A GRAPHICAL REPRESENTATION FOR NETWORK MANAGEMENT

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Network management is currently a difficult task because of the volume of data that must be examined. Often, network problems become hidden in the masses of available data. A more serious problem than the over abundance of data is the manner in which data is presented. It is difficult to visualize a network by examining tabular data output.

Many similar problems in science and engineering have been solved by converting the data into computer graphic presentations. By presenting computer network data in graphical form instead of numerical, the network manager will be able to discover problems in the network much faster and easier than traditional methods have previously allowed.

PROBLEM

Network management is currently a difficult task due to the large amount of data which must be examined. Often, network problems become hidden in the masses of available data. This can be compared to looking for a single four leave clover surrounded by hundreds of three leave coves.

A more serious problem than the over abundance of data is the manner in which the data is presented. Network managers traditionally view computer networks through numerical data. The problem is that this data often proves to be too massive and variant for easy examination. Consequently, it can be very difficult to quickly determine network performance.

Many similar problems in science and engineering have been solved by converting the data into computer graphic presentations. By presenting computer network data in graphical form, a network manager is able to discover problems in the network much faster and easier than traditional methods have allowed. It also becomes possible to see problems that traditional tools have not shown due to the volume of data under consideration.

This paper suggests ways of presenting network operational data in more natural, intuitive and effective forms. Such presentation schemes will greatly aid in network planning and diagnostics.

INTRODUCTION

Networks for the most part have only been around since the late 1960's. Effective network management has been around far less than that. The approach for network management has often been to increase the size or capacity of the network when the performance of the net dropped, the "Bigger is Better" mentality. Although this approach is acceptable in some cases, it will usually prove to be very expensive.

As computer networks increase in size, it becomes increasingly difficult to manage them. Proper management of a network is necessary in order to optimize network cost and performance. Large companies spend an inordinate amount of money on telecommunications. For instance, American Airlines spends about 16 million dollars a month. A reduction of just one percent in cost of network operations for a company of this size would result in a significant savings.

TRADITIONAL APPROACH

Many of the available tools for network management are designed only for specific types of networks and give only single views...
of networks. It seems apparent that network management would be greatly enhanced by tools that would allow concurrent presentations of networks and their performance characteristics. Such tools should be generic in their presentation and allow users to examine data in both global and local spaces.

Network management needs tools which provide a network map so that errors can be quickly traced. Such a map should be updated on a frequent basis, to ensure a current view of the network is always available. The ability to trace a problem quickly and accurately is extremely important because of the great cost of network down time. Many corporations like airlines, face shut down when their network goes down, because the ability to sell their services is severely impaired.

In today's networks, there is almost always more than one vendor providing services regardless of the network size. For example, if there was a small network which connected Salt Lake City and Los Angeles, it would require at least three vendors. When more than one vendor exists in a network and a problem arises, the vendors will often resort to finger pointing (placing the blame on the other vendor(s)). Consequently, it is important to identify quickly and accurately what part of the network has failed, so that vendor contention is eliminated and full network service is restored quickly.

Network management has several aspects whose combined goal is to keep the network up and running with the best possible performance at the best possible cost. Towards this goal, network management addresses itself to the following areas: band width allocation, billing, inventory, tariff optimization and disaster recovery.

There are many network management tools available on the market today. Unfortunately, there does not seem to be any tools which address all of the above issues in a satisfactory manor. The tools that do exist are for the most part machine dependant. Eventually tools will need to exist that cover all of the concerned areas of network management and will interact with all machines. This paper discusses concepts of presentation that should be in such a tool. Most communication hardware manufactures vend network management tools (IBM, Hewlett-Packard, Digital equipment Corp, Tektronix, etc.) The problem is that these tools generally only work on the manufactures equipment. One of the reasons for this is that the industry lacks any good communications protocol standards. Until standards are developed, the networking industry will remain in a fragmented management state.

We have developed communication standards that have allowed us to connect differing hardware, (CCITT X.25, IEEE 802, TCP, OSI, etc.) and similar standards are needed in the area of network management protocols. There is one standard for network management called Simple Network Management Protocol (SNMP), but this protocol is not robust enough to report on and to control a network. SNMP's aim is to be simple and universal and is consequently a step in the right direction.

The International Standards Organization (ISO) has been developing a network management communication protocol as part of its Open Systems Interconnection (OSI) standard. This standard is being referred to as layer 8 of the OSI protocol. The OSI layer 8 protocol was not complete at the time that this paper was being developed, consequently, this paper does not utilize it.

SOLUTION

To develop and demonstrate concepts which should be part of any good network management tool, a network management display program has been constructed. In the
sections which follows, the following concepts will be discussed:

- Digraph Depiction
- Color Modulation
- Hierarchical Structure
- Multiple Windows and Data Sources

**Digraph Depiction**

Networks are easily convertible to a digraph. Figure 1 is an example of such a conversion. Figure 1 shows the National Science Foundation network (NSFnet). NSFnet is a fiber optic based backbone network that operates with T1 carriers which are capable of handling 1.544 megabits per second (Mb/s).

By converting networks to digraphs the network manager is able to quickly picture the topology of the network. The obvious relation of the network to a digraph is a relation such that a digraph node represents a network node and a digraph arc represents a network link.

This view of the subnet shows the physical topology of the network. The problem is that the Oakland and San Francisco sites are so close together that the link between the two is hidden. A more valuable view of the subnet would be a logical view if the two sites are pulled apart slightly as figure 3 demonstrates. The significance of this argument will become clear as the paper continues.

![Figure 1](image1.png)

**Figure 1**
NSFnet

In figure 2, a piece of a network that might tie together the Seattle, San Francisco, Oakland and Los Angeles airports is shown.

![Figure 2](image2.png)

**Figure 2**
Physical view

![Figure 3](image3.png)

**Figure 3**
Logical view
Another important aspect of the presentation of the network is use of arc widths to suggest relative link capacities. In the view in figure 4 the lines are four pixels in width which represents a high capacity link. The user should be able to set partitions by which the link capacities are encoded to line widths. For example, figure 5 shows a pop up window that allows this.

With the settings of figure 5, any link with capacity 2400 bits per second (bps) or less will be displayed with a width of one pixel. Any link with capacity in the range of 2401-19200 bps will be displayed with two pixels. Any link with capacity between 19201 and 1,000,000 bps will be displayed with 3 pixels. And finally, any links with capacities greater than 1,000,000 bps, such as the T1 carriers in figure 4, will be displayed with 4 pixels.

Justification for this can be seen by considering a network of heterogeneous link capacities where multiple problems exist in the network or when static routing tables are being constructed. A network manager is far more interested in the T1 1.544 megabits per second (Mbps) link than the voice grade 2,400 bps link.

<table>
<thead>
<tr>
<th>Capacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partition #1 limit</td>
</tr>
<tr>
<td>Partition #2 limit</td>
</tr>
<tr>
<td>Partition #3 limit</td>
</tr>
</tbody>
</table>

Figure 5
Capacities
Another concept that is demonstrated in figure 4 is the use of displayable neumonic names for the nodes. In a small network this is of little value. But as a network takes on 100 or more nodes, the network manager quickly loses the desire and ability to memorize node names. Both the varying arc widths and the use of neumonic names should be a user selectable option. The advantage of a view, such as figure 1, where all lines are a single pixel in width, and neumonic names are not used, is that more nodes and links can be displayed without cluttering the viewing space.

**Color Modulation**

Perhaps one of the most powerful concepts demonstrated is the use of color to represent network performance. In this application, the range of 0 - 100 percent has been divided into ten percentile zones. To each zone is assigned a color from a color palette. The assignments are as follows:

<table>
<thead>
<tr>
<th>Range</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>White</td>
</tr>
<tr>
<td>1%-9%</td>
<td>Ice Blue</td>
</tr>
<tr>
<td>10%-19%</td>
<td>Light Blue</td>
</tr>
<tr>
<td>20%-29%</td>
<td>Medium Blue</td>
</tr>
<tr>
<td>30%-39%</td>
<td>Blue</td>
</tr>
<tr>
<td>40%-49%</td>
<td>Dark Blue</td>
</tr>
<tr>
<td>50%-59%</td>
<td>Pale Yellow</td>
</tr>
<tr>
<td>60%-69%</td>
<td>Yellow</td>
</tr>
<tr>
<td>70%-79%</td>
<td>Light Orange</td>
</tr>
<tr>
<td>80%-89%</td>
<td>Orange</td>
</tr>
<tr>
<td>90%-99%</td>
<td>Medium Red</td>
</tr>
<tr>
<td>100%-∞%</td>
<td>Red</td>
</tr>
</tbody>
</table>

This color modulation is valuable in displaying network data such as 'Load to Capacity' ratios. The 'load to capacity' ratio...
can be demonstrated by displaying a representative color. This allows the network manager to quickly ascertain the performance on the network with regards to load to capacity ratios. If a network manager sees a link that is bright red he or she will know that a problem exists in the network. If on the other hand, the network manager sees that the average color of the nodes and links are dark blue, he or she might conclude that the network is performing according to specification (see figure 6.)

The value of color digraphs is that it allows the manager to quickly determine the health of the network. As the old adage says, "a picture is worth a thousand words." In networking, this could be changed to, "a color digraph is worth many pages of printouts." One must be careful in the use of color graphics not to lump too much information into one picture and consequently lose valuable data. For example, links are usually full duplex or bidirectional. It is possible that if a link is running 95% utilization in one direction and 20% utilization in the other, the average of the two is 58% which would be a pale yellow. Pale yellow signifies a healthy link, when in reality the link and perhaps the network is in serious trouble. A combined or averaged view of in-bound and out-bound traffic is still very valuable, but it can not be relied upon as the only display of utilization. The network manager must also have views that discriminate in-bound and out-bound traffic. Figures 7 - 9 demonstrate this concept.

The color palette, which basically ranges from blue to red with intermediate shades, was chosen to suggest a transition from cold to hot.

Building on this concept of using color to present values, delay is another network characteristic that is examined to determine the health of a network. By setting a standard for comparison, a network manager could set a standard such as 600 milliseconds, and color code the delay of each node and link relative to the 600 millisecond standard. If this is done to the NSFnet as shown in figure 6, the resulting view is that of figure 10.

![Figure 7](image)

In and Out bound combined view
Another useful view of the network is that of link type. It is valuable for a network management tool to display the links using color coding to represent the link types. For example, a twisted pair might be represented as ice blue, 75 ohm coax cable as light blue, a satellite channel in yellow, fiber optic as orange and microwave as red. As a result, the network manager is able to determine quickly more of the physical aspects of the network (See figure 11).

There are other network parameters that are worthy of a color graphic display such as bit error rate, however it is not the intention of this paper to present all the possible views, but rather to demonstrate the concept of color modulation to display network parameters. Color modulation can be a powerful tool for the rapid display of information. It might become common to find networks monitored more carefully as a result of tools which utilize concepts such as those being discussed in this paper. Further problems that are not currently visible in a network or that are difficult to see, may become visible due to the use of better tools. Better tools will allow the user to see pictures instead of numbers, which is a less painful way to examine network performance.
It is quite common that a network manager has other jobs besides that of network management. Consequently he or she does not have the time or the desire to frequently examine printouts to see how the network is performing. Rather the network is tuned or repaired when dissatisfied users call in and report a problem. By improving network management tools and the human factors interface, the network manager’s job is simplified and as a result the network will be better maintained.

Hierarchical Structure

Networks by nature are not linear in one domain as most tools have treated them, but rather they are hierarchical and must be treated as such. For example, in the case of educational and research institutions there is a network as shown in figure 1 called the National Science Foundation net that is a nation wide backbone network.

Tied to the NSFnet are geographically smaller networks or regional networks, such as WestNet, Northwestnet, NYSERNET, SURANET. Connected to the regional networks are university campus networks which are tied to departmental networks which may in turn be tied to local laboratory networks. To display all of the nodes of all of the networks in a geographic area, as a linear flat display, in general would not be useful because of the potentially large number of sites. The viewing space would be quickly obscured with too much data.

757 Navigational Avionics System A similar problem exists for the Boeing 757 & 767 jet aircraft flight navigation avionics system. The navigation of this aircraft has been
Figure 11
Link Type

Figure 12
Layer 2, WestNet
fully automated, so that a navigator is not needed. The aircraft has an on board computer which contains a geographical database which has data on all of the airports at which the aircraft could land, navigational aids, airport runway structure and flight routes. With this system, the pilot enters the flight plan into the computer including departure and arrival airport gates. Before, during and after flight, the computer presents a route map and gives graphical directions to the pilot. If all of the information in the database was displayed at once, the system would be useless to the pilot because of the volume of data.

To overcome this problem the computer allows the pilot to select a viewing range and also select what entities are displayed on the screen. For example, at the airport, a pilot can set the computer to display only information within a 10 mile area. After take off, a pilot can set the computer to 20 miles and as altitude is gained, the viewing range is increased up to a maximum of 310 miles. As a plane descends on the arrival airport, a pilot can step the view down again.

The same concept of layering that is used in the Boeing 757 & 767 navigation avionics system can be used in network presentation. For example, figure 1 shows NSFnet which is defined as a layer 1, network, WestNet has been defined as a layer 2. Campus networks have been defined as layer 3 and so on. In this model only five layers have been implemented, but additional layers are available. When the user wants to view the networks, the system must be told which layer to view, and consequently only nodes and links that belonging to that particular layer will be displayed.

Figure 13
Layer 2, BYU's Campus Network (partial)
**Figure 14**  
Partial Layer Interconnection of NSFnet

**Icons** Figures 12 and 13 show two of the lower layers in NSFnet, specifically the regional network WestNet and Brigham Young University's campus network Y-net. Figure 12 demonstrates another concept which is the use of icons. Basically there are two type of nodes. Plain nodes which are just computers and switching nodes such as routers and gateways which tie networks together. To signify a plain node, a circle is used. To signify a router or a gateway a rectangle is used which has an apex either on the top, bottom or both. An apex on the top of the rectangle would signify a connection to a higher level network while an apex on the bottom would signify a connection to a lower level network. Certainly, a node could be connected to both upper and lower layer networks, in which case the icon would look like a diamond.

Of less significance than the connections within a layer, but yet still very important, is the interconnection of the networks through the layers. It is important to be able to see this strata in a fashion similar to the normal layered view. In viewing this interconnection, only nodes which are routers or gateways to different layers should be shown. If this restriction is not met, then the display will be cluttered to the point of rendering the view useless. Figure 14 shows a side view or the interconnection between the layers.

In Figure 14, a network interconnection is shown where nodes are only connected to nodes directly above or directly below the specific layer. This interconnection, however is not realistic. The display tool should in general be able to connect a node on layer i with a node on layer j. A gateway could tie into a high speed network on one side, which has been defined as a high level network, and on the other side tie into a small low speed network that has been defined as a low level network. In any case, the display device
should be flexible enough to handle any connection inside or outside of a given layer.

As an alternative to the side view, the display engine should allow the user to ask for the parent or children of a router or gateway. This has been accomplished in the demonstration program by having the user select a node and ask for the parent or children to be displayed in green.

It is conceivable that a device is a router to more than one network, and these networks might be on different layers. It is consequently up to the user to move to the desired layer(s). In any event, the parent or children will be displayed in green. All other nodes will be colored according to the view that is currently in effect. Figure 15 shows a query for the children of the NSFnet node WestNet.

**Zoom Area** In the model that was constructed for this paper, a plane of 40,000 by 40,000 units was constructed into which all nodes are mapped for a logical placement. Such a large plane is needed to properly map a network such as NSFnet and its affiliated sub networks which spans the United States. Certainly with such a large viewing space, if each coordinate point was mapped to a pixel on the display, the display would not be large enough to handle each of the $40,000^2$ points. Consequently, it must be possible for the user to select the size of the view port and to scroll through the view region.

In addition, the user should be able to set a scaling factor whereby the view port is set to display the network in different resolutions. With this ability the network manager is able to fill the screen with the defined area to view. This ability reduces the need to scroll through the viewing space. Figure 12 is a zoomed in area of figure 16. Figure 12 shows a display...
of the WestNet regional network without the outlining networks being shown.

Figure 16 shows horizontal and vertical scroll bars by which the user is able to adjust the viewing area. Further, these scroll bars give an idea of the general location of the window with in the 40,000 by 40,000 grid.

Multiple Windows and Data Sources

Since the graphics program is capable of displaying networks with differing views, it is convenient to view the network with multiple views concurrently. Consequently, the demonstration program was constructed to utilize four windows. Each window is independent in its presentation, that is. Each window can zoom into a different or the same area of the network. Further, each window can be set to display different performance characteristics. For example, in figure 17, a multiwindow view of the NSFnet model at level 1 is given. The first window is set to display in-bound and out-bound load to in-bound and out-bound capacity. Window two is set to display in-bound load to in-bound capacity. Window three is set to display delay against a user selected 600 millisecond standard. Window four is set to display in-bound and out-bound load versus in-bound and out-bound capacity of WestNet on layer 2.

Network problems are often not discovered from a single snap shot due to time dependant problems. After all, the network performs differently in the morning than it does in the early afternoon or even the late afternoon. The network manager needs to see a representative picture of the network throughout the day. Towards this end, multiple data banks or data sources are need. With this multiple data source capability, the windows need to be additionally able to select which data source to present. For instance, the screen could be set so that each window displays a distinct data source or so each window displays the same data source or some combination between the
two extremes. As an example of a time dependent discovery configuration, window 1 could be set to display the 8:00 a.m. view of the network, window 2 could be set to display the 1:00 p.m. view, window 3 could be set to display the 4:00 p.m. view and window 4 could be set to display the 8:00 p.m. view. Multiple data sources gives the network manager the ability to view the network through time.

Since each window now has several display parameters (view, data source, layer number) the windows should present this parameter setting information to the user. In this particular application, this information is displayed above each of the view ports along with the window number.

**Active Window Presentation** The display tool that was constructed was built on a Macintosh II color computer. As a result, the demonstration program was built so as to conform to the Macintosh user interface standards. Consequently, the program utilizes the mouse for many of the operations. Placing a node in one of the view ports or window, as Apple computer calls it, requires the selection of a location with the mouse. With multiple windows on the screen, it becomes confusing which window is the active window. To enhance the active window beyond what the machine automatically does, the background color of the active window is changed from black to gray. The approach seems to reduce a lot of operator error due to the wrong window being active.
DATA STRUCTURE

In order to support the capabilities of the demonstration program, an appropriate data structure was developed. This data structure follows:

Node Element Record
[address of node]
Id: array of 5 integers
{neumonic name for the node}
Code: string of 6 characters
{actual name for the node}
Name: string of 25 characters
{physical location of the node}
Users point: array of 2 integers
{logical location of the node}
Ms point: array of 2 long integers
{in bound message load}
In msg: long integer
{out bound message load}
Out msg: long integer
{in bound message capacity}
In msg cap: long integer
{out bound message capacity}
Out msg cap: long integer
{delay}
Delay: long integer
{defined level for the link}
Level: integer
{internal link number for use with multiple links between nodes}
Link number: integer of range 0..255
{internal flag to denote a record available for use}
Free: boolean

Arc Element Record
{link identifier}
Id: integer
{address of source node}
Src id: array of 5 integers
{address of destination node}
Dest id: array of 5 integers

Window Data Record
{pointer to machine internal window record}
TheWindow
{X & Y axis scaling factors in effect for window}
Scale: array of 2 long integers
{top left corner of screen in master coordinate, 40,000 x 40,000 viewing grid}
Origin: array of 2 long integers
{internal pointer for scroll bars}
H Cntrl
{internal pointer for scroll bars}
V Cntrl
{flag to denote if window is in a zoomed view}
Zoomed: boolean
{data source that the window is displaying}
Data Source: integer sub range 1 to max number of data sources
{internal variable to record the view in effect}
View: integer
{flag to denote layer infrastructure view}
Side view: boolean
{variable to hold modulation standard for delay if the delay view has been set}
Max delay: long integer
Level: integer
{ flag to denote if parent or children are being searched for }

Family view: integer
{ address of parent or child if a parent or children view is selected }

Filter: array of 5 integers

Data List Record
{ table of capacities for arc presentations }
Capacity table: array of 3 long integers
{ list of all nodes }
Node table: array of node elements
{ list of all arcs }
Arc table: array of arc elements
{ current high water mark for arcs in the table }
Num arcs: integer;
{ current high water mark for nodes in the table }
Num nodes: integer;
{ pointer for path information }
Routing: Path ptr

Field Explanations
Not all of the fields of the records need explanation, what fields do will now be discussed.

Node Element Record The "id" field is composed of five integers, with the idea that the address will be compatible with the NSFnet address scheme. The NSFnet has addresses which look something like "128.12.3.150.2", the NSFnet address is limited in each portion of the address by a single octet range, where as the constructed model uses two octets per sub address.

The "user point" field is intended to allow the system to store the physical location of the site. This field is not however used by the system. Rather the "ms point" or master space point field is used by the system and contains the logical location of the node with in the 40,000 by 40,000 grid.

The "parent id" field is used to store the address of a link from the specified node to another node on another layer, usually a high layer. While this data structure could do with out this field, this field allows the system to update the screen faster because the amount of processing for screen updates is reduced with this field. This field is also used in conjunction with determining the correct icon to use for the node. This field is also a filtering parameter for the side or layer view. The "link to lower level" field is a similar field, but this field is a flag that identifies whether a link to lower layered nodes exist.

Arc Element Record The "id" field is used to distinguish between arcs in the case of multiple arcs between nodes. In the case of multiple arcs between nodes, identifying an arc can not be done with the source and destination nodes along. Hence another discriminator is needed, this is the "id" field.

The "source" and "destination" fields are used internally to record the positions of the end points of the arc. Ultimately, this information is gathered from the nodes directly. These fields are used as a means of speeding up the display process. These fields reduce redundant processing and at the same time maintain a relative amount of independence between the arc and its nodes.

The "link number" field is used internally to number the links between particular nodes. This is different than the "id" field in that with, this field contains a distinct id which is numbered sequentially from zero. This sequential number is needed for displaying the arcs so that the arcs are not placed on top of one another.

Window Data Record The "scale" field is used to record the scaling that is to be done to the window before displaying. This field contains information for scaling on both the X & Y axis independently.

Data List Record The "capacity table" field is used to hold the partition boundaries
for the encoding of link capacity to arc widths.

The "num arc" and "num node" fields are high water makers which are used to denote the highest assigned table position for the arc and node tables respectfully. If a node or link is deleted from the database, the individual record is marked as free but the "num arc" or "num node" field is left untouched. Node or arc records that are marked free will be reused in future node or link additions.

The "routing" field is a pointer to a chain of arcs which have been defined as a path between two nodes. This chain is supplied from external communication and if present will be displayed in place of the database arcs. These externally supplied arcs should however correspond to database arcs.

**Data Structure Design**

The underlying data structure was designed for speed rather than elegance. For this reason a table was used to contain the arcs and nodes. An alternative approach would have been to use a linked list of pointers. The problem with this approach is that operations become sequential instead of random access. With many applications this is of no concern, but graphic applications are in general slow. Tables or rather arrays are faster than pointer linked lists. An elaborate linked list data structure that is faster than a table could have been developed, but the goals of the demonstration program was to demonstrate display concepts and not to provide an end product. Consequently, the table approach was adopted.

The data structure contains redundant information which could be eliminated, such as the master space coordinates of the arc starting and ending points. This redundancy can again be justified by the improvement in speed obtained by having the information immediately available. The cost of this is really not severe, because even a network of a thousand nodes will only occupy 200,000 - 300,000 octets of memory.

This data structure contains only a subset of the fields that would be valuable to a network manager. Additional fields such as bit error rate should be added to this data structure.

**EXTERNAL CONNECTIONS**

Certainly this demonstration program would be of far less value if it did not have any external connection capability. The demonstration engine can be connected to through a RS-232 port on the machine. Since there does not currently exist any fully defined protocols which are rich enough to properly drive the display engine, a protocol was developed to bridge the gap until such time when a reasonable standard protocol exists, perhaps the OSI layer 8 will prove rich enough.

A description of the protocol is not given, but one aspects of the protocol is worth mentioning. The protocol is mostly a one way protocol, that is, the communication traffic is mainly in the direction of the display engine. The one exception to this is a protocol data unit (pdu) that requests a path between any two given nodes. This pdu is not expected to be used abundantly.

**DATA STORAGE**

It is not responsible to expect the display engine to hold all of the characteristic data for the network. Discretion is needed in building the data structure. Certainly information that is going to be called upon regularly such as node and link performance information must be contained in the display engine. If this information is held remotely, the traffic to the display engine will be immense and will limit the processing and display time for the display engine. Other information such as routing tables must be contained remotely. This type of
information can be quite voluminous and consequently would require a large amount of memory for storage and could bog down the communication line to the display engine down. Since the routing information will not be used as much, by comparison, as the performance information, it can be remotely requested as needed. For example, in the demonstration program, when a user wants the path between two nodes, the display engine puts a request for the path on the communication line and then displays any response paths that are returned.

**NUMERICAL DISPLAY & GRAPHICAL DISPLAY**

The graphical display is not meant as a complete replacement to the numerical or tabular presentation method. Rather, the graphical interface is meant as a primary interface to locate problem areas. It is expected that the user will have to request the specific numerical data to ultimately solve many problems. A graphical display engine should be capable of displaying reasonable numerical data.

**CONCLUSION**

The area of network management is in its infancy compared to where it must be in order for networks to be tuned for optimal performance at optimal cost and so networks can be kept up and running. Future network management tools need to abide by a common communication protocol that is robust enough to handle most any management communication needs. Further, the approach of displaying network performance information in a numerical format needs to be enhanced with a display mechanism which utilizes presentation techniques such as digraphs, layering, color modulation and icons. Such network management tools will allow network managers to economically manage networks in such a way as to get the best possible performance at the best possible price. Further, such tools will allow managers to quickly and intelligently adjust networks when components fail.

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