# Acquisition, Modelling and Visualisation of Inter-domain Routing Data

Pedro Andrés Aranda Gutiérrez[1], Paul Malone[2], Mícheál ÓFoghlú[2],Stefan Michaelis[3],Jörn Seger[3]

[1]Telefónica I+D, IP Network Access Technologies, C./ Emilio Vargas, 6, E-28043 Madrid, Spain(paag@tid.es)

[2]Telecommunications Software & Systems Group, Waterford Institute of Technology, Waterford, Ireland ({pmalone,mofoghlu}@tssg.org)

[3]Elektronische Systeme und Vermittlungstechnik, Universitaet, Dortmund, Germany ({stefan.michaelis,joern.seger}@uni-dortmund.de)

*Abstract*

*The INTERMON project aims at inter-domain IP QoS monitoring, measurement and modelling. An important part of this project is exploring the use of inter-domain data in these tasks. Inter-domain topology information provides a level of abstraction, which is much higher than at intra-domain level. The impact of inter-domain routing events on end-to-end QoS measurements is expected to be more drastic than the effect of possible intra-domain routing events in each of the domains. One of the scientific results expected from the INTERMON project is the validation or rejection of this hypothesis. This paper demonstrates how the INTERMON project captures, models and visualises this inter-domain topology information.*

The INTERMON project is funded by the European Commission under the FP5 Programme: IST-2001-34123.

## 1. Introduction

Integration of inter-domain routing information in network management systems has always been cumbersome. Routers providing full routing can be queried via SNMP to read the routing tables. Using different points of the routing table, one may discern which routes are installed in the routing table by which protocols. This approach is tainted because the amount of processing power required to fulfil an SNMP request for its full Internet routing table (150K+ entries) by any backbone router can impact on performance of the network.

The approach proposed in this paper is less resource intensive since the independent BGP-4 probe does not access backbone routers.

## 2. BGP-4 Topology Collection

The BGP-4 Topology Collector tool is based on tools from Merit's Multithreading Routing toolkit[MRT1]. Extensive documentation can be found at the projects Website and the source code can be found at the CVS repository [MRT2].

The tools where proposed for the INTERMON project and their usage is described in INTERMON deliverable D8 [IM8], which also describes the adaptation work necessary in order to make the tools work properly within the project's framework.

The framework consists of a significant number of programs with different objectives, of which only two were selected to construct the topology probe:

- **sbgp**: simple BGP-4 speaker.
- **route_btoa**: converts binary BGP-4 routing information, as provided by sbgp, into human readable ASCII. Parsing this format is easily implemented in any programming language like C or Java.

Figure 1 shows the topology probe architecture, and the different components of the probe:

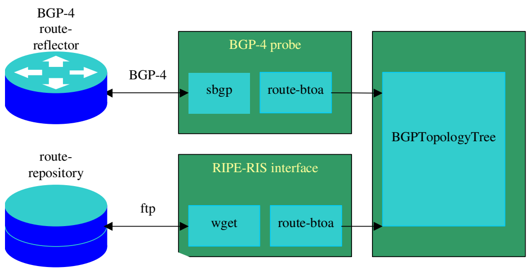


**Figure 1. The BGP-4 Topology Collector**

The selection of the MRT tools has broadened the INTERMON project's research scope since the binary data format for BGP-4 events is also used in the RIPE's[RIPE] route repositories, which store historical BGP-4 routing data (routing tables and routing events) for selected routers in the Internet. This method can then be used as a substitute for the information from the topology probes, when operators do not allow access to the routing infrastructure.

The INTERMON tools process the routing information and generate a graph, which contains the active end-to-end path and all alternative paths as seen from the intermediate Internet entity (Internet eXchange Point, ISP, etc.) that is delivering the routing data.

## 3. BGP-4 Topology Data Structure

A data structure to represent the BGP-4 inter-domain topology information has been devised as part of the INTERMON project. The data structure is described through the use of an XML schema.[W3C1] The motivation for using XML is to provide a means of representing the topology information that is easily understood by all INTERMON tool developers and which can be exchanged between distributed toolkit components independent of their interfaces and communication environment.

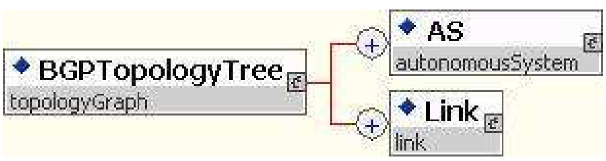


**Figure 2. BGPTopologyTree root Element**

The root element of the topology schema is the *BGPTopologyTree* element, shown in Figure 2. The element contains a set of *AS* elements representing individual Autonomous Systems (independent networks in a BGP-4 structure) and a set of *Link* elements representing the connections between these autonomous systems.

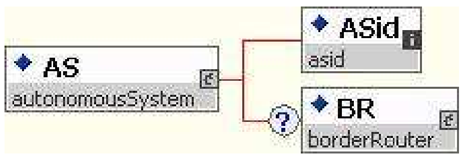


**Figure 3. AS Element**

Each *AS* element contains an *ASid* element with the unique identifier for that autonomous system. In addition, each *AS* contains 0 or more border routers represented by a *BR* element. See Figure 3 for structure.

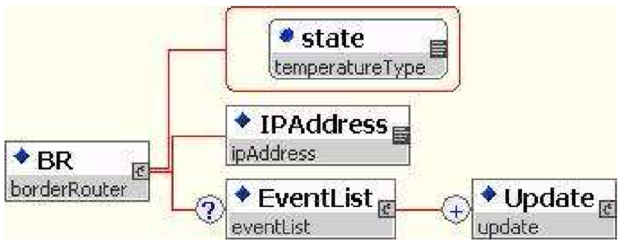


**Figure 4. BR Element**

The *BR* element (Figure 4) has an *IPAddress* element, a *state* element denoting the level of BGP-4 update activity and an *EventList* element which itself contains a set of *Update* elements. Each of these *Update* elements provides details of a BGP-4 update for this particular border router (Figure 5).

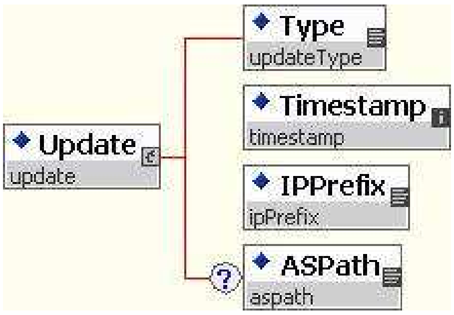


**Figure 5. Update Element**

## 4. Topology Visualisation

The INTERMON project's data can be divided into two basic types:

1. Topology data that is necessary to get an overview of the surveyed networks and their relationship to the inter-domain context;
2. Trace data (measured or simulated) that is essential for insight about critical parameters.

In most cases it is useful to combine topology visualisation with other visual data mining evaluations to see relations between trace data, either single links or complete paths, and the corresponding networks.

One goal of the creation of this tool was to provide a sophisticated implementation with a defined interface to other work packages to allow an easy use of the tool for a simple integration into other INTERMON main action lines. During the design and implementation of the prototype it became clear that existing state of the art tools, as investigated already in the project proposal process, were not suitable for this task. Most available tools are not designed to serve for inter-domain visualisation and do not provide the flexibility for other work-packages to "dock" into the visualisation enabling interactions with the user and with other applications.

Therefore, a new prototype was implemented, based on common knowledge of graph theory and visualisation methods.

JAVA and JAVA3D were used to implement the prototype. This provides easy platform independence without recompilation for different operating systems. The ability of the prototype to run on multiple platforms was key, in order to respect the heterogeneous nature of the consortium and the network administration community in general where implementations work on many different operating systems and hardware platforms.

The process of creating a tool for topology visualisation could be divided into two major steps:

- Graph theory based network topology specification [IM7]
- Specification based visual prototype using 3D visualisation techniques [IM12]

The main rationale for this division was to keep the pure topology free from any visualisation issues. The design proposed[IM7] allows the users of the tool, e.g. topology detectors or simulators, to build the network topology without thinking about a visual representation. All entities like routers or connections identified in the database specification find their complement in the general topology specification. Additionally each entity has the associated necessary attributes with it, e.g. each router provides methods to access and set its IP address.

## 5. Building the Topology View from the BGP-4 XML Data

The general parameters provided by each node to build the network topology allow a direct mapping of the detected border router and domain data. The XML based BGP-4 topology can be parsed and the corresponding objects created. The specialised 3D topology described in the paragraphs above implements the visualisation of generalised network topology. The BGP-4 detector is not aware of the concept of visualisation. Utilising the XML BGP-4 data mapping to the graph objects the complete topology visualisation is build automatically.

The 3D visualisation is able to directly display the hierarchy of large inter-domain networks in addition with the detected border routers. Transparent cones show the domains and spheres at the border of the domains denote the presence of border routers. Additional features enable the visualisation to also display core routers and end systems inside the domains. For BGP-4 purposes this is not necessarily needed, but could be used if topology data about the interior of single domains is available.

This kind of visualisation has some advantages over the usual 2D graph display. The user can interactively change the point of view, e.g. taking a bird's eye view on top of the rendered topology, which is very similar to classical 2D graph networks. Alternatively the user can zoom into the network and concentrate on single domains and the border routers associated with these domains for further analysis.

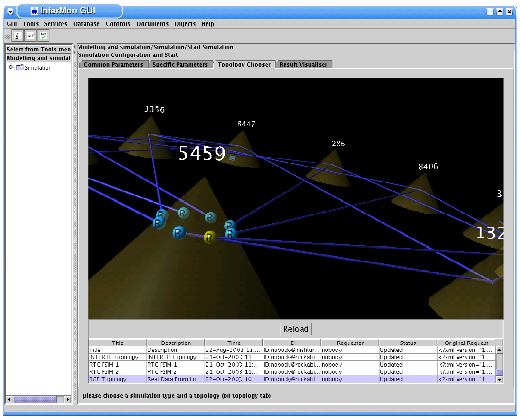


**Figure 6. INTERMON BGP-4 3D Topology GUI**

## 6. Building Supporting Applications Using the Visualisation Framework and BGP-4 Data

The visualisation does not end with the simple rendering of the BGP-4 and inter-domain topology. The visualisation toolkit developed allows the application developer to bind applications to individual network elements. For example, the detection and displaying of a BGP-4 topology at a certain point of time gives only an impression of the topology snapshot. The load and status of border routers will change over time. So for subsequent BGP-4 detection the generated XML topology data contains information about status changes of each border router (BGP updates) which may have impact on inter-domain network throughput and routing. These BGP-4 update events need to be visually indicated to the user. The simplest possibility is to change the colour of border routers where these critical events have occurred. The user however requires more information than simply knowing that critical events have occurred. It is necessary to provide more detail about the individual events. To achieve this end the visualisation toolkit allows the developer to associate

Certainly the user will need further information about the details what and when the problem happened at the border router.

For this purpose each node inside the topology visualisation allows the developer to bind applications directly to the object.

The user can interact with the nodes, open popup menus showing the registered applications on this node. For the BGP visualisation this will bring up a menu showing all relevant events for this router allowing the user select the entry to show details about each event. Figure 7 shows just such a pop-up menu giving details of the BGP Update events.

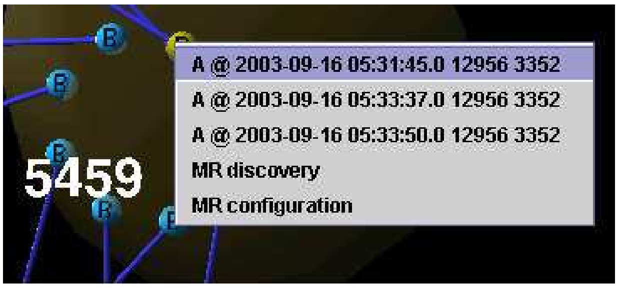


**Figure 7. Pop-up Menu showing Details of the BGP Updates on an active Border Router**

The registration mechanisms for applications on nodes and connection build the open interface to access external applications from inside the topology visualisation.

The case flow is always as follows:

1. Topology detection with explicit focus on domains, interdomain connections and associated border routers
2. Creating a generalised XML data file containing the detected topology, including border router advertisements
3. Rendering the BGP-4 topology and associating the advertisement information applications to the nodes
4. Registering additional external applications to the network elements
5. The external applications are initiated on user request for more detailed analysis of network

For example, Figure 7 also shows, in addition to the BGP Update events, the fact that it is possible to also run other applications using the BGP information as input parameters to the application. In this case the applications are traffic monitoring client applications, developed within the project.

Another example of applications developed with the INTERMON project is that of specialised network simulators which can use the BGP-4 topology data as an input to simulations. This allows for network administrators and planners to create "what-if" scenarios using real world topological data as input parameters. Several such simulators were developed within the INTERMON project.

## 7. Summary

The work presented demonstrates the reduced overhead of acquiring BGP-4 data as a means of viewing inter-domain topologies and routing information. The visualisation toolkit being demonstrated abstracts the topology from the visualised object in a manner that frees the application developer from a deep understanding of the visualised components mapping and rendering. The work also demonstrates that modelling BGP-4 data in a portable form such as XML allows for easy integration of this information with other tools that can make use of the XML data. Furthermore, these tools can be initiated by the user through a direct interaction with the network visualisation toolkit.

## 8. References

[MRT1] MRT: Merit's Multithreaded Routing Toolkit, http://www.mrtd.org

[MRT2] MRT: Sourceforge CVS repository, http://sourceforge.net/projects/mrt/

[IM8] *Prototype of inter-domain QoS monitoring and structure discovery components,* INTERMON Consortium, http://www.ist-intermon.org/download/im-wp403-v103-nec_ds_d8.pdf

[RIPE] RIPE Routing Repositories http://data.ris.ripe.net

[W3C1] *XML Schema Part 1: Structures,* W3C recommendation May 2001. Available at: http://www.w3.org/TR/xmlschema-1/

[IM7*] Specification of visual data mining and user inter-face*, INTERMON Consortium, http://www.ist-intermon.org/download/im-wp6-v123-udo-ds-deliverable_d7.zip

[IM12] *Implementation of visual data mining and user interface*, INTERMON Consortium, http://www.ist-intermon.org/download/IM-WP6-v151-UDO-Deliverable-D12.pdf