Visualisation of ATM network connectivity and topology

Oliver Saal and Edwin Blake

CS00-13-00

Collaborative Visual Computing Laboratory
Department of Computer Science
University of Cape Town
Private Bag, RONDEBOSCH
7701 South Africa
e-mail: {oliver,edwin}@cs.uct.ac.za

ABSTRACT

We have visualised ATM network connectivity with respect to traffic service classes and the logical and the physical structure of the network. We are developing a tool to display information specific to how an ATM network can alter its *virtual path connection network (VPCN)* **as well as providing a list of visual metaphors to convey this information in a compact view. Our intention is to provide administrators and researchers with a concise display of the changes in the virtual structure of an ATM network.**

1 PROBLEM DESCRIPTION

ATM networks are designed to carry a wide range of services, with differing bandwidth and quality of service requirements. Underlying each ATM network are *virtual path connections (VPCs)* which form logical direct end-to-end connections between all *origin-destination (OD)* pairs. These end-to-end connections create fully meshed logical networks or *virtual path connection networks (VPCNs)* upon sparse physical networks.

It is possible to dynamically adjust the routes and bandwidth of VPCs in near real time in order to maintain an optimally designed VPCN. Understanding the dynamic VPCN is generally hard and complex due to its abstract nature and the large volumes of data which needs to be comprehended. Visualisation is widely accepted as a means of conveying complex information in a simple and concise manner[4]. For this reason, we employ visual representations or *metaphors* to convey information in a simplified, understandable and concise way.

We have developed a set of 3D high-level network metaphors to help network users understand the dynamic connectivity involved in ATM networks. We show how our revised *platter* metaphor highlights interesting trends and enhance the user's understanding of the VPC network structure.

Furthermore, we show how these metaphors are more suited to providing critical ATM network connectivity information than most traditional network visualisation tools.

2 BACKGROUND AND RELATED WORK

Dynamic reconfiguration is a network management control which reserves transmission capacity on the communication links in order to form dedicated logical paths for each *origin-destination (OD)* flow. Reconfiguration will occur in the ATM network as it adapts to the slow time scale variations in the traffic call patterns. This highlights an issue which needs to be addressed in network analysis tools : can the analysis tool provide a means of detecting structural changes in the VPCN that is designed on top of the physical network. This question has not received much attention.

Conventional network analysis tools tend to concentrate more on the structure of the physical network and less on the VPCN[1, 5]. ATM networks cater for various traffic services and can guarantee a QoS[1] for some individual traffic services. Traditional analysis tools often overlook this feature and as a result concentrate mainly on cell level analysis with little regard for the higher level call services.

Past visualisation tools were predominantly based on the *two-dimensional network map* which is a node and link diagram. That is, the nodes represent static network entities while the links represent communication media between each entity. This metaphor worked well for sparse networks but experienced visual *cluttering* in cases where the network was large and complex.

Examples of traditional analysis tools (see SeeNet[1] and Avatar[5]) were also developed when ATM networks were less widespread. As a result, ATM characteristics like logical links,

[1] Quality of Service

dynamic routing, VPCN and origin-destination pairs have received little attention.

We have therefore undertaken to visualise the process of dynamic reconfiguration, in collaboration with the University of Stellenbosch's Computer Science department. In the process, we will address the problems mentioned above as well as provide the more critical ATM connectivity information which has often been neglected by previous network visualisation tools.

3 INITIAL METAPHOR REPRESENTATIONS

3.1 Helix metaphor

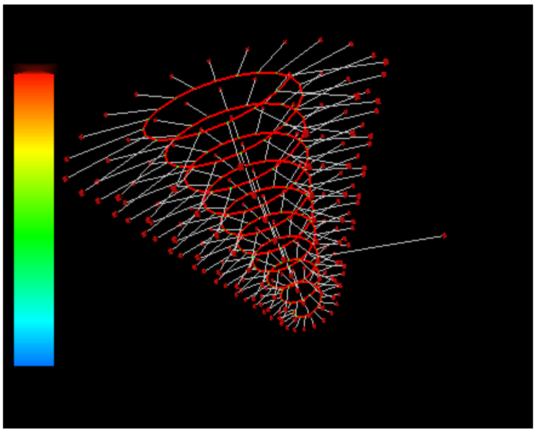

Figure 1: First version of the *helix* where each OD pair is represented by protruding rods off a spiral. The protruding rod on the lower right indicates a route with a substantial increase in capacity compared to other routes.

The *helix* metaphor implementation was our first prototype to address visualising dynamic routing in ATM networks. This metaphor was employed in a visualisation tool which contained physical and logical network view windows[6]. Interaction was achieved through mouse clicks on 3D objects in these windows. Figure 1 shows a picture of the *helix* metaphor detailing all routes as rods protruding from a spiral.

The metaphor provided insight into the XFG dynamic routing algorithm[2, 3] and the resulting VPCN structure. Changes were more easily detected than with the textual data. We provided geographic information about nodes in OD pairs and the routes that used these nodes. Users of this system were able to query and interact with nodes and links to gain greater insight into their specific properties. We described the physical and logical characteristics of ATM networks and the changing traffic on these networks.

The *helix* metaphor has two main drawbacks :

1. It provides no history or log of the ATM structural changes. A possible solution to this problem includes an animation sequence detailing the changes over time.

2. For a large number of routes, the spiral becomes cluttered replicating similar problems experienced using traditional 2D network analysis tools.

However, we will show how another metaphor used in conjunction with the *helix* addressed our main concerns.

3.2 Helix and Levels metaphor

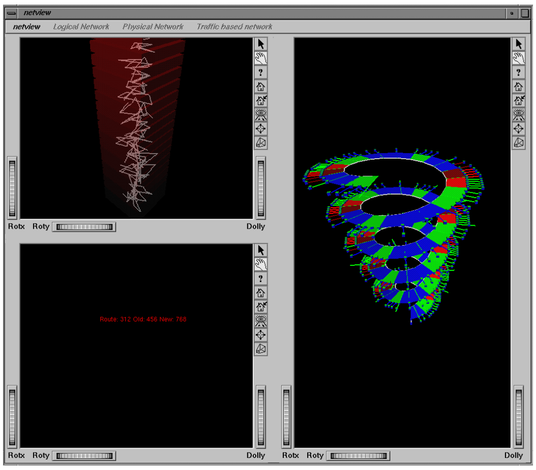

Figure 2: First version of the *levels* and *helix* metaphor combination. Top left : the *levels* metaphor. Right : *helix* metaphor. See figure 3 for a more detailed view of the *levels* metaphor

A *levels* metaphor was developed in conjunction with the *helix* metaphor to provide more specific ATM information. Geometrically, it consists of a stack of 3D partially-transparent boxes piled on top of each other. Each box represents an OD pair. Routes are represented as a series of connected lines encased in an OD pair box. These routes were placed in their geographically correct position. The material properties, such as colour and transparency, encode individual characteristics of each route. Since these boxes are stackable, they could be viewed individually or as a group. When this stack was viewed from above, these combined boxes created a network map with all nodes and routes in their geographically correct context.

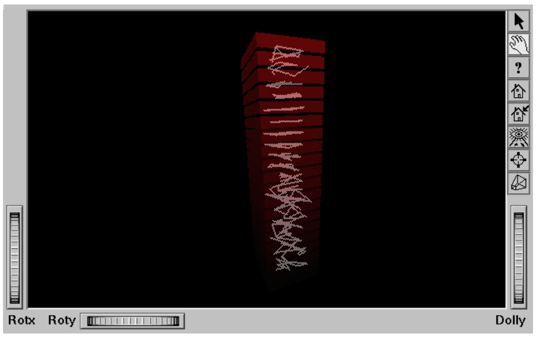

Figure 3: The *levels* metaphor was the first metaphorical prototype which concentrated on OD pairs with interaction techniques to allow greater insight into the routes which connected each OD pair. Each box contains a set of routes used in each OD pair.

The *helix* metaphor represents the change in logical capacities for each route. For this reason, we designed the *levels* metaphor to represent the following core information :

1. The number of routes connecting each OD pair.
2. The maximum and minimum capacity of each route in an OD pair.

The *levels* metaphor emphasises our main ATM unit of information which was an OD pair and displayed the information mentioned above. This metaphor highlighted the number of OD pairs and grouped routes into sets which were placed with their correct OD pair. This alleviated, in most cases, the cluttering experienced using the *helix*.

Drawbacks of the *levels* metaphor include the following :

1. Occlusion caused by boxes when viewing multiple OD pairs in their geographic context.
2. Difficulty in identifying interesting or problematic routes in an OD pair.

Our first experimental test involving a network expert led us to the conclusion that although the *levels* metaphor placed emphasis on the OD pairs, it created more overhead in terms of user understanding and cognition. We opted therefore to create a simpler metaphor while still focusing on OD characteristics.

As we will show in the following section, our current *platter metaphor* is geometrically less complex than the *levels* and *helix* metaphors, while still providing ATM network connectivity information.

4 PLATTER METAPHOR AND CURRENT SYSTEM IMPLEMENTATION

Our metaphor progression has led us to the *platter* metaphor, which is an adaptation of the Flodar[7] platter metaphor. The metaphor consists of concentric circles forming a platter shape. Individual routes are represented by cylinders placed on the platter. An OD pair is represented by the collection of routes in a straight line projecting from the centre towards the circumference of the *platter*(see figures 4). The image formed by multiple OD pairs resembles the spokes of a wheel. As with the previous metaphors, we have direct manipulation and menu interaction techniques to help users query and investigate objects in the metaphor.

There are numerous advantages to this design :

1. Clutter can be minimised by aggregating a number of routes into a single cylinder.
2. Route information can be represented using the height, radius and material properties of each cylinder.
3. The symmetrical design allows user to spot interesting trends and patterns at a quick glance.
4. Overall network context is maintained, allowing users to investigate individual OD pairs without losing focus on other interesting network features.

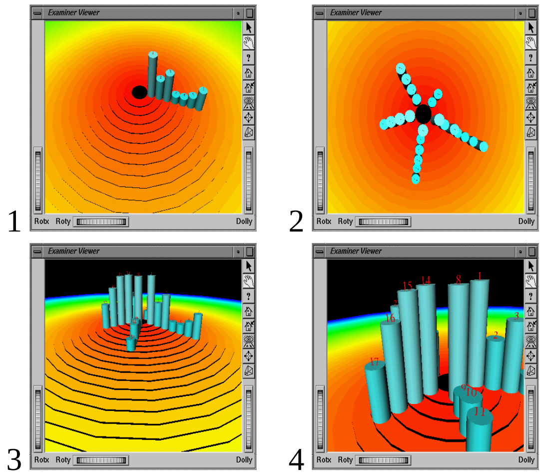

Figure 4: Screen shots of each metaphor : 1. Side view of a single OD pair with 7 routes. The height of each cylinder represents the capacity on that route; 2. Platter metaphor with 5 OD pairs - each OD pair has a varying number of routes. 3. Platter metaphor showing distinct ring separation. 4. Zoomed in view of an OD pair with the capacity figure.

The metaphor provides detailed information about the resultant structure of the VPCN network. The layout of routes in each OD pair indicate modelling trends in the network. For example, a good network design will result in a small number of high capacity routes, whereas a poor design will have a large number of low capacity routes. The metaphor was designed to identify this problem using the above mentioned visualisation techniques.

In the following section we will highlight preliminary results and our initial experience with this metaphor.

5 INITIAL EXPERIENCE WITH THE SYSTEM

We examined a field example using the *platter* metaphor. The field example was based on the XFG dynamic routing algorithm[2, 3]. Our results were examined by an ATM network management expert. The immediate goals of this field example were to :

1. Show the difference between two resultant network topologies when we apply *tie-breaking* and *non tie-breaking* routing switches to the XFG algorithm;

2. Highlight the capacities of routes which make up an OD pair in each of the above mentioned cases.

The XFG algorithm was applied to a Manhattan grid network model[3]. Examination of the *tie-breaking* versus the *non tie-breaking* cases using the metaphor revealed interesting trends with respect to its OD pairs. The output of the algorithm, for both cases, created an almost identical optimal VPCN. The number of routes in each OD pair, for each case in this optimal network, was displayed in our metaphor(see figures 6,5). As is evident, an identical platter

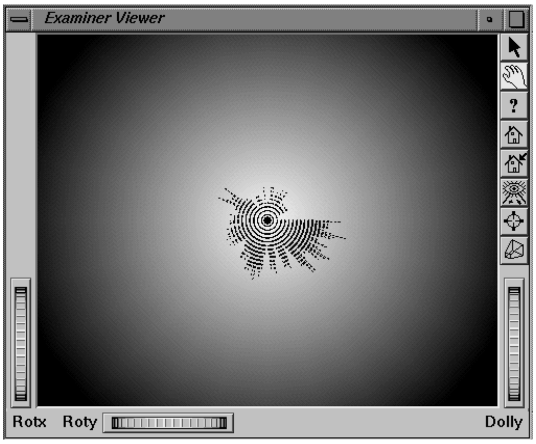

Figure 5: Top-down view of *platter* metaphor showing the number of routes connecting each OD pair for a *non tie-breaking* example. Notice that although the *spokes* of each OD pair are longer in the *tie-breaking* case, it still maintains the same overall shape.

shape is visible in both cases while a contrast exists in the number of routes assigned to each OD pair.

The metaphor has highlighted an interesting pattern. This pattern shows that although both cases have the same optimal network usage design they differ with respect to the number of routes in each. From a management viewpoint, a smaller number of routes is preferable.

6 CONCLUSION

We analysed ATM network connectivity using well-known visualisation techniques and customised 3D network metaphors. We focused on the abstract and dynamic VPCN network structure which has often been ignored by previous network visualisation tools.

Inherent in past visualisation tools are problems which make visualising ATM networks difficult and confusing :

1. Visual clutter caused by interconnecting and overlapping links and routes
2. Limited visual support for ATM network specific features
3. Static displays for dynamic reconfiguration
4. Limited user interaction

We have developed 3D metaphors to help network users understand the dynamic connectivity involved in ATM networks. We showed how our revised *platter*, in section 4 metaphor highlights interesting trends and enhanced the user's understanding of the VPC network structure while attempting to overcome the main problems encountered in past network visualisation tools.

Our ATM network management expert revealed advantages and drawbacks to our main *platter* metaphor. It is encouraging to discover that the metaphor addressed the main problem of OD

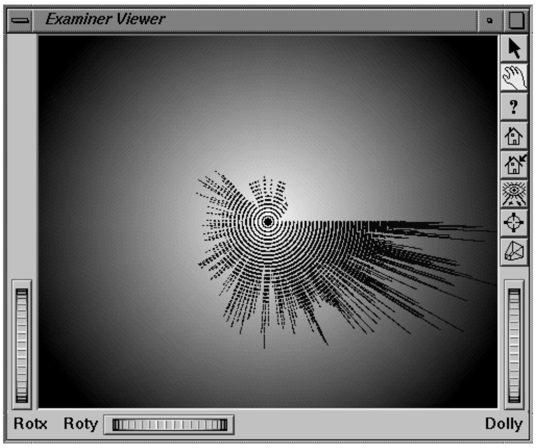

Figure 6: Top-down view of *platter* metaphor showing the number of routes connecting each OD pair for *tie-breaking*. Each distinct ring represents an integral value for the number of routes i.e. starts from 1 at the centre and increments towards the outer rings. This indicates that the dynamic routing algorithm uses more routes for each OD pair, in general, when *tie-breaking* is applied.

pair emphasis. He has reported an increased awareness of the overall logical network structure with its routes and capacities. The metaphor allows a better understanding of the changes in an ATM network's logical structure as a result of changing traffic patterns and demands.

REFERENCES

[1] Richard A. Becker, Stephen G. Eick, and Allan R. Wilks. Visualizing Network Data. *IEEE Transactions on Visualization and Computer Graphics*, March 1995.

[2] S.A. Berezner and A.E. Krzesinski. Call admision and routing in ATM networks based on Virtual Path Separation. In *4th Int Conf on Broadband Communications*, Stuttgart Germany, April 1998. 4th Int Conf on Broadband Communications.

[3] S.A. Berezner and A.E. Krzesinski. Optimal Reconfiguration of Large Manhattan grids. Technical report, University of Natal and University of Stellenbosch, 1998.

[4] Nahum Gershon and Stephen G. Eick. Information visualization. *Computer Graphics and Applications*, pages 28–31, 1997.

[5] Stephen E. Lamm, Will H. Scullin, and Daniel A. Reed. Real Time Geographic Visualisation of WWW traffic. Technical report, University of Illinois, Unknown.

[6] Oliver Saal, Jinsong Feng, E. Blake, and A. Krzesinski. Visualisation of ATM network connectivity and topology. In *SATNAC98 Proceedings 1st Annual South African Telecommunications, Network and Applications Conference*, pages 71–78. University of Cape Town, University of Cape Town Press, August 1998.

[7] Edward Swing. Flodar : Flow visualisation of Network traffic. *IEEE*, pages 6–8, September and October 1998.