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(54) **DYNAMIC ACTIVITY MODEL OF NETWORK SERVICES**

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G06F 15/173 (2006.01)

(52) **U.S. Cl.** **709/224**

(58) **Field of Classification Search** 709/224
See application file for complete search history.

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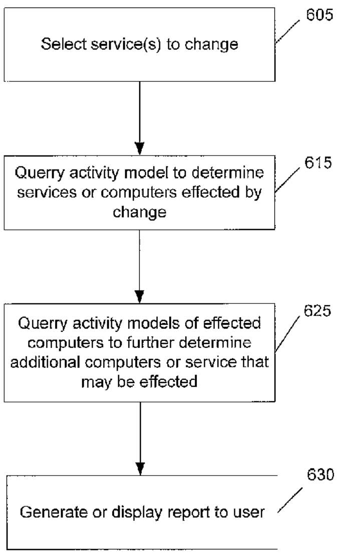
(57) **ABSTRACT**

An activity model is generated at a computer. The activity model may be generated by monitoring incoming and outgoing data in the computer. The collected data is analyzed to form a graph that describes and predicts what output is generated in response to received input. Later, a window of input and output data is collected from the computer. This collected window of data is used to query the activity model. The graph in the activity model is then used to give the probability that the collected window of data was collected from the computer used to generate the activity model. A high probability indicates that the computer is performing normally, while a low probability indicates that the computer may behaving erratically and there may be a problem with the computer.

20 Claims, 8 Drawing Sheets


Select service(s) to change
605
Querry activity model to determine services or computers effected by change
615
Querry activity models of effected computers to further determine additional computers or service that may be effected
625
Generate or display report to user
630

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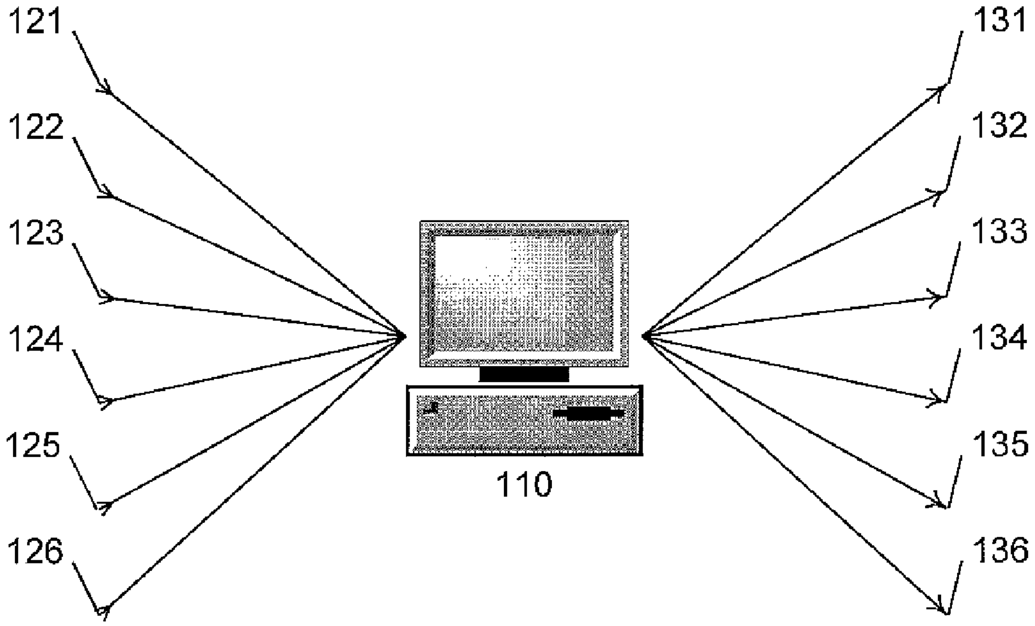

FIG. 1

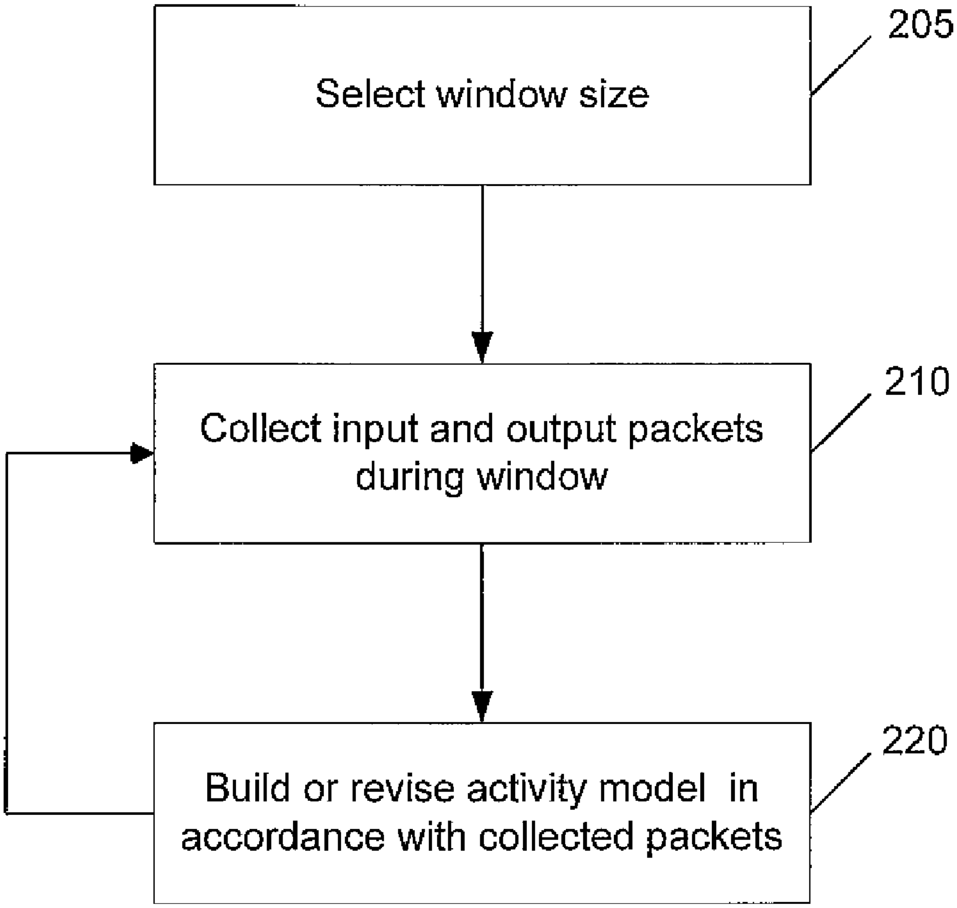
Select window size
205
Collect input and output packets during window
210
Build or revise activity model in accordance with collected packets
220

FIG. 2

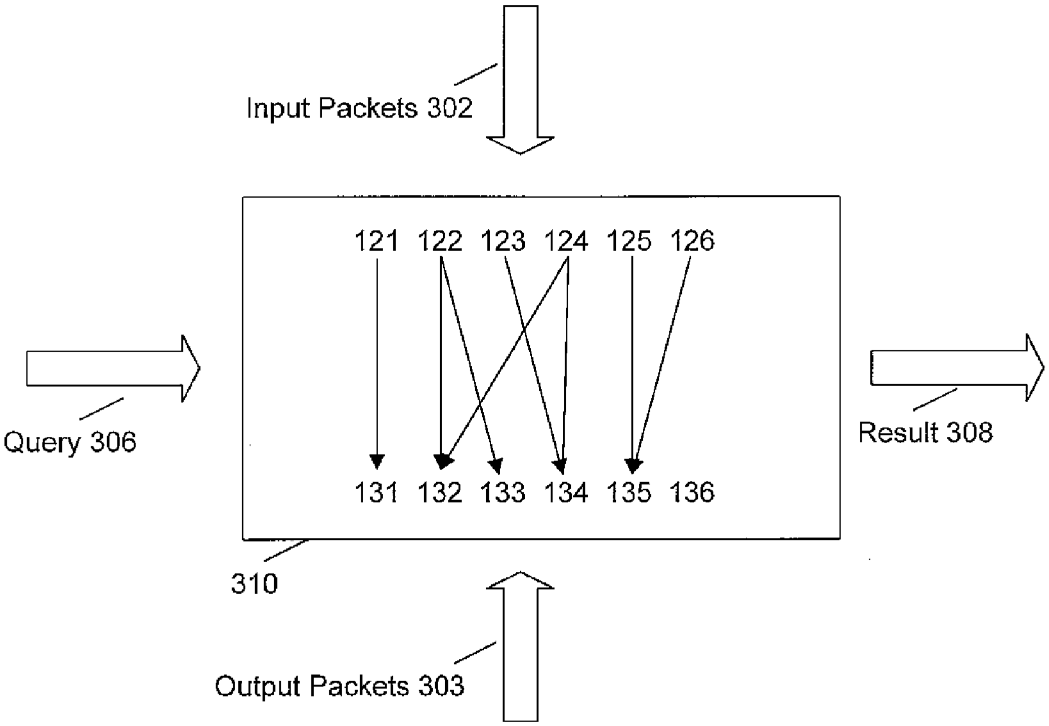
Input Packets 302
121
122
123
124
125
126
131
132
133
134
135
136
Query 306
Result 308
310
Output Packets 303

FIG. 3

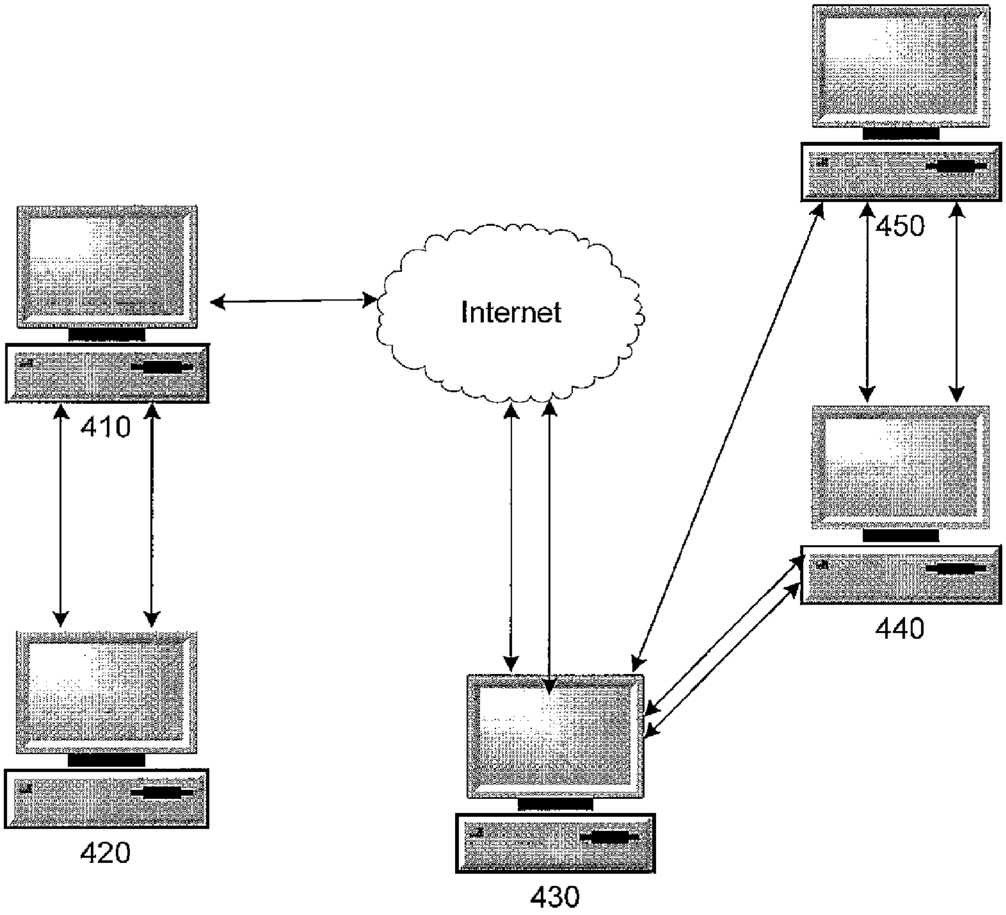

FIG. 4

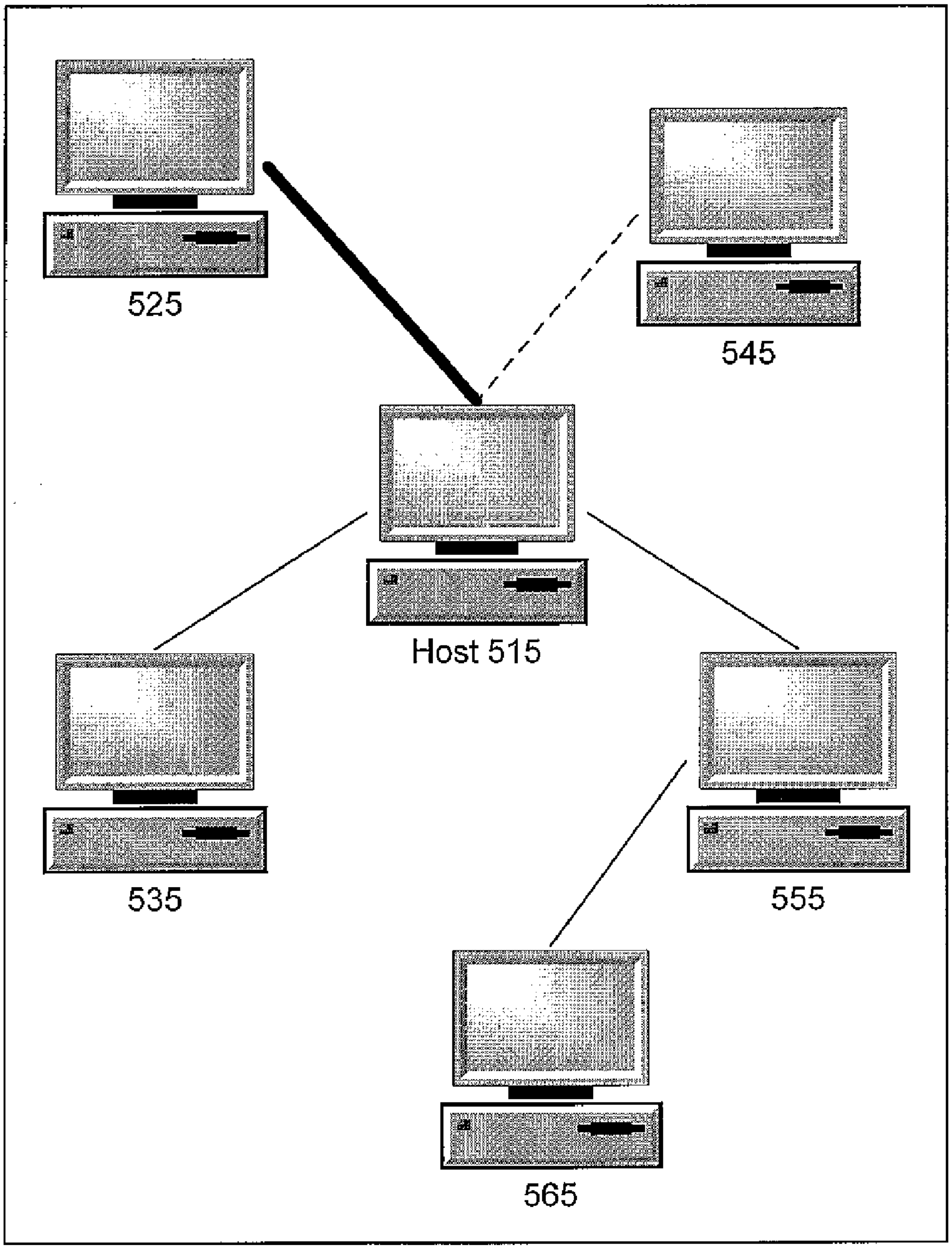

FIG. 5

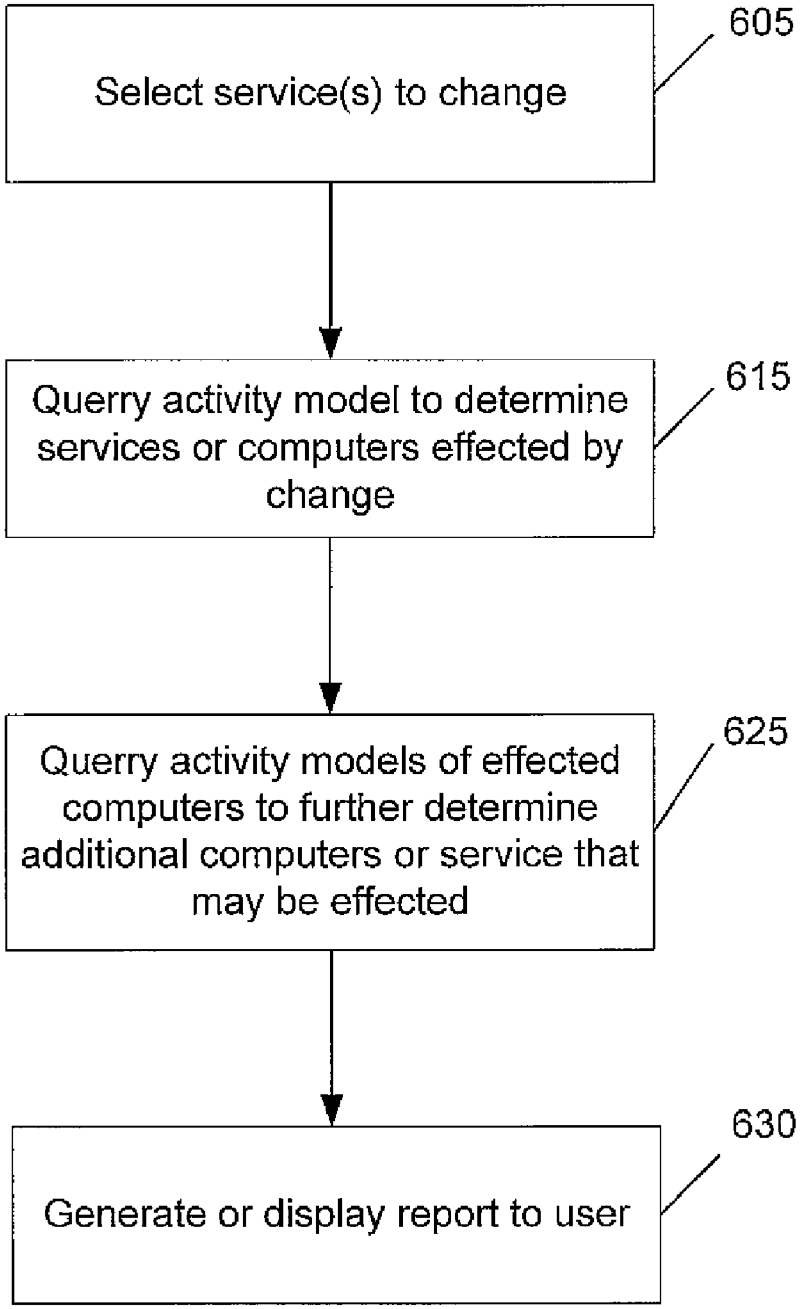
Select service(s) to change
605
Querry activity model to determine services or computers effected by change
615
Querry activity models of effected computers to further determine additional computers or service that may be effected
625
Generate or display report to user
630

FIG. 6

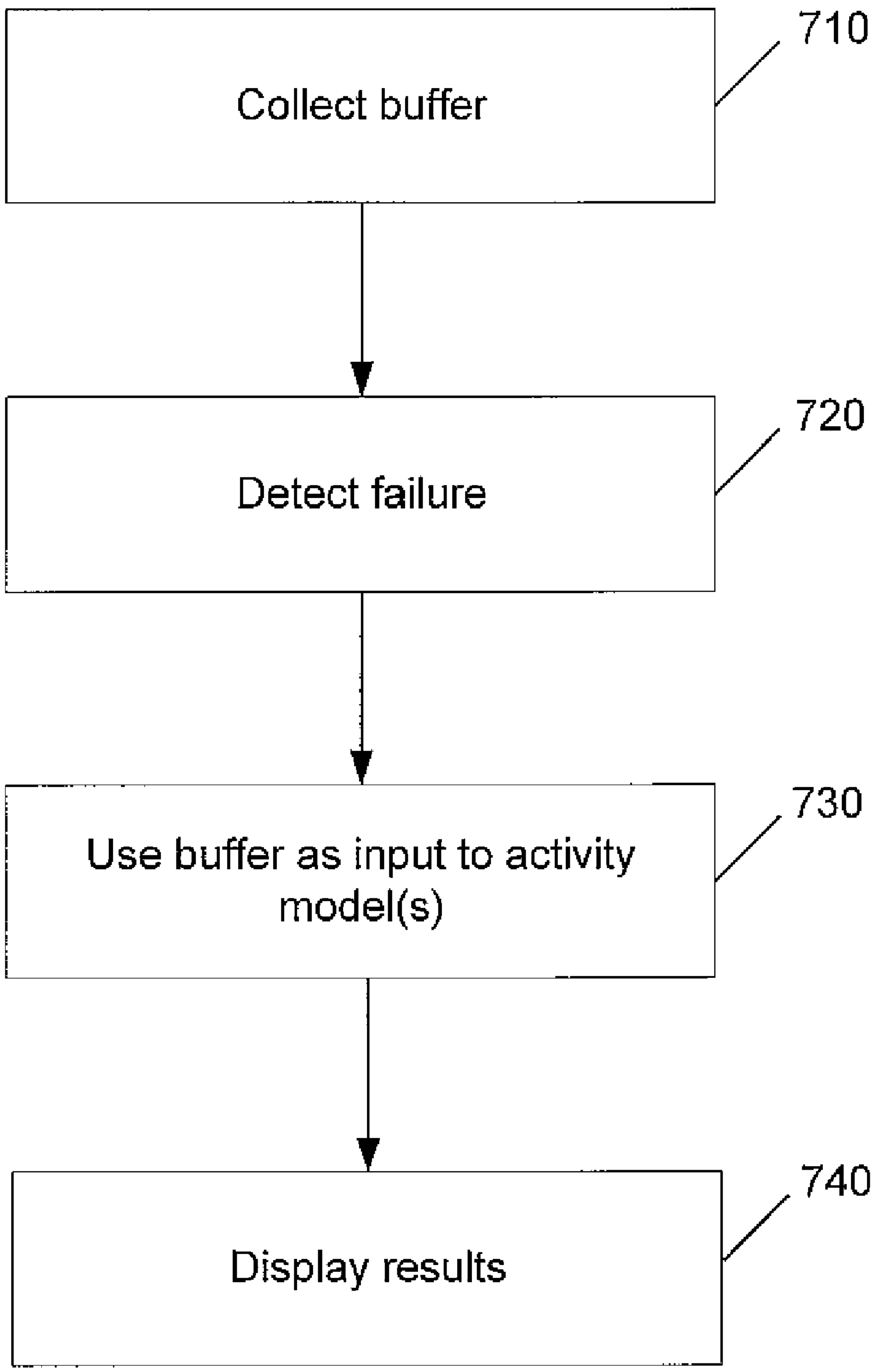
Collect buffer
710
Detect failure
720
Use buffer as input to activity model(s)
730
Display results
740

FIG. 7

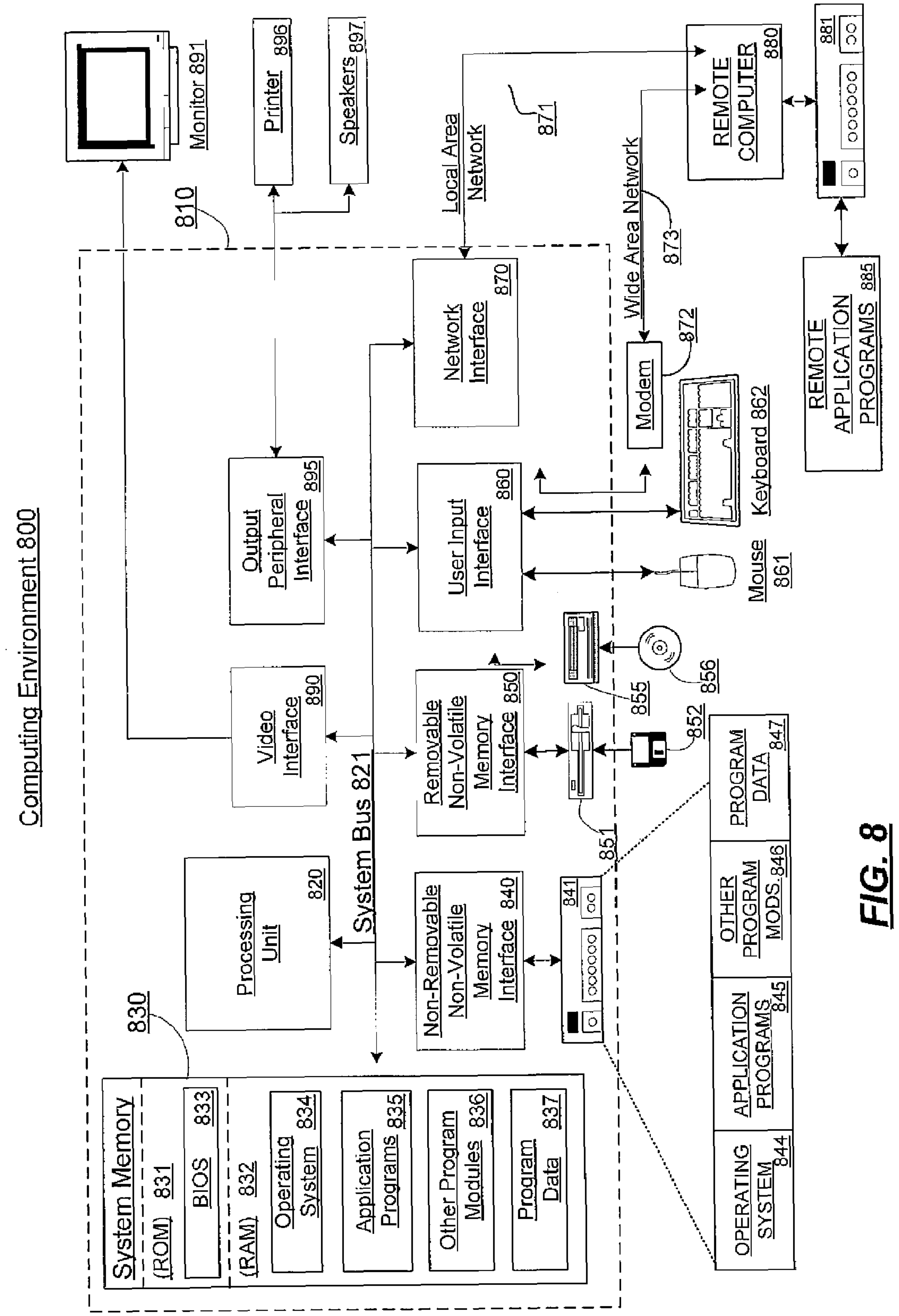
Computing Environment 800
810
830
System Memory
(ROM) 831
BIOS 833
(RAM) 832
Operating System 834
Application Programs 835
Other Program Modules 836
Program Data 837
Processing Unit 820
System Bus 821
Non-Removable Non-Volatile Memory Interface 840
841
Removable Non-Volatile Memory Interface 850
851
852
855
856
Video Interface 890
Output Peripheral Interface 895
User Input Interface 860
Network Interface 870
Monitor 891
Printer 896
Speakers 897
Local Area Network
871
Wide Area Network
873
Modem 872
Keyboard 862
Mouse 861
REMOTE COMPUTER 880
881
REMOTE APPLICATION PROGRAMS 885
OPERATING SYSTEM 844
APPLICATION PROGRAMS 845
OTHER PROGRAM MODS. 846
PROGRAM DATA 847

FIG. 8

DYNAMIC ACTIVITY MODEL OF NETWORK SERVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to the U.S. patent application titled "Distributed Detection with Diagnosis", filed herewith. The contents of the application are hereby incorporated in its entirety.

BACKGROUND

Modern computers receive and transmit an increasingly large amount of packets. These packets represent communications with other computers, such as requests for services and data, for example. Because of the large volume of packets sent and received, it is difficult to determine problems and performance issues with the various services on the computer or that are available on the network.

Existing solutions to this problem generally rely on processing some type of alarm or error data to determine the cause of a particular problem. Other solutions repeatedly probe existing services to determine if they are available or working correctly. Processing alarm data fails to solve the problem because it may require a substantial infrastructure to be added to the system or network and may require dedicated hosts or applications to collect, aggregate and analyze the data. This alarm information is typically routed or collected at a central location, and may require data from various interdependent services. Often, the data is not particularly detailed, and it can be therefore difficult to determine what were the underlying causes of the alarms.

The repeated probing of services is also flawed in that there is a delay introduced before a problem can be detected. For example, if a system is set to probe each service every five minutes, then a problem may possibly go undetected for up to five minutes. Probing may also fail to detect intermittent errors, where a service is only working some of the time, but just happens to work when probed.

Furthermore, the perception of the behavior and performance of services may change depending on the viewpoint. For example, mailboxes may work for email users in Philadelphia, but may not work correctly for users in Europe. This problem may be a result of an error with the active directory service in Europe, and have nothing to do with the mailboxes themselves. However, conventional methods of error detection would initially attribute the error to the mail server and not the active directory service running in Europe. This added delay could result in increased expenses or losses, for example.

SUMMARY

An activity model is generated at a computer. The activity model may be generated by monitoring incoming and outgoing data in the computer. The collected data is analyzed to form a graph that describes and predicts what output is generated in response to received input and vice-versa. Later, a window of input and output data is collected from the computer. This collected window of data is used to query the activity model. The graph in the activity model is then used to give the probability that the collected window of data was consistent with the normal operation when the activity model was formed. A high probability indicates that the computer is performing normally, while a low probability indicates that the computer may be behaving erratically and there may be a problem with the computer.

Alternatively, a postulated window of input data may be considered by querying the activity model to provide the likely output from the computer were it to be presented with such input data.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a computer system including input and output channels;

FIG. **2** is an illustration of an exemplary method for creating an activity model;

FIG. **3** is an illustration of an exemplary activity model;

FIG. **4** is an illustration of an exemplary network of hosts including activity models;

FIG. **5** is an illustration of an exemplary screenshot of a connection view system;

FIGS. **6** and **7** illustrate applications of the activity model; and

FIG. **8** is a block diagram of an example computing environment in which example embodiments and aspects may be implemented.

DETAILED DESCRIPTION

FIG. **1** is an illustration of a computer system including input and output channels. As shown, the computer **110** includes a plurality of input and output channels. The input channels are labeled **121**-**126**, and the output channels are labeled **131**-**136**. Those skilled in the art will appreciate that the particular number of input and output channels shown is arbitrary, and for illustrative purposes only. There is no limit to the number of input and output channels that the system may support.

Input and output channels may represent connections to another computer on a network, or a connection to a particular service, for example. Services may include networked applications such as email, web, file browsing, and management applications, together with underlying protocols such as SMTP, RPC, HTTP, MSProxy, SMB, Netbios, Active Directory, DHCP, NTP, for example

Packets or messages are desirably received through input channels, and packets or messages are desirably sent through the output channels. These packets may contain information such as source or destination address, a name of a particular service associated with that packet, and the actual data payload containing information for the particular service to process or utilize.

An activity model may be generated for the computer **110** by keeping track of the packets that that are sent and received on the various input and output channels. This activity model may then be used as a reference to describe the normal behavior of the host computer **110**. For example, after some period of observation, it may be known that typically, when a packet is received at input channel **121**, two packets are sent from output channel **134**. Later, this information can be used to identify a possible problem in computer **110**. For example, if a packet received on input channel **121** does not result in two packets on output channel **134** as expected there might be a problem in the system. The activity model, and its construction, is described further with respect to FIGS. **2** and **3**.

FIG. **2** is an illustration of an exemplary method for creating an activity model. At **205**, a window is desirably chosen. The window is the length of time that packets will be collected or observed on the various input and output channels into the computer. The window may also be defined in terms of the number of packets collected or observed. The information collected during this window will be used to construct the activity model. The length of time, or amount of packets, selected for the window is a trade off between the accuracy of the model and the resources needed to create the model. A larger window will yield a more accurate model, but at the expense of the increased processing time and other resources required to manage the larger amount of data. Any method known in the art for determining an optimal window size may be used.

At **210**, the system may begin to collect packets according to the specified window size. In one embodiment, only the origin and destination address (i.e, the input and output channels) of the particular packet is recorded. However, additional data regarding the packet may also be collected such as the payload data and any associated application or service. This additional data can be used to create a more detailed activity model that can predict system behavior using the associated payload data as well as the packet origin and destination information. However, the greater the amount of information collected, the greater the system resources needed and more complicated the resulting activity model will become.

At **220**, the system may begin to construct, or modify, the activity model. The activity model may be constructed using a variety of statistical methods and machine learning techniques. These methods are described in more detail with respect to FIG. **3**, for example. However, those skilled in the art will appreciate that a wide variety of techniques may be used.

Because the activity model is dynamic, and may change over time, the model is desirably continuously updated. The activity model is desirably updated automatically, in a way that is transparent to a user of the particular host computer. The activity model may be updated at the end of every window of data collection, or at whatever frequency a user of administrator may desire.

FIG. **3** is an illustration of an exemplary activity model. As shown, the activity model may be represented by a graph where nodes represent the input and output channels. In the current embodiment, each node represents one channel, i.e., an IP address of a packet. However, in other embodiments the nodes could further represent other aspects of a packet such as the service associated with the packet, or the particular data fields or payload comprising the packet, for example.

In the example graph, and edge between any two nodes represents an observed probabilistic relationship between the nodes. For example, the line between node **121** and **131** represents a high probability that a packet received on channel **121** will result in a packet output on channel **131**. Similarly, the line from **124** to **132** and **134**, represents a high probability that a packet received on channel **124** will result in a packet output on channels **132** and **134**.

In one embodiment, the probabilistic graph of the activity model is generated using the noisy-or method. In this method the graph of the activity model may comprise a bipartite graph with a set of nodes Q representing the incoming packets or channels, and a set of nodes P representing the output packets or channels. The model assumes that the graph only comprises edges from nodes in Q to nodes in P. Further, the model also assumes that the relationship between a node in P and its parents in Q is logical-or with noise. To achieve this, a statistical parameter Z is associated with each edge, and the probability of a particular output packet from a particular node is modeled as a logical function depending on the particular Z values associated with the edges into that node.

In another embodiment, the probabilistic graph of the activity model is implemented as a bipartite Bayesian network with arbitrary parameterization. In contrast with the previous embodiment, this model removes the noisy-or structural assumption, to allow for more complex probabilistic relationships between the input and output nodes.

In another embodiment, the probabilistic graph is implemented using a Bayesian classifier model. The graph is modeled with classification problems, using one for each output in the host system. The host inputs are the classification features and the "class" comprises the host output activity. Different Bayesian classifiers may be used including Naïve and TAN, for example.

In yet another embodiment, the activity model is implemented using arbitrary graph structures. As illustrated in FIG. **3** and described in the two models above, the graph only comprises edges from input to output nodes. However, a more complete activity model may also consider probabilistic relationships between multiple input, or multiple output nodes. For example, when an input is received on channel **121**, there may be a high probability that an input is also received on channels **122** and **124**. However, if there is no associated output packet that is sent with a high probability, the above two models would be unable to express the probabilistic relationship between the inputs because the models do not allow edges between input nodes. Removing the restriction on the graph structure will increase the predictability of the activity model, but requires a greater investment to create and maintain the resulting activity model.

As illustrated in FIG. **3**, the activity model can be used to determine the probability of a particular observed set of input and output packets. The system desirably accepts a query **306**, such as an observed set of inputs and an observed set of outputs, for example. The system may then use the generated activity model to determine the probability that the observed inputs and outputs are consistent with the activity model. For example, the system might use the activity model to generate a Z value for that set of input. The Z value may then be referenced against a Gaussian distribution to determine how unusual the particular observed sets of inputs and outputs are. This probability may comprise the Result **308**. Those skilled in the art will recognize that the particular methods for determining the probability of a given set of inputs and outputs depend on the statistical methods used to generate the underlying activity model. Similarly, those skilled in the art will also recognize that a wider variety of statistical methods may be used.

FIG. **4** is an illustration of an exemplary network of hosts including activity models. As illustrated, there are several host computers shown. These include hosts **410**, **420**, **430**, **440**, and **450**. Each of these hosts may be connected to one another through a variety of channels, illustrated by the arrows connecting the hosts. Further, each of these hosts may have an activity model along with some type of activity model client that maintains the activity model, as well as responds to queries made to the activity model. Note that while the illustrated network comprises only five hosts, it is for illustrative purposes only, and not meant to limit the invention to networks of five hosts. There is no limit to the number of hosts that may be supported.

The system illustrated in FIG. **4** desirably allows hosts to not only query their own activity models, but also the activity models of the other hosts on the network. For example, a user at host **430** may learn that a some users are having difficulties with their email. Accordingly, the user may query the activity model of the host **430** using an API such as one discussed above. However, rather than simply taking a window of packets and comparing them against the activity model to determine if there is a statistically significant change in the behavior of the system that may indicate a problem, the revised API may take the further step of recursively querying the activity models of the hosts on the network that the host **430** receives packets from, or has channels with. These hosts may then recursively query the activity models of the hosts that they receive packets from, and so forth.

The results from each of the various hosts are then returned to the host **430** who is then able to see which, if any, of the various hosts on the network may be the cause of the email difficulty. Once the host **430** determines which host is not behaving correctly according to its activity model, the host **430** may use its own activity model to isolate the various channels and packets that connect it to that particular hosts and further query its activity model using a window comprising those packets to further determine the service or cause of the failure.

In another embodiment, when the host **430** queries its activity model, the activity model may only recursively query the activity models of hosts who have a high connectivity to other hosts on the network. The, the activity model can be used to determine, given a particular input, which computers is the host computer likely to send output packets to. In a similar way, it may be determined which hosts the particular host **430** is most connected to or most dependent on. Therefore, when determining the source of an error by recursively querying active directories, the host **430** may conserve resources by first only querying hosts who it is highly connected to, and that are therefore the most likely candidates for the source of the error.

FIG. **5** is an illustration of an exemplary screenshot of a connection view system. The connection view system desirably provides a user or administrator of a host computer with a graphical view of the computers, and or service, that the particular host computer may depend on. As shown, the host computer **515** depends, or receives packets from computers **525**, **545**, **535**, and **555**. In addition, the host computer **515** indirectly depends on computer **565** through its dependency on computer **555**.

As described above, the particular computers shown in the dependency graph are desirably determined using the activity model associated with host computer **515**. The activity model of the host computer **515** can determine which computers send packets to the host computer, and which computers receive packets from the host computer. Accordingly, these computers may be shown in the connection view. In one embodiment, all computers that are connected to the host computer **515** are shown. In another embodiment, only computers that meet some connectivity threshold are illustrated. This threshold may be determined by a user or administrator, for example. Any system, method, or technique known in the art may be used.

As shown in FIG. **5**, the relative importance or strength of the connection between the computers and the host computer **515** is illustrated by the thickness of the line connecting the computers. For example, the thick line between computer **525** and host computer **515** denotes a strong or high dependency. Similarly, the hashed line between computer **545** and host computer **515** denotes a weaker or low dependency. In addition, colors may be used to illustrate the dependency. Those skilled in the art will recognize that the relative dependency of the computers may be illustrated by a variety of well known methods. Any technique known in the art may be used.

The connection view system may be further used to illustrate to a user the health of the host computer and the health of those computers connected to it. For example, the activity model of the host computer may be queried, along with the activity models of the various computers connected to the host computer. If the activity models report that their respective systems are behaving normally, then the corresponding icons for those systems may be displayed normally, or with a shade of green to indicate everything is working correctly. Similarly, if an activity model shows that a particular system is behaving strangely, then the system may display the icon associated with that computer in some way to illustrate the problem, such as a shade of red, for example.

Another aspect of the connection view system may be to display to the user which services or resources are associated with the computers displayed in the connection view. As described above, the activity model may be allowed to inspect the received and sent packets to determine which service or services they may be associated with. Also, separate service specific activity models may be kept to help determine if the particular service is behaving correctly. Using these features, the activity model may be referenced to determine which services are provided from, or associated with, each displayed host. The service or services may be displayed next to the associated computer. In addition, the activity models of the associated computers may be additionally queried to determine if these services appear to be working correctly. These services may they be displayed in such a way as to indicate their health, e.g., red or green.

As described above, the connection view may initially only show the computers that have connections to, or send packets to, the host computer **515**. However, an alternative embodiment may include the feature of allowing a user to select and expand a particular host computer to view the computers connected to the selected host. For example, as illustrated in FIG. **5**, computer **565** is connected to computer **555**, which is connected to the host computer **515**. Initially computer **565** may not be displayed to a user of the host computer **515** because it is not directly connected to it. However, the user may be able to expand the view by clicking, or otherwise selecting computer **555**. After expanding the view the user may be presented with one or more additional computers connected to computer **555**, for example. The computers that connect to computer **555** may be determined by querying the activity model of computer **555**.

As will be apparent to those skilled in the art, the activity model, particularly the activity model capable of querying other activity models in a networked environment, may be useful for a variety of specialized applications. For example, one such application may be anomaly detection. A particular system may continuously query its own activity model in order to detect anomalies. If the detected behavior is not predicted by the activity model, or differs from the activity model in a statistically significant way, then it may be useful to alert a user that an anomaly has been detected.

Similarly, in a networked environment, systems on the network that detect anomalies may alert other systems on the network to query their activity models to see if they detect a similar anomaly, or to warn them of possible anomalies. This may be particularly useful for the detection of flash crowds, or a denial of service attack for example.

The activity model may be particularly useful for the differentiation between flash crowds and denial-of-service attacks. A flash crowd is when an unusually large number of users attempt to view a particular web site at the same time. This is usually the result of the posting of an article referencing the web site on a popular internet site that serves to direct a large number of users to the particular web site. In contrast, a denial-of-service attack is a concentrated malicious attack that attempts to crash, or otherwise render inoperable, a web server by repeatedly resending requests to it.

Often web pages are served not by a single web server, but by several web severs, each with a separate IP address. When a typical user makes a request for a web page, the actual server that serves the request is not known to the user, but may be selected according to some load balancing algorithm, for example. In contrast, when a malicious web user or users attempt a denial of service attack, they generally specify the IP address of the server they are attacking. This observation can be used by the activity models to differentiate between the two types of attacks. Thus, when a server under heavy load queries its activity model, and determines that the amount of traffic it is receiving is unusually high it desirably first recursively queries the activity models of the other servers connected to it. If the activity models of the other servers generally show that they are also experiencing unusually high traffic, then it may be assumed that a flash crowd is taking place. However, if few servers are also experiencing the high traffic, then it may be assumed that a denial-of-service is taking place and appropriate action may be initiated.

FIG. **6** illustrates yet another application of the activity model. In this example, the activity model may be used to perform a service dependency performance analysis. At **605**, a user or administrator may desire to make a particular change to a service, for example. However, rather than actually make the change and observe the effects, the user may wish to use the activity models to generally predict the impact of the service change to the overall system or network.

At **615**, the particular host or host(s) where the initial service change has been determined to take place, may have their activity models examined or queried to determine which systems on the network will be affected by the change in the service. This may be determined by using the activity model to identify which systems receive output packets from the particular host or host(s) that are deemed to be part of the changed service, for example.

At **625**, the set of computers on the network that depend or will be most affected by the change in the service have their activity models queried to determine which services or resources on those computers will be affected by the change in the service. This may be accomplished by using the incoming packets that were found to be associated with the changed service to determine the outgoing packets that are statistically associated with the incoming packets according to the activity model. These services may be presented to the user in a report at **630**, or if desired, the computers associated with the outgoing packets may in turn have there activity models queried and so forth. In this way the number of computers potentially affected by the change in service can be determined to whatever degree the user may desire.

At **630**, the user may be presented with a report indicating the effect of the proposed service change to the system. This report may be similar to that illustrated and described with respect to FIG. **5**, for example, and show the computers most effected by the proposed change in service. In addition, the services that may be affected as determined by the activity models may also be displayed along with an indicator of the probability that they will be affected, for example. However, those skilled in the art will appreciate that the report data may be displayed to the user using a variety of techniques known in the art for the presentation of data.

FIG. **7** illustrates yet another application of the activity model. Here, the network of activity models is used to determine the cause of a detected network outage or failure. At **710**, the computers comprising the computer network may begin maintaining a buffer of the last N packets sent to, or received from, other computers on the network. These packets may then be used later to reconstruct the network activity prior to a detected failure. The actual number of packets chosen to buffer is a tradeoff between the memory required to store the packets, and the desire to have as much information available to reconstruct the network activity prior to the failure.

At **720**, a network failure or outage may be detected. This failure may be a service failure, or the failure of one or more of the computers on the network. The failure may be detected by a user or administrator, one or more of the activity models available on the network, or by the computers themselves.

At **730**, after detecting the network failure, one or more of the computers on the network may use the buffered packets to query their activity model to determine the source of the failure. The buffered packets desirably serve as a snapshot of the network activity just prior to the detected failure. Accordingly, the computer where the failure was detected may query its activity model with the recorded packet activity. In addition, the other computers on the network may similarly query their activity models using their collected packets. Depending on the results of the queries, service specific activity models may also be queried in order to further determine the source of the failure.

At **740**, the user may be presented with a report indicating the possible sources of the network failure as detected by the activity models. This report may be similar to that illustrated and described with respect to FIG. **5**, for example. However, those skilled in the art will appreciate that the report data may be displayed to the user using a variety of techniques known in the art for the presentation of data.

Exemplary Computing Arrangement

FIG. **8** shows an exemplary computing environment in which example embodiments and aspects may be implemented. The computing system environment **800** is only one example of a suitable computing environment and is not intended to suggest any limitation as to the scope of use or functionality. Neither should the computing environment **800** be interpreted as having any dependency or requirement relating to any one or combination of components illustrated in the exemplary operating environment **800**.

Numerous other general purpose or special purpose computing system environments or configurations may be used. Examples of well known computing systems, environments, and/or configurations that may be suitable for use include, but are not limited to, personal computers, server computers, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, network PCs, minicomputers, mainframe computers, embedded systems, distributed computing environments that include any of the above systems or devices, and the like.

Computer-executable instructions, such as program modules, being executed by a computer may be used. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. Distributed computing environments may be used where tasks are performed by remote processing devices that are linked through a communications network or other data transmission medium. In a distributed computing environment, program modules and other data may be located in both local and remote computer storage media including memory storage devices.

With reference to FIG. **8**, an exemplary system includes a general purpose computing device in the form of a computer **810**. Components of computer **810** may include, but are not limited to, a processing unit **820**, a system memory **830**, and a system bus **821** that couples various system components including the system memory to the processing unit **820**. The processing unit **820** may represent multiple logical processing units such as those supported on a multi-threaded processor. The system bus **821** may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnect (PCI) bus (also known as Mezzanine bus). The system bus **821** may also be implemented as a point-to-point connection, switching fabric, or the like, among the communicating devices.

Computer **810** typically includes a variety of computer readable media. Computer readable media can be any available media that can be accessed by computer **810** and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer readable media may comprise computer storage media and communication media. Computer storage media includes both volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CDROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can accessed by computer **810**. Communication media typically embodies computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. Combinations of any of the above should also be included within the scope of computer readable media.

The system memory **830** includes computer storage media in the form of volatile and/or nonvolatile memory such as read only memory (ROM) **831** and random access memory (RAM) **832**. A basic input/output system **833** (BIOS), containing the basic routines that help to transfer information between elements within computer **810**, such as during start-up, is typically stored in ROM **831**. RAM **832** typically contains data and/or program modules that are immediately accessible to and/or presently being operated on by processing unit **820**. By way of example, and not limitation, FIG. **8** illustrates operating system **834**, application programs **835**, other program modules **836**, and program data **837**.

The computer **810** may also include other removable/non-removable, volatile/nonvolatile computer storage media. By way of example only, FIG. **8** illustrates a hard disk drive **840** that reads from or writes to non-removable, nonvolatile magnetic media, a magnetic disk drive **851** that reads from or writes to a removable, nonvolatile magnetic disk **852**, and an optical disk drive **855** that reads from or writes to a removable, nonvolatile optical disk **856**, such as a CD ROM or other optical media. Other removable/non-removable, volatile/nonvolatile computer storage media that can be used in the exemplary operating environment include, but are not limited to, magnetic tape cassettes, flash memory cards, digital versatile disks, digital video tape, solid state RAM, solid state ROM, and the like. The hard disk drive **841** is typically connected to the system bus **821** through a non-removable memory interface such as interface **840**, and magnetic disk drive **851** and optical disk drive **855** are typically connected to the system bus **821** by a removable memory interface, such as interface **850**.

The drives and their associated computer storage media discussed above and illustrated in FIG. **8**, provide storage of computer readable instructions, data structures, program modules and other data for the computer **810**. In FIG. **8**, for example, hard disk drive **841** is illustrated as storing operating system **844**, application programs **845**, other program modules **846**, and program data **847**. Note that these components can either be the same as or different from operating system **834**, application programs **835**, other program modules **836**, and program data **837**. Operating system **844**, application programs **845**, other program modules **846**, and program data **847** are given different numbers here to illustrate that, at a minimum, they are different copies. A user may enter commands and information into the computer **20** through input devices such as a keyboard **862** and pointing device **861**, commonly referred to as a mouse, trackball or touch pad. Other input devices (not shown) may include a microphone, joystick, game pad, satellite dish, scanner, or the like. These and other input devices are often connected to the processing unit **820** through a user input interface **860** that is coupled to the system bus, but may be connected by other interface and bus structures, such as a parallel port, game port or a universal serial bus (USB). A monitor **891** or other type of display device is also connected to the system bus **821** via an interface, such as a video interface **890**. In addition to the monitor, computers may also include other peripheral output devices such as speakers **897** and printer **896**, which may be connected through an output peripheral interface **895**.

The computer **810** may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer **880**. The remote computer **880** may be a personal computer, a server, a router, a network PC, a peer device or other common network node, and typically includes many or all of the elements described above relative to the computer **810**, although only a memory storage device **881** has been illustrated in FIG. **6**. The logical connections depicted in FIG. **6** include a local area network (LAN) **871** and a wide area network (WAN) **873**, but may also include other networks. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets and the Internet.

When used in a LAN networking environment, the computer **810** is connected to the LAN **871** through a network interface or adapter **870**. When used in a WAN networking environment, the computer **810** typically includes a modem **872** or other means for establishing communications over the WAN **873**, such as the Internet. The modem **872**, which may be internal or external, may be connected to the system bus **821** via the user input interface **860**, or other appropriate mechanism. In a networked environment, program modules depicted relative to the computer **810**, or portions thereof, may be stored in the remote memory storage device. By way of example, and not limitation, FIG. **6** illustrates remote application programs **885** as residing on memory device **881**. It will be appreciated that the network connections shown are exemplary and other means of establishing a communications link between the computers may be used.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

What is claimed:

1. A method for constructing and maintaining an activity model, comprising:

capturing a first window of input and output data into a computer, the first window of input and output data corresponding to a plurality of input channels and a plurality of output channels on the computer;

analyzing by one or more computer processors the collected first window of input and output data to identify statistical relationships among the data, wherein the relationships comprise a determination that receiving a packet at a first input channel of the plurality of input channels on the computer causes a packet to be transmitted from a first output channel of the plurality of output channels on the computer; and

generating by the one or more computer processors an activity model from the identified statistical relationships among the first window of data.

2. The method of claim **1**, further comprising:

capturing a second window of input and output data into the computer; and

querying the activity model using the captured second window of data to determine the likelihood that the computer is behaving normally.

3. The method of claim **1**, further comprising continuously capturing subsequent windows of input and output data and updating the generated activity model to account for the captured windows of input and output data.

4. The method of claim **1**, wherein the activity model comprises a graph.

5. The method of claim **4**, wherein the graph comprises a noisy-or graph.

6. The method of claim **4**, wherein the graph comprises a Bipartite Bayesian Network.

7. The method of claim **4**, wherein the graph comprises an Arbitrary Graph Structure.

8. The method of claim **4**, wherein the graph comprises a Bayesian classifier model.

9. The method of claim **1**, wherein the data is packets.

10. The method of claim **9**, wherein analyzing the collected first window of input and output data to identify statistical relationships among the data comprises analyzing origin and destination addresses of the packets.

11. The method of claim **9**, wherein analyzing the collected first window of input and output data to identify statistical relationships among the data comprises analyzing service information associated with the packets.

12. A computer-readable storage medium, where the computer-readable storage medium is not a signal, containing computer-executable instructions for performing the method of:

selecting a first window of input and output data, the first window of input and output data corresponding to a plurality of input channels and a plurality of output channels on the computer;

analyzing the collected first window of input and output data to identify statistical relationships among the data, wherein the relationships comprise a determination that receiving a packet at a first input channel of the plurality of input channels on the computer causes a packet to be transmitted from a first output channel of the plurality of output channels on the computer; and

generating an activity model from the identified statistical relationships among the first window of data.

13. The computer-readable storage medium of claim **12**, further comprising computer-executable instructions for:

selecting a second window of input and output data; and

querying the activity model using the captured second window of data to determine if the captured second window of data is predicted by the generated activity model.

14. The computer-readable storage medium of claim **12**, further comprising computer-executable instructions for continuously selecting subsequent windows of input and output data and updating the generated activity model to account for the subsequent windows of input and output data.

15. The computer-readable storage medium of claim **12**, wherein the activity model comprises a graph.

16. The computer-readable storage medium of claim **15**, wherein the graph comprises one of a noisy-or graph, a Bipartite Bayesian Network, a Bayesian classifier model, and an Arbitrary Graph Structure.

17. The computer-readable storage medium of claim **12**, wherein the data is packets.

18. The computer-readable storage medium of claim **17**, wherein analyzing the selected first window of input and output data to identify statistical relationships among the data comprises computer-executable instructions for analyzing origin and destination addresses of the packets.

19. The computer-readable storage medium of claim **17**, wherein analyzing the selected first window of input and output data to identify statistical relationships among the data comprises computer-executable instructions for analyzing service information associated with the packets.

20. A method for constructing an activity model, comprising:

capturing a first window of input and output packets into a computer;

analyzing by one or more computer processors the arrival time and the source and destination addresses of the packets to identify statistical relationships among the packets; and

generating by the one or more computer processors an activity model from the identified statistical relationships among the packets.

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