Looking beyond the Single Pane of Glass: Visualization and Perspective in Enterprise Network

Maria C. Velez-Rojas[1], Serge Mankovskii[1], Michael Roberts[2], Steven Greenspan[1], and Esin Kırış[3]

[1] CA Technologies, Research Staff Member, NY, USA
{maria.velez-rojas,serge.mankovskii,steven.greenspan}@ca.com
[2] CA Technologies, Sr User Interface Designer, NY, USA
michael.roberts2@ca.com
[3] Syncsort Incorporated, Technology Architect, Product Design & Strategy, NJ, USA
ekiris@syncsort.com

Abstract. Managers and operators of modern Enterprise IT environments deal with massive amounts of information in a very stressful environment. They routinely manage hundreds of thousands of interconnected elements while collaborating with multiple business stakeholders under strict time constraints. This paper proposes a visualization method to simplify managing large amounts of information called the LSF view method. The LSF view method simplifies visualization by generating overviews of the network emphasizing the connections that are most salient to the user. This method also provides users with three key capabilities: manipulating of layer semantics, selecting instances of relevant concepts, and focusing on relevant information.

Keywords: Information/knowledge visualization, Visualization, Network Abstraction, IT Enterprise Management, User Centered Design.

1 Introduction

Management of information technology (IT) infrastructures in the modern Enterprise is a challenge even for experienced IT professionals. IT managers and IT analysts need to monitor the performance of a wide range of physical and logical elements interconnected in a complex network of physical connections, logical dependencies, across multiple levels of abstraction and composition. At the same time, IT practitioners are required to meet certain key performance indicators (KPIs) such as minimum resources availability, mean time between failure and mean time to repair. Understanding the status of network elements and their dependencies is crucial for analyzing how problems propagate and for identifying the stakeholders that need be engaged to solve a problem as soon as a change in an element status is reported.

Visual representations of data are used in IT management solutions to communicate patterns and facilitate the exploration of the complex relations between elements. With data visualizations, users can identify patterns and trends that would be otherwise hidden on massive text-based reports and tables. It is this potential to communicate

A. Marcus (Ed.): DUXU/HCII 2013, Part IV, LNCS 8015, pp. 581–590, 2013.

complex information at a glance that is making data visualizations pervasive in IT management environments. For instance, Dashboards often use charts (e.g. pie charts and histograms) to provide executive summaries of important metrics as shown in Figure 1. More complex data visualizations such as the node-link diagram in Figure 2 are often used to provide detailed technical information about network elements and their relationships.

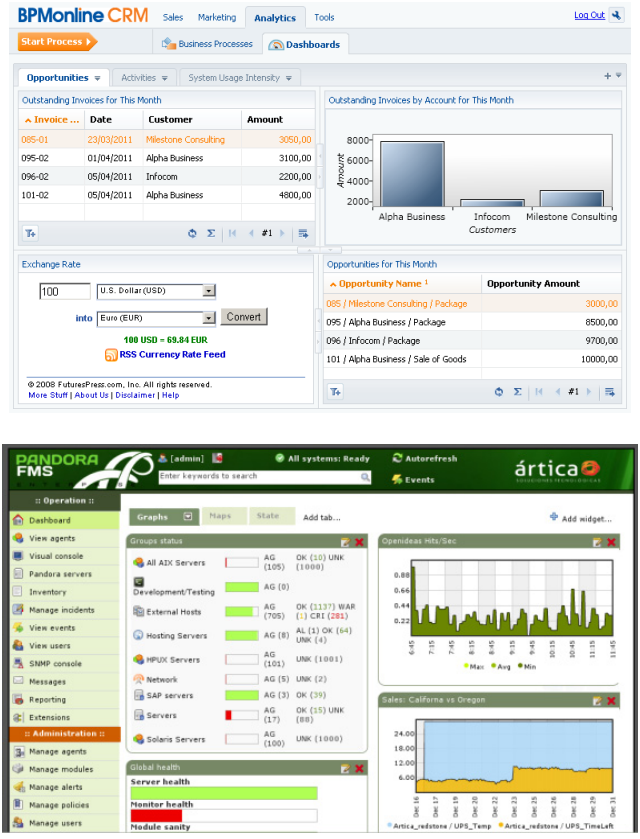

Fig. 1. Dashboard designs with elements commonly used on IT management solutions. Top design by BPMonline (Own work) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL. Bottom design by 4zHaR screenshot done by me (Own work) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons.

Data storage, data management and visual interfaces have matured over the last decade and have successfully been adopted in corporate environments. However, the integration of data visualizations as part of IT management solutions has been modest. Although it's technologically possible to create data visualizations capable of representing large-scale databases (e.g., [1], [2]), other important aspects need to be addressed for data visualizations to become pervasive on IT management. Factors such

as lack of data exploration capabilities, ineffective data representation and complex user interfaces have been found [4] to inhibit the adoption of data visualizations.

In this paper we present a novel data visualization approach designed using the requirements identified in interviews with IT professionals regarding the role data visualization play on their workflow. We propose a data visualization that creates simplified overviews of complex IT environments by emphasizing areas of the network and connections that are relevant for the user. This visualization provides the means to explore data by selecting the semantics that define layers within the network environment, selecting instances of relevant elements or areas, and interactively filtering irrelevant information.

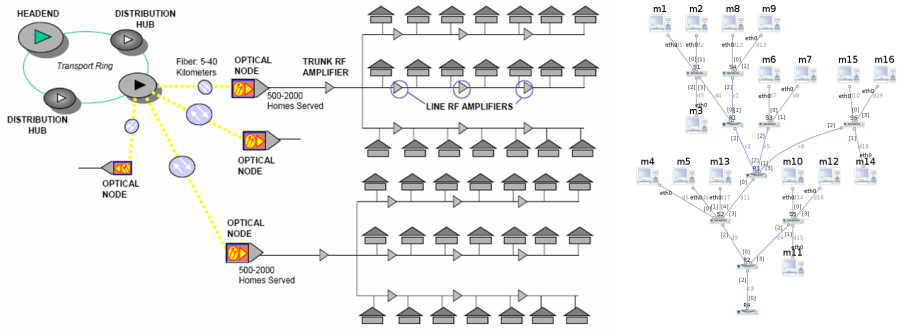

Fig. 2. Node-Link diagram visualizations used to represent the elements and relations in networks infrastructure. Top diagram by Unforgettable fan en:User:Unforgettable fan [Public domain], via Wikimedia Commons. Bottom diagram by Luca Saiu, Jean-Vincent Loddo/Marionnet. (www.marionnet.org) [GPL (http://www.gnu.org/licenses/gpl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons.

2 Methodology

We interviewed 20 IT professionals with 2 to 15 years of experience from the areas of change and configuration, IT service delivery, software engineering, infrastructure engineering and software architecture c.f. Table 1. The goal of our interviews was to understand how everyday work activities of IT professionals are supported by data visualizations and to identify the issues that arise when the complexity of the network infrastructure increases. We asked a series of open-ended questions to capture the workflow, current use of visualization tools and needs of the interviewees.

We divided the interview in three parts. First, we asked questions related to the participant's work environment. In particular we asked the user to describe in detail:

– *Work activities*: Personal or organizational goals and actions carried out to pursue these goals.

Table 1. Profile of IT professionals interviewed

Profile	*Description*
Change and configuration	Ensure that the risk of making any change is understood by all parties involved
IT service delivery	Manage the needs and requests of customers in the shortest time possible
Software engineering	Design products and interfaces based on user requirements
Infrastructure engineering	Design and implement monitoring infrastructure, provide feedback on perceived solution design flaws and recommending product improvements
Software architecture	Define requirements and design solutions, ensure that all products or implementations follow common architectural guidelines

- *Context*: user roles defined explicitly defiled by the company and implicitly developed as part of the job requirements.
- *Work artifacts*: information retrieved, created and modified during work activities.

Part 2 of the interview focused on the data visualization used to work with this information. We asked participants to describe how they currently use data visualization tools to perform their jobs and what value they see in them. We also asked participants to think of any area of their job that would benefit from having a visualization tool available without limiting themselves to the functionality currently provided by their IT management solutions.

We conclude the interview by asking participants to reflect back on their answers and to think of any comments of information that they would like to share with us.

3 Challenges in Complex Environments

Participants were asked to identify the main challenges faced when working with very large network environments and to discuss the role that visualization tools play on those scenarios.

Participants reported that the single most important variable determining the value of an IT management solution is support to user's tasks that results on minimization of the time it takes for IT professionals to perform their job. Two factors were identified as having a significant impact in the time it takes them to perform their work activities: Ease of navigation and exploration of the data related to the task at hand and collaboration and communication with multiple stakeholders. Although the details of the workflow for each IT professional were different, these two factors were prevalent among all interview participants.

3.1 Navigation and Exploration

Interview participants expressed their preference for interfaces designed to present an overview of their workspace (e.g., list of open customer tickets that require attention, list

of alarms triggered by network components, etc.), that provides them with the "minimum detailed information" required to related to take the next step on task to be performed. Node-link diagrams (NLDs) of network infrastructure (as the example shown on Figure 2) were identified as visualizations with scalability and navigability issues.

NLD visualizations can display millions of elements and provide tools to improve navigation such as intelligent zoom and network overviews [2]. However, overviews often do not reflect the way IT professionals think about their network environments. Participants also noted that after zooming-in, visual search of elements and properties on the screen is a complex task due to all the "noise" or unnecessary information.

IT Professionals compartmentalize the Enterprise according to the aspects they are interested in. For instance, service assurance managers divide the infrastructure according to abstract business services (e.g., payroll service, email service, etc.) and the physical elements that are part of them. At the same time, infrastructure engineers can see the Enterprise as a set of interconnected sub-networks that are distributed across multiple locations. Therefore, the overview of the Enterprise infrastructure and relevant detailed information varies according to the task that the IT professional must perform.

Visual overviews provided by network infrastructure visualization solutions mostly focus on aggregating elements based on structural properties of the IT environment and the semantic areas of IT networks are represented as superimposed layers that contain certain types of elements on the infrastructure. Just like blueprints, these layers can be dynamically added or subtracted to the NDL visualization according to the needs of the user.

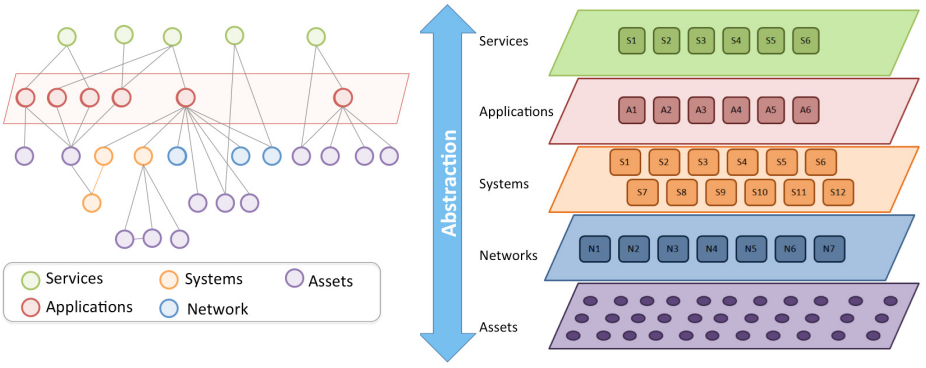

Fig. 3. Layer element selection. Elements are assigned to different layers within the network based on their properties.

4 Navigation

We designed and implemented a prototype for a visualization tool that presents a semantically rich overview of the network elements within a context relevant to the user. We allow users to define *"layers"* within the network infrastructure that represent the areas of information they are interested in. As shown in Figure 3, each layer is defined by a subset of the elements in the network structure and a subset of the relations between elements.

The elements on each layer are then viewed as Euler Diagrams. Euler diagrams are a way to intuitively depict the union and intersection of sets [5]. They consist of closed shapes (e.g., circles, rectangles or other polygons) that depict sets of elements. The overlap between shapes represents common or shared elements as shown on Figure 4.

This data visualization supports fast navigation of large environments and simple transition between overview and detailed data, while retaining the information displayed within a context relevant to the task being performed by the IT professional. It also provides the capability to see dense relations in a summarized form.

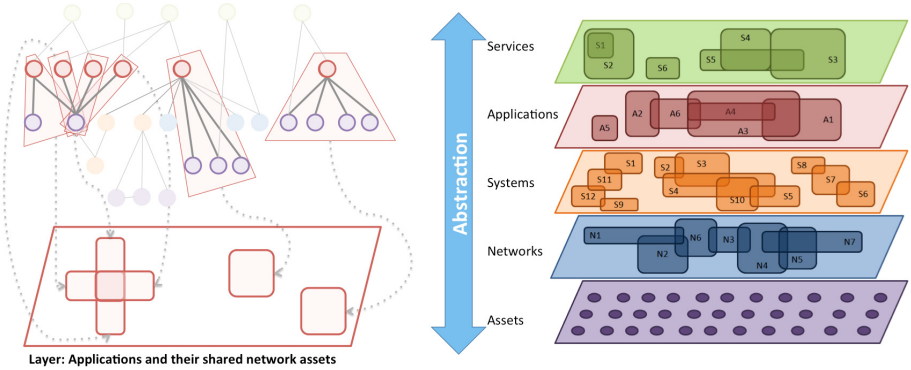

Fig. 4. Layer elements dependencies selection. A subset of the resources connected to the layer elements is selected based on their properties and type of relation. The elements on each layer are viewed as areas that overlap depending on the resources they share.

5 Exploration

Users navigate and explore the infrastructure by selecting and un-selecting different regions of the layer. As shown on Figure 5, the overlaps of the layer regions correspond

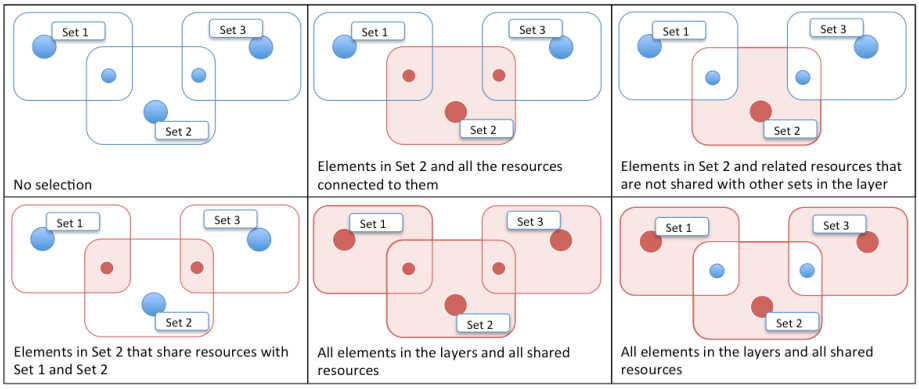

Fig. 5. Selection of areas on the layer and equivalent selection syntax

to relationships between sets of elements in the layer. The selection mechanism in the Layer view allows informal expression of formal logical query used as filter expressions for graph visualizations.

Multiple layers can be defined with a network environment and the relations of elements between layers can be examined. To illustrate, consider the following: An application server is affected by power supply. Within the server there is a single operative system, which hosts many applications interacting with one another. The proposed visualization allows IT professionals to explore relations between elements at the critical levels in this infrastructure and answer the following question: *How are applications impacted by a single power supply?*

As illustrated on Figure 6, users can define four layers in the network environment: (i) Power supply layer, (ii) application servers layer, (iii) operative system layer and (iv) applications layer. By selecting an element on the power supply level, all the applications related to that particular power supply are clearly visible. In this case, database queries connecting the Power supply layer and Applications layer are expressed in terms of the intermediate layers (i.e., the application servers layer and operative system layer), and the results of the queries are visible as dependencies between elements at the end layer (i.e., power supply layer and applications layer).

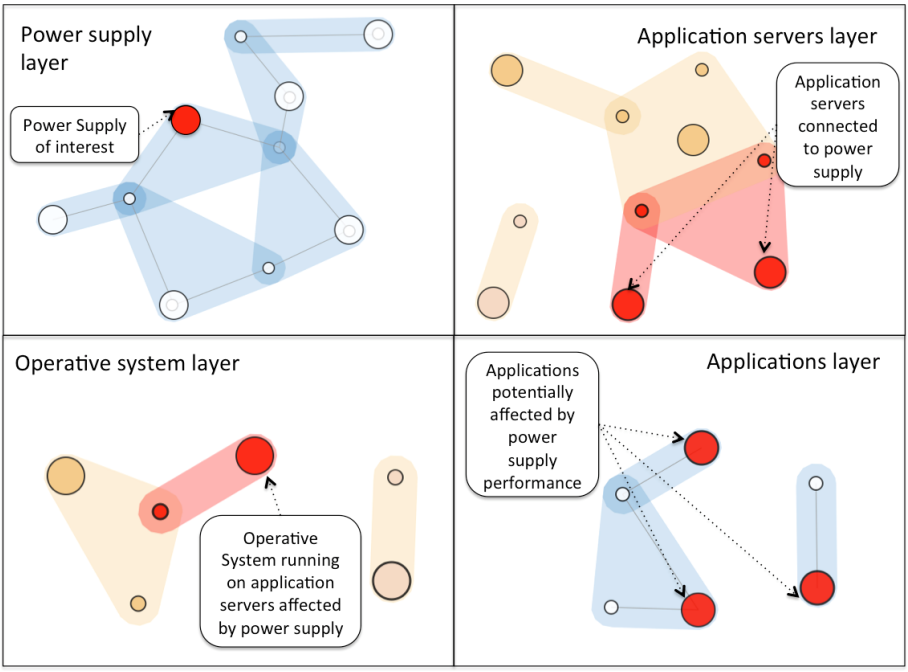

Fig. 6. Selection of four network layers: (i) Power supply layer, (ii) application servers layer, (iii) operative system layer and (iv) applications layer. Dependencies between elements on the different levels can be explored.

When the regions of interest are selected, users can analyze the detailed information in those areas by displaying the selected elements and relations on data visualizations that emphasize the sub-network's structure, semantics (i.e., the mining of elements and relations properties), as well as temporal or statistical properties. We can also extend the semantics of this data abstraction beyond exploration to action. When a region is clicked, for example, log, alert and emails may be displayed, along with workflows for notification and other relevant contextual information.

Graph representation creates a level of abstraction above the data sources. It is possible that data in one layer would come from a data source dramatically different from data in another layer. Moreover, within one layer it is possible that elements from the top set would come from a data source different from the source of bottom elements. The LSF view visually emphasizes the relationships within data sources. At the same time, set semantics of Euler diagrams enable an interactive visual representation of filter expressions.

6 Collaboration and Communication

Management of large IT enterprise environments is a collaborative endeavor spanning multiple levels of an organization. Independent groups work simultaneously on different aspects of the network and require well-established communication channels to avoid conflicts. Communication between groups involves weekly meetings and continuous asynchronous collaboration within and between business units. Some of the visualization tools provide simple annotation capabilities, but most are not well integrated with common collaboration tools such as email and messaging applications.

Interview participants require communication tools that will enable them to see activities taking place in multiple areas of IT environments, to explore the history of activities and comments left by others, and to share insights that will allow other to address issues in an effective way. IT professional see a great potential for visualization tools to be the communication artifact that establishes common ground among stakeholders, facilitating conservation and change. However, interviewees indicate that this requirement is often neglected in tool design.

Participants of IT management possess a variety of skills and seek to accomplish different, sometimes conflicting goals. For example, operations personal strive to maintain infrastructure in operational state and reduce the impact of change. Business development and asset management personal evolves infrastructure, reflecting changes in technology and business requirements.

While participants know details of their own domain of expertise, no one has total knowledge and understanding of all aspects of the management process in the enterprise. The IT management tools and their interface become a primary source of shared understanding and means of achieving synergy among the participants enabling them to resolve problems and develop new capabilities.

We are investigating how to best incorporate communication models similar to those found on social networking sites such as Facebook to support the management of large IT networks. Through these tools we aim to capture the perspectives that each stakeholder has with respect to the elements that are part of their individual

workspace. For instance, by looking at the comments left by other stakeholders, a change engineer can select a date and time to program an update in one of the hardware components of the network.

By adding the scheduled change to the social exchanges related to this element, other stakeholders will be aware of the upcoming update and avoid potential conflicts. Social exchanges can also provide insight to new IT staff on who the stakeholders for each network component are and what workflow senior staff members follow. As shown on Figure 7, comments by IT practitioner can be added within the context of an alarm, they could be related to IT metrics, to element properties such as it location or to the priority of the element.

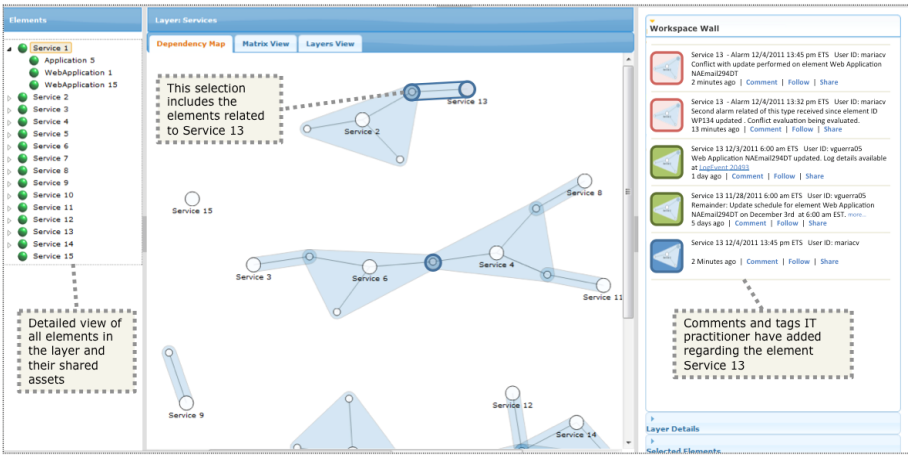

Fig. 7. Data visualization with social network interaction and collaboration support

7 Future Work

As part of our future work, we are working on the improvement of the social network communication tools and considering other collaboration features to be included in our visualization design. Specifically, a rating model based on previous practitioner exchanges is worth investigation. Informal presentations have been well received by customers but a quantitative study is necessary to determine the usability of these visualization tools.

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