

Infosim Whitepaper

Optimization of IP Networks

*The wise adapt themselves to
circumstances, as water moulds
itself to the pitcher .*

(Chinese Proverb)

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Whitepaper Contents

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Executive Summary

An ongoing explosive growth of the Internet can be observed, both from number of users and from the amount and the diversity of traffic generated. This rapid expansion is accompanied by severe network congestion and by a decrease of the Quality of Service (QoS) seen by the user. There are many reasons for this performance degradation. On the one hand the IP network just expands in number of nodes without being designed by a traffic engineering based planning process, which leads to unbalanced network loading. On the other hand in today's Internet practice the routing principle implemented ranges from *fixed or static routing* to *slowly adaptive routing*, although routers do have built-in capability to perform more adaptive and efficient routing schemes, should they be better dimensioned. Most of the routing parameters in existing network are set by default configurations, which are rarely changed or modified by network administrators due to a lack of proved methods.

In this whitepaper, the authors exploit the potentials to optimized today's IP networks without adding new hardware components such as more powerful routers or higher capacity links. First of all, we give a survey of the different routing algorithms used in today's IP networks. We show the drawbacks of these existing routing protocols and offer a solution packaged in the form of a new product called StableNet IPO (StableNet Intranet Protocol Optimizer). The StableNet IPO is a solution package and forms a part of the network management suite known as StableNet®. StableNet provides many new features for a network Administrator, e.g. optimal routing, load balancing and improved behavior of the network in the presence of link failures without adding new hardware. We give a deeper understanding of the underlying mechanisms and describe in detail the StableNet IPO product and its features.

Routing in today's IP networks

In classical circuit switching networks, Quality of Service is an essential aspect that influences the entire network design process. Quality of Service is achieved in that environment by calculating switch and link capacities through a combination of prescribed performance standards and efficient routing schemes. Today, packet switching networks – such as the Internet – are being used to transport a variety of new and traditional network services. At the heart of this effort is the use of IP based networks to provide this transport. The original intent of the IP protocol was to provide a “best effort” service – but now, services with strict Quality of Service requirements are being introduced. As a result of this introduction of such services into IP-based networks, routing to support QoS has become increasingly important. Special concepts such as integrated service and differentiated service IP networks have been proposed for implementation. However, few methods exist for determining the optimal routing for IP packets in a particular network. To date, most of the effort has been invested in improving and changing the routing protocol itself. The rapid explosion in the use of the Internet for web browsing, telephony and video services, as well as the more traditional services such as mail and ftp, has resulted in a massive increase in traffic load. With this increase in traffic volume, there has been a concurrent significant increase in congestion due to the lack of network resources and due to the inflexibility of the Interior Gateway Protocols (IGPs). The IGPs do not adapt their routing based on the actual traffic loads (state of the network) and, because of this, some parts of the network suffer from heavy loads whilst other parts can be lightly loaded and tend to have free capacity.

It should be noted that packet networks are known to be quite sensitive to state changes and system administrators are often reluctant to dynamically change routing patterns according to the state of the network as this can lead to the



phenomenon of “route thrashing” and instability. As a consequence, it is very common for routers in IP networks to be set with “static costs” in order to avoid such instability problems. Unfortunately, this reluctance can lead to an inability to exploit free capacity in the network when it is present and congestion can arise on heavily loaded routes. Thus, to enable Quality of Service in IP networks, efficient routing of IP packets becomes a crucial issue both from the providers' and the users' point of view.

Introduction to IP Routing Protocols

In IP networks routing is performed according to different unicast IP routing strategies employed by router manufacturers (e.g. EIGRP from CISCO) or the IETF (Internet Engineering Task Force). The following figure gives an overview of the most important ones.

Basically, the routing protocols are classified as:

- Interior Gateway Protocols (IGP) and
- Exterior Gateway Protocols (EGP).

An exterior gateway protocol is designed to route packets between routing domains or autonomous systems. Thus, several security and policy issues are involved in the routing process, whereas the IGP Protocols are designed to deliver the packets from the source to the destination as quickly as possible. In this white paper, we concentrate on the Interior Gateway Protocols. The IETF defines interior gateway protocols as

protocols used for “networks that are under a common network administration”. The most popular interior routing protocols include:

- Intermediate System to Intermediate System Routing Protocol (IS-IS)
- Enhanced Internet Gateway Routing Protocol (EIGRP)
- Open Shortest Path First (OSPF) Protocol

These protocols have to be configured in their respective network environments by setting certain parameters in the router's database. Router manufacturers publish detailed instructions about router configuration, although they do not provide guidance on specific parameter settings. All interior routing protocols follow the same principle. They define the *cost* of a link with a protocol dependent metric and determine the *shortest path* according to these values. The shortest path in EIGRP additionally depends on values that are not only link dependent but also path dependent such as the reliability of a path.

Routing Protocols in Practices

IP is connectionless and, therefore, a new routing decision is made independently at each router. In a router, all IP packets with the same destination are routed on the same path independent of their source (destination based routing). For example, the two flows from A and B have the same destination F. The flows meet each other at Router C. Current routing protocols insist that from this point they must use the

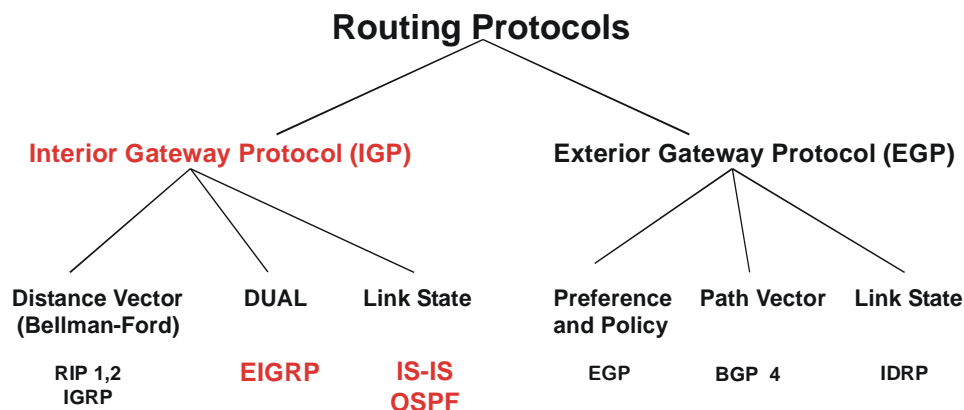


Figure 1: Systematic of IP-Routing Protocols.



same path until they reach the destination. The decision as to which of the two possibilities in Figure 2 will be selected, is based on the shortest path principle using the prescribed metric of the routing protocol.

Inside an intranet or within the network of an Internet Service Provider (ISP), the chosen path is the shortest path fol-

lowing this routing protocol metric. Note that the shortest path approach may generate congestion if the capacity of the common path is insufficient to satisfy the two demands A – F and B – F simultaneously. One of the world’s largest router manufacturer, CISCO, defines the metrics of EIGRP OSPF and IS-IS as shown in the following table:

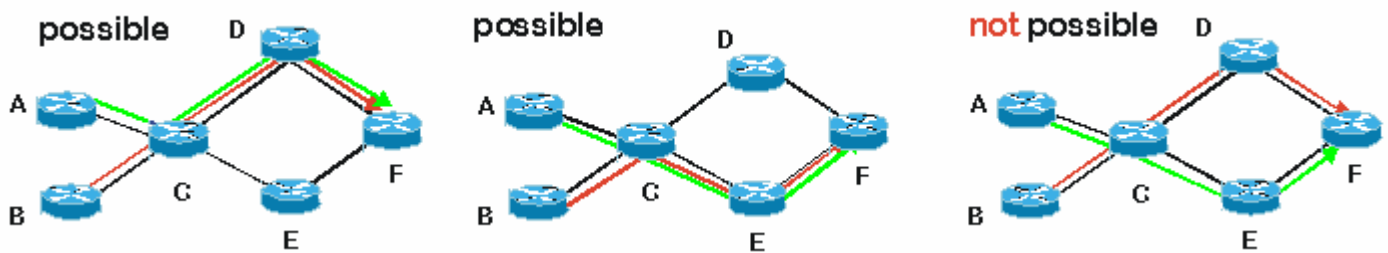


Figure 2: Possible IP Routing decisions.

EIGRP	$M = \left[K_1 \frac{1}{\min_i(C_i)} + \frac{K_2}{256 - load} + K_3 \sum_i delay_i \right] \cdot \frac{K_5}{R + K_4} \quad \text{if } K_4 \neq 0 \text{ and } K_5 \neq 0$
OSPF	$M = \sum_i \frac{100,000,000 bps}{C_i}$
IS-IS	The cost for Level-1 and Level-2 is configured in the range between 0 and 63

Table 1: Link cost/metric specifications for common protocols

In the above table, C_i is the (unloaded) bandwidth of link i measured in kilobits per second. The $\min_i(C_i)$ is interpreted as a minimum over all links of the path. The $load$ is interpreted as an integer in the range 1 – 255 and represents the effective bandwidth of the route. A value of 255 indicates that the route is saturated. The $delay$ time is the amount of time it takes to get to the destination along that path, assuming an unloaded network. The reliability (R) of a path indicates the current error rate and it is the ratio of expected packets to the number of actual packets that arrive at the destination undamaged. For EIGRP, it will be noted that there are five “weight factors” labelled $K_1 \dots K_5$. The default router values are

defined to be $K_1=K_3=1$ and $K_2=K_4=K_5=0$, so the metric is re-interpreted as: $M = \text{bandwidth} + \text{delay}$. The minimum value of the above metric is select to decide the best path for routing of the packets.

Irrespective of the protocol, all these metrics are implemented as link costs to be summed over the network. The cost values are traffic-independent parameters. In the majority of cases, the values are simply taken as default values and not varied over time according to the state of the network. But they can also be modified independently in the router’s database by the system administrator or via an automated process – provided that this process has modification privileges. This modi-



fication capability forms the basis of the proposed optimization method in the StableNet IPO package of the StableNet network management software suite.

Static or Adaptive Routing

As discussed in the previous section, and despite the implications that router data is being obtained dynamically, *routing in IP networks is static in practice* because router settings are assigned default values and lack of knowledge about the impact of router settings has tended to deter system administrators from altering these default settings. This means that only in the case of link failures do the existing IP routing protocols react in a dynamic fashion and automatically find an alternative path. But to make the most efficient use of a company intranet or an ISP network, it is clear that an optimal adaptive routing approach to exploit the current state of the network is required and sensible. This is the starting point for StableNet IPO as it can assist a network administrator to implement adaptive routing instead of static routing as used in today's IP networks.

Routing Optimization

This white paper is concerned with the potential to perform optimization in today's IP networks. There are many different interpretations of what we mean by the word "optimal". Different groups may have opposing views about an optimal design. For example, network routing could be optimized from a provider (ISP) viewpoint or a customer viewpoint. It is conceivable that these two viewpoints could lead to quite different optimization strategies for routing IP packets in a network. Optimization can be implemented globally or locally (leading to a suboptimal solution), it may also be dynamic or static in nature. The Internet is a large distributed system that is broken into many different regions and managed by many different systems employing a mixture of routing protocols. In practice, it is not possible to provide a global solu-

tion to the routing problem in the Internet. Instead, it is necessary to perform optimizations within a defined intranet (local) environment – this is the focus of the current white paper.

Optimization without Investments into Hardware

To date, most of the effort in route optimization has been focused on improvements and changes to the routing protocol itself; whereas, few methods deal directly with the optimization of the routing in a particular network. Methods for directly optimizing the routing are mainly known from telephone networks with fixed circuit switched connections. In contrast to telephony or other connection-oriented networks, in IP networks the possibilities for optimizing the routing of packets are more restricted due to the nature of existing routing protocols.

Basic Algorithms and StableNet IPO Operation Sequence

As indicated in the introduction, it is essential to define what will be interpreted as an "optimal" routing scheme. The objectives of the method used by StableNet IPO are to achieve an optimal traffic distribution by:

1. Minimizing the maximum link utilization
2. Minimizing the average network utilization
3. Keeping the physical delays within a specified bound

The basic algorithm follows the application flow chart shown in Figure 3 below:

1. Firstly, the topology is discovered and a traffic flow matrix is measured.
2. Based on this information, the link costs are computed in two steps. In the first step, the optimal paths for given flows in the network are specified. These paths



satisfy the condition that link costs exist such that the calculated paths correspond to the shortest paths. Link costs corresponding to these paths are then computed in the second step.

3. The link costs or calculated weights can be accepted or modified manually by the network administrator. If the network administrator accepts the proposed solution, a configuration file for the routers is generated and forwarded to the routers. Thus, the configuration process is automated.
4. As a result of the dynamic nature of the traffic flows in a network, the application flow is a cycle, which has to be repeated from time to time in a manner that ensures network performance and stability and to adapt the traffic matrix on the current traffic situation.

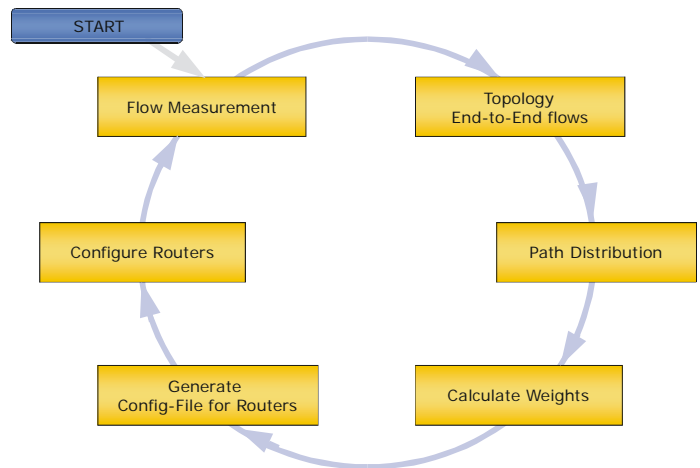


Figure 3: Application Flow of StableNet IPO

StableNet IPO

Infosim StableNet is a software-suite for management and optimization of small to large scale corporate networks (intranet) and ISP networks (internet). Using StableNet enables network administrators to manage all of their tasks from one portal. StableNet is modular in design and offers powerful components for:

- ◆ routing optimization
- ◆ configuration and provisioning
- ◆ security
- ◆ performance management
- ◆ fault management
- ◆ service assurance and
- ◆ user management

StableNet integrates all aspects of network management into one intuitive graphical user interface. Installing and getting acquainted with the software is easy and timesaving.

StableNet IPO is a single module which include only the Optimizer and the Configuration tool. The traffic measure-

ment is done by tools like StableNet PME and the traffic data is imported via designated interfaces.

Improving networks with StableNet

Load balancing is one of the most important techniques for optimizing the traffic distribution in IP networks. Load balancing is required, in practice, when a routing protocol determines that the costs on two (or more) paths are equal. In such cases, the traffic is evenly distributed over the links. For this purpose a lot of different commercial products are available.

StableNet is different! StableNet optimize the network from a global viewpoint. StableNet is the only product which improve and optimize the entire network itself!



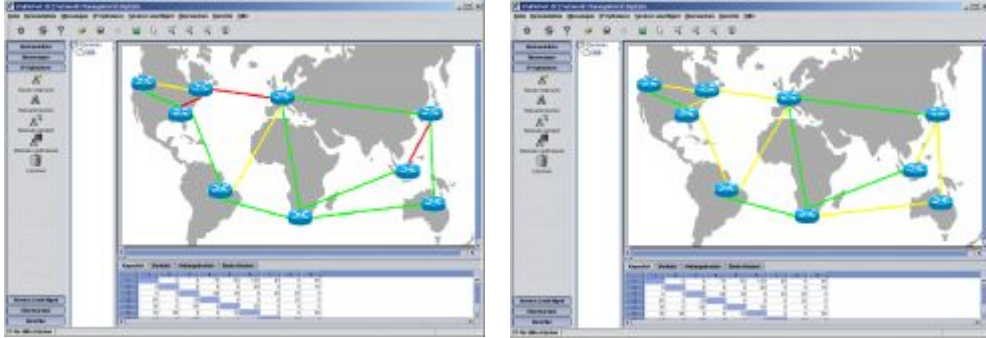


Figure 4: Example of Routing Optimization with StableNet IPO.
StableNet Client with sample network before (left) and after (right) optimization.

That StableNet can dramatically improve your network can be seen in Figure 4. The routing of the data packets in the left figure follows the standard routing protocol. Three overloaded links can be seen (red), with the consequence of packet loss. Also the yellow links are indicating crowded links, which will be soon overloaded. This links should be updated very soon, to handle the traffic in the network. The Figure on the right side shows the same network with the same traffic flows, but with optimized routing parameters. The load is distributed homogenous over the network. If you compare the maximum utilized link in the standard and the optimized network you see a reduction of the load of nearly 40%. Figure 5 compare both networks. The green bar shows the load of the maximum utilized link in the network. The red bar depict the average load in the network. Because of the same traffic matrix you will only see minor difference in the average load of both

networks. The blue bar characterize the difference between the lowest and the highest utilized link in the network. In a network with standard routing the difference is very high (see Figure 5). Thus, parts of the network are overloaded and other parts of the network . Whereas the optimized network distributes the traffic homogenous in the network.

Using StableNet to optimize the network, one will achieve:

- ◆ higher the consumer satisfaction
- ◆ utilize your network resources in the best way
- ◆ save network resources and
- ◆ better fulfill your SLAs

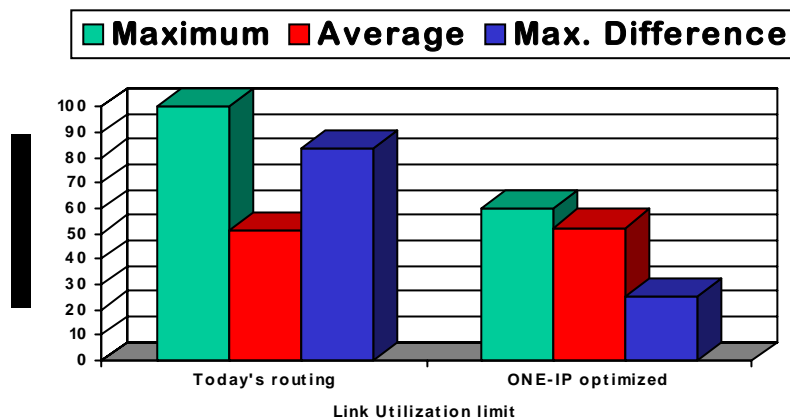


Figure 5: Improvement of 40% through the Optimizer.



Recovering from a link failure

The basic principle of StableNet IPO is to equally distribute the traffic in the network. Because of this basic principle, the

operation of StableNet IPO could also help in the case of link failures.

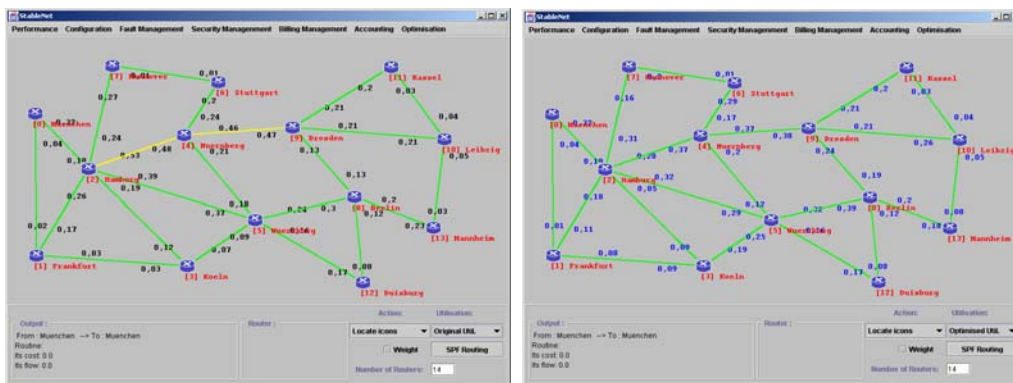


Figure 6: StableNet Client with sample network with (left) and without (right) optimization.

Figure 6 shows a network without StableNet. It's well designed and only two links (yellow) are loaded more than the others. The network on the right side is using StableNet. No yellow links are visible.

Now, one link is going down. The network without StableNet don't react on the link failure. The routing protocol only tries to shift locally traffic from on link to the other. The network is unstable and losing packets (see Figure 7 left). In this situation the network administrator has to react very fast to

maintain the business for his customer. Totally in contrast is the network optimized with StableNet.

Because of the homogenous traffic distribution in the network, the traffic over the defective link could be easily transmitted over the neighbor links. The network administrator gets more time to react on the failure and the business of the customers from the ISP is not broken down.

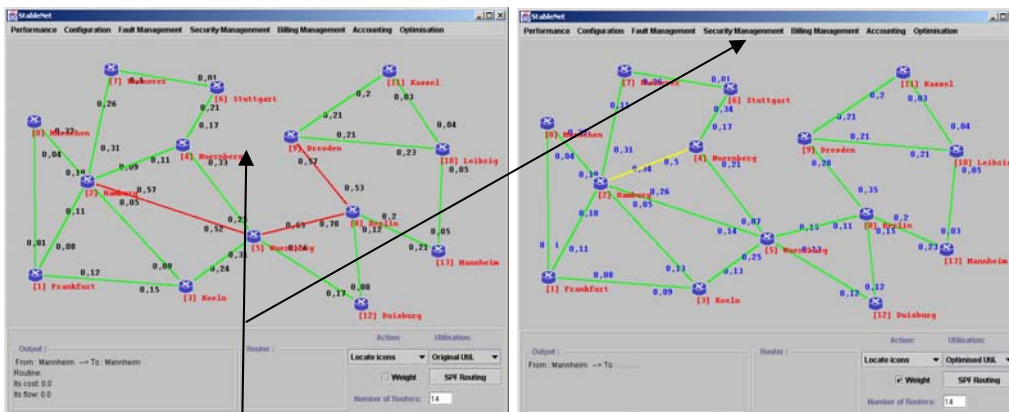


Figure 7: Link Failure Recovery using StableNet IPO Routing Optimization



Scalability

The basic approach can be used without changes for the deployment and planning of new networks. If the ISP wants to optimize the traffic distribution in real-time (e.g. every 5 minutes) it is necessary to split a large network into pieces (subnets) of approximately 30 routers and individually optimize these subnets. As it is possible to split larger networks in this way, the proposed approach is very scalable and flexible - even for large IP-backbones.

New Technology

StableNet is a software suite specialised for the management of IP networks. But also MPLS networks benefit from StableNet. The MPLS path distribution is based on IP routing calculation. Thus, the optimized IP routing from StableNet enables traffic engineering in MPLS networks. The specific features of MPLS and optical network will be soon available in the StableNet-Suite. Ask a representative of infosim for more details.

Consulting

StableNet IPO as a standalone or as part of the StableNet Suite provides the capability to optimize the routing using existing routing protocols and without the need to incorporate new hardware. It has been shown that the results obtained by StableNet IPO are currently applicable to the most important routing protocols such as IS-IS, OSPF and EIGRP. An optimal calculation of the routing parameters could have an enormous improvement for an ISP and users alike. It improves the Quality of Service for the user; utilizes the network homogeneous and leads to a better behavior in the case of link failures.



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