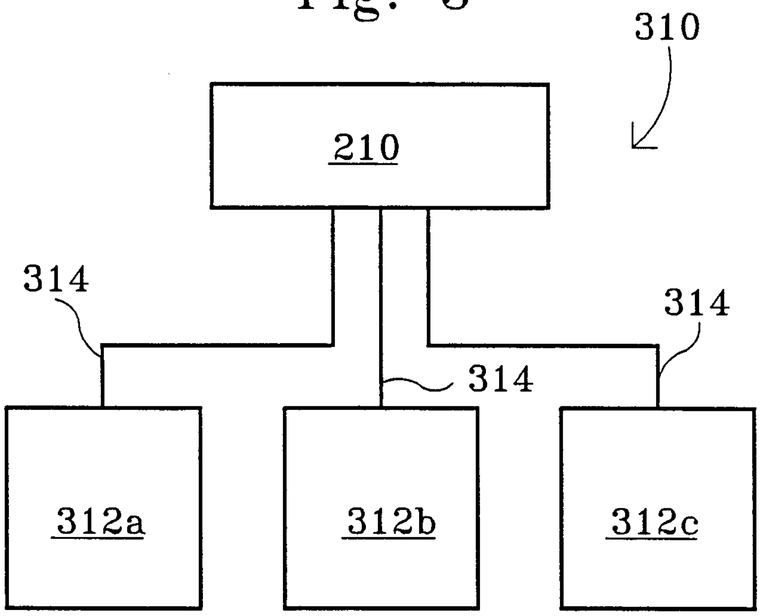


Fig. 5

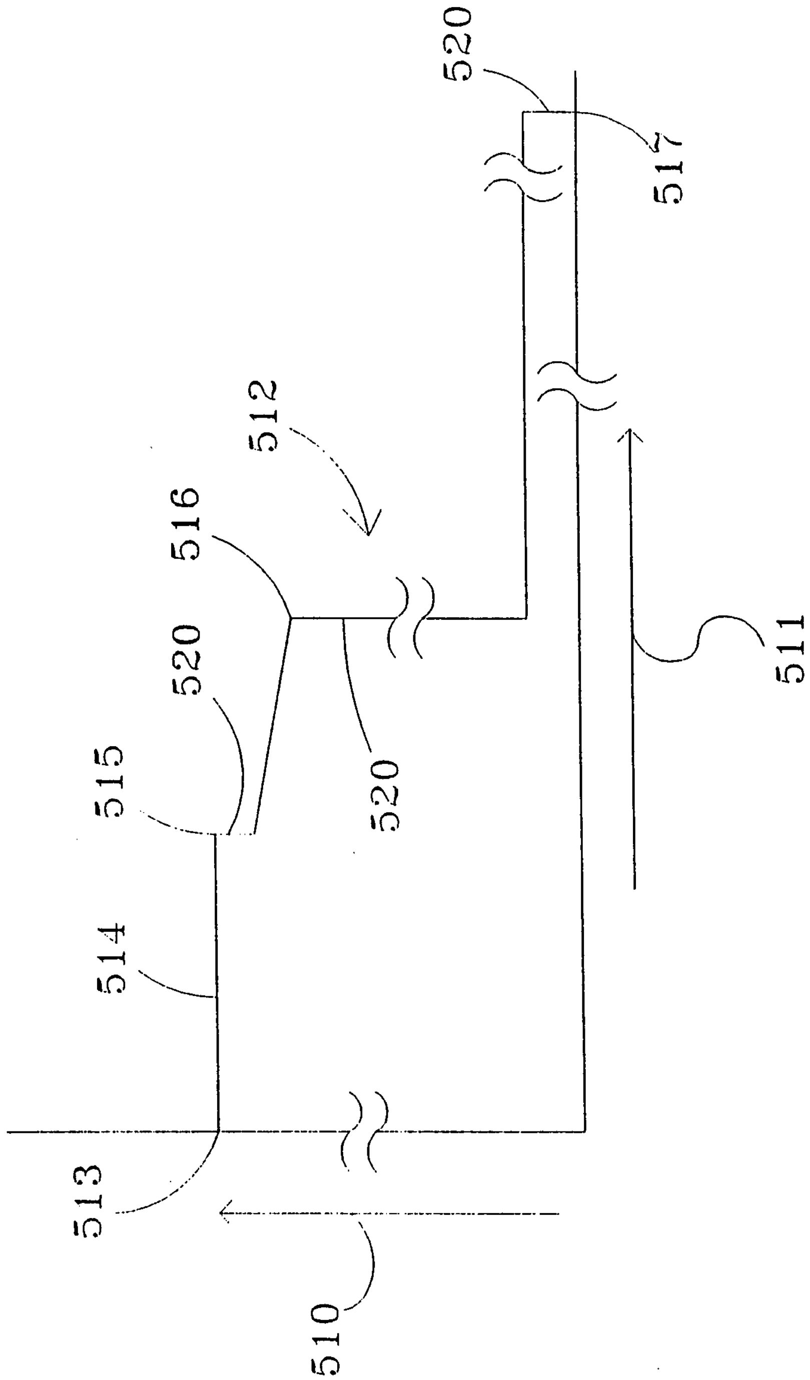
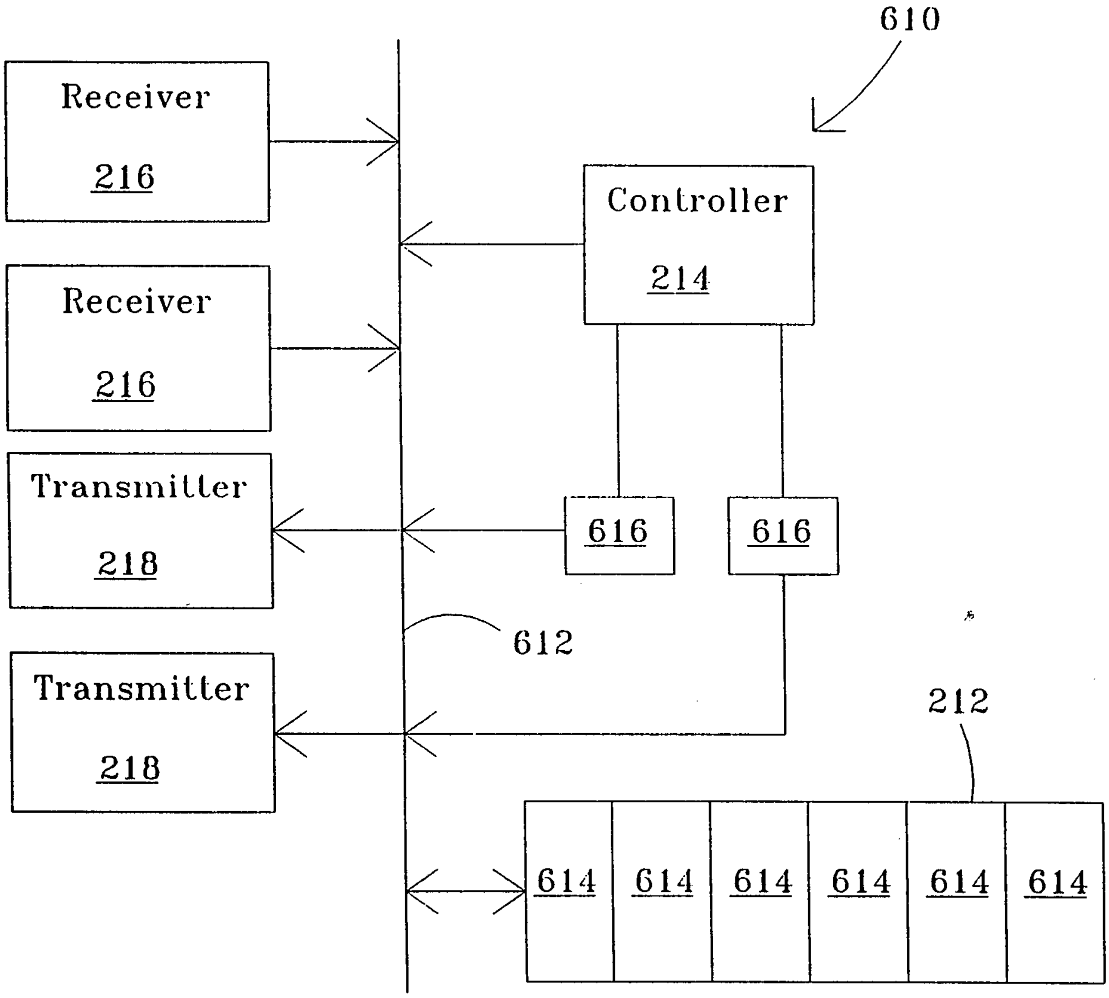


Fig. 6


610
Receiver
216
Controller
214
Receiver
216
Transmitter
218
616
616
612
Transmitter
218
212
614
614
614
614
614
614

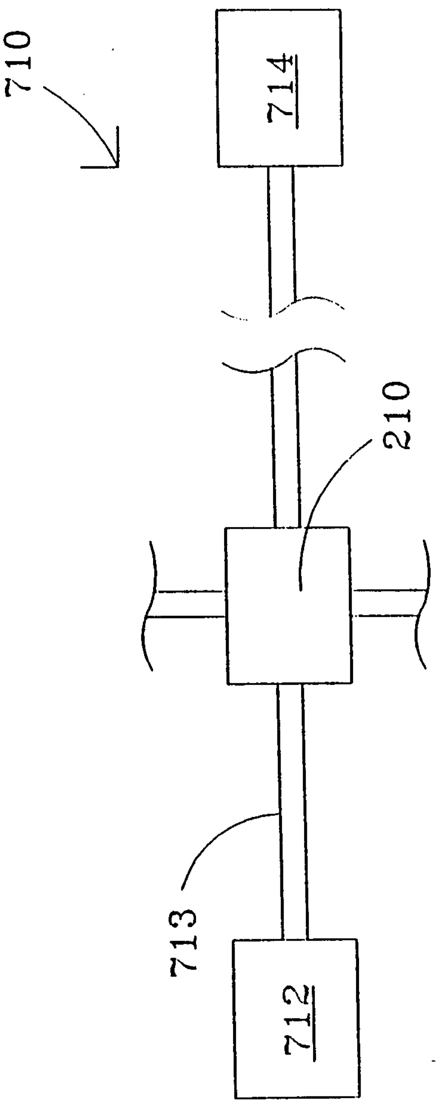

710
714
210
713
712

Fig. 7

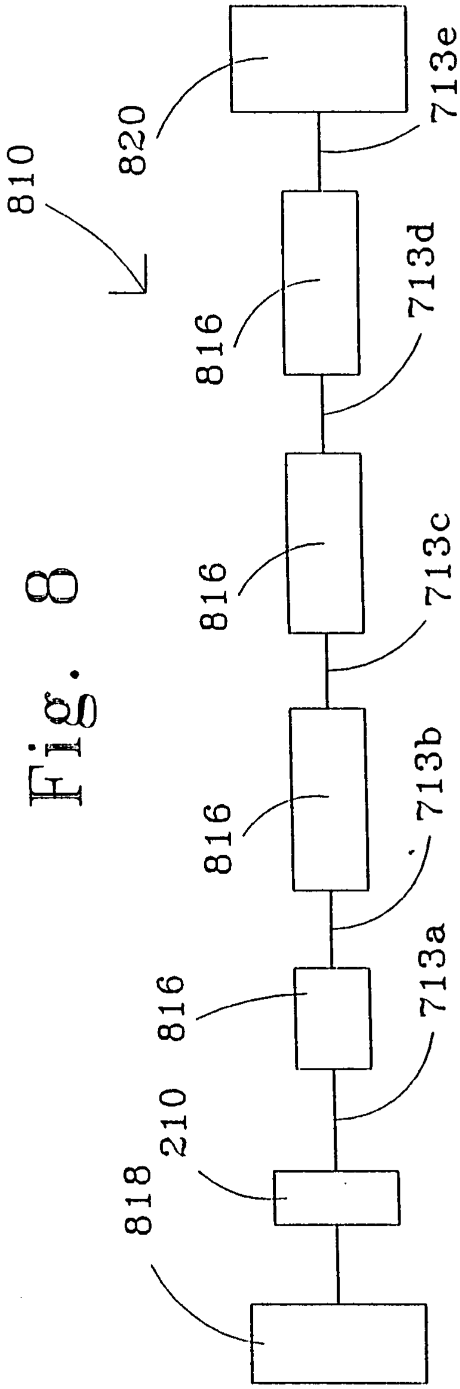

810
820
713e
816
713d
816
713c
816
713b
816
713a
210
818

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No. PCT/US94/08656

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06F 13/00
US CL :395/200
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. : 395/200,250,275; 340/825.5; 370/60,61,85.1,85.5,94.1

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)

APS - variable, latency, packet, buffer, threshold, bridge, transfer, data, efficiency, adaptive, throughput,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A 4,839,891 (Kobayashi et al) 13 June 1989, Abstract, Col. 1, claim 3.	1-19
A	US,A, 4,845,709 (Matsumoto et al) 04 July 1989, Abstract, Figure 1	1-19
A	US,A, 4,926,415 (Tawara et al) 15 May 1990, Abstract, Claim 1	1-19
A	US, A 5,103,446 (Fischer) 07 April 1992, Abstract, Col. 5 lines 45 et seq.	1-19

☐ 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 part 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
16 SEPTEMBER 1994	JAN 23 1995

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