



## **Diploma Thesis for Andreas Siegrist**

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| Task Description: | Martin Waldburger, Prof. Dr. Burkhard Stiller                                                                                   |
| Topic:            | <b>Internet Route Stability and Mechanisms for Guaranteed Paths between End Systems in the Internet</b>                         |
| Start Date:       | October 15, 2007                                                                                                                |
| End Date:         | April 15, 2008                                                                                                                  |
| Supervisor:       | Martin Waldburger, Prof. Dr. Burkhard Stiller (University of Zürich)                                                            |
| Location:         | Department of Informatics (IFI), diploma students' room                                                                         |
| Support:          | Commercial electronic services; Internet organization; contract formation; routing and legal domains; private international law |

### **1. Introduction and Motivation**

The provision of commercial electronic services over the Internet requires the respective support services for commercialization to be designed and implemented. This is due to the fact that Internet design principles do not focus on commercially offered services, as the Internet was shaped originally as a military and later as a research network which then grew into a global infrastructure offering a plethora of services made available to businesses and end consumers.

The range of necessary support services for commercialization is determined by the according set of applicable commerce law determinations. To reach legal compliance, *e.g.*, support mechanisms for reliable authentication, authorization, accounting, auditing, and charging (A4C) [4][5] are being developed. These mentioned mechanisms, however, are not sufficient for full legal compliance, since they focus on the service provisioning phase, but do not cover the contract formation phase.

Commercial offerings for electronic services—in terms of an electronic good—base on contractual agreements. In the case of bilateral contracts, these are concluded between a service provider and a service customer, and the service is consumed by a service user, whereas service customer and service user can be different organizational bodies. Besides those support mechanisms mentioned, the formation of such contractual agreements itself is required to be legally compliant too [9].

Contract law is a part of commerce law, which in turn is part of private law. As contracts for electronic services in the Internet are considered, it is the task of so-called private international law to determine what specific contract type and what legislation is applicable for a given agreement. The Internet is a global infrastructure. However, it does not provide for a notion of geographical location. This is in contrast to any type of legal determination as these apply in a determined, geographically bound area only, typically within a territory.

With regard to an automated, legally compliant contract formation and in order to overcome this fundamental design gap between geographically un-aware organizational domains of the Internet and the inalienable territoriality principle of legal determinations, two distinct prerequisites need to be satisfied [9]. First, a mapping between so-called Autonomous Systems (AS)—organizational domains in the Internet—and geographical location needs to be found. Secondly, mechanisms for stable communication paths between contractual parties have to be in place. The first is important to determine the geographical location of contract partners. This information forms the basis for the selection of the appropriate law according to the specific contract to be concluded. The second is of relevance, since not only the respective end systems of contract parties need to be considered but also the communication paths between. For instance, it might be required to assure that information is not conveyed through an unwanted legal domain.

Driven by the overall context of legal compliance in contract formation given, and in accordance with those two prerequisites introduced, this thesis is concerned with the *second* prerequisite.

## 2. Description of Work

The Internet is organized as a network of networks. Within a network, Interior Gateway Protocols (IGP) are used to determine the way to reach a given end system (ES) over a number of intermediate systems (IS). Between networks, Exterior Gateway Protocols (EGP) are in use for the same purpose. Originally, a so-called Autonomous System (AS) was determined by the fact that it was a network applying a specific IGP. This notion of an AS has changed slightly over time to become a synonymous of an organizational domain [1][2]. Accordingly, ASes are seen today as organizational domains of the Internet.

Figure 1 depicts an environment with 4 ASes and 4 legal domains (LD), the latter being typically a representative of a territory. While ASes 2 and 4 each are fully embraced by a distinct LD, ASes 1 and 3 span across several LDs. According to peering agreements concluded between network operators, access to routing information of a neighbor AS is granted. Based on configured filters, exchanged routing information is included into or excluded from the respective routing tables of a given AS. Consequently, AS 2 might setup a rule that prefers traffic destined for AS 4 to be sent through AS 1, whereas AS 4 might prefer data destined for AS 2 to be routed through AS 3.

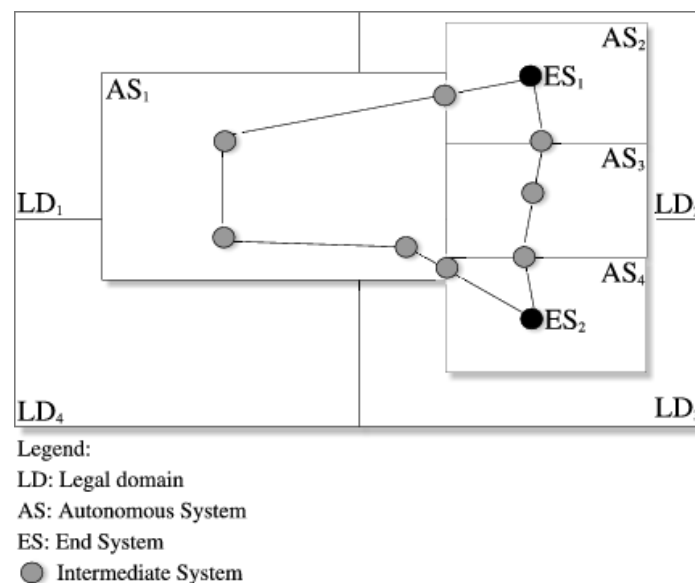


Figure 1: Legal and Organizational Domains (adapted from [9])

This example constellation reflects ambiguity in symmetry of communication paths as well as path stability over time. Thus, paths for bidirectional data transfer between two given ESes are not to assumed to be necessarily symmetric and taken routes might change over time. The given example increases in complexity when considering in plus mobility of systems.

Driven by the motivation given, *i.e.*, with the overall goal of legal compliance in contract formation for electronic services in the Internet in mind, reliable assumptions on stable communication paths between contractual partners might be required. For instance, a given contract to be concluded might include data protection and privacy statements. Such determinations need to be respected at the respective end points, but also apply for conveyed data between ESes. For that, communication could be encrypted, which, however, might conflict with export restrictions.

Thus, this thesis is concerned with two inter-related research questions. First, it is concerned with a comprehensive study on Internet route stability. This study investigates into assumptions on how often route updates are exchanged between neighbor ASes. Secondly, and based on the study's outcome, this thesis addresses the design, prototypical implementation, and evaluation of possible solutions for a mechanism that guarantees stable, but not necessarily symmetric communication paths between given ESes in a given time frame.

### 3. Thesis Goals

- The main objective of this thesis is found in finding a mechanism that provides for stable communication paths between given ESes as motivated and outlined. This mechanism has to satisfy the following requirements:
  - It shall be based and in full compliance with those insights gained through the mentioned study on Internet route stability. Besides theoretical investigation, that study preferably also integrates practical experiments and/or real data. For instance, a uni-directional peering with Switch [8] might be envisaged, whereas a machine at the IFI would act as a sink for internal BGP [6] updates propagated from Switch.
  - Primarily, the mechanism shall allow for *reliable* assumptions on paths between considered ESes. This is, however, always bound to an envisaged time frame in which paths have to remain guaranteed.
  - The mechanism shall be as *non-intrusive* as possible. This means that it shall serve its purpose with preference by exploiting existing protocols such as MPLS [3][7] and infrastructure in the Internet wherever possible. Consequently, the mechanism needs to respect network operator incentives and shall be based on realistic deployment assumptions.
  - It shall provide for an as *automated* solution with as *few overhead* as possible, keeping entry barriers for users and providers low, making the solution transparent as far as possible. Despite this general goal, candidates can also embrace methods that are in conflict with this objective, but only if these candidates appear to provide excellent results *ex ante*.
- Unless one single method is found that satisfies those requirements sufficiently *ex ante*, *i.e.*, before implementing and evaluating the according candidate, several candidates need to be considered, whereas at least two promising candidates shall be investigated in further detail.
- Along with the written report, the work shall cover the full design, implementation, simulation, and evaluation details of those selected candidate methods. Implementation in this work is performed by means of prototypes that demonstrate the practical feasibility of a candidate, allowing for an evaluation to be conducted.

### 4. Activities

Based on the description of work, the following activities—some in parallel—are recommended:

- Provide an introduction to fields of interest and provide a motivation for your work. Focus is to be set on Internet organization and Internet route stability, whereas assumptions on the latter are put into context of legally compliant contract formation of electronic services in

the Internet. This includes also an outline of detailed objectives, general mechanism requirements as well as of used concepts and terms.

- Give an overview of state-of-the-art with respect to related work in the areas of:
  - Internet organization. Provide insight into the Internet's organization principles into ASes together with applied mechanisms and protocols. Introduce relevant actors in the field with their respective set of incentives. Put special emphasis on Internet routing and interconnection of Internet Service Providers (ISP) at all tiers.
  - Internet route stability. Provide an embracing and detailed overview of ongoing work in the area of Internet route stability. Outline empirical results from related studies documenting route stability. Furthermore, present and compare mechanisms that can be leveraged to guarantee stable paths. Focus primarily on mechanisms that exploit or extend existing protocols and infrastructure, but present also work that does not respect this requirement.
- Out of the motivation and the analysis of related work, derive requirements allowing you to compare and select best-suited candidate methods. Besides ideas that base on related work, develop your own candidates. Combinations of several candidates targeting at specific sub-tasks or altering the overall reliability to be expected shall be considered too. The comparison shall be based on the self-developed or well-established set of key criteria complying with this thesis' overall objectives. Develop and outline in detail design characteristics and the overall methodology for those promising candidates (including potential combinations) that were pre-selected according to the conducted comparison. As a non-mandatory but highly recommended part to assess available related work in the area of Internet route stability, design experiments (such as the one mentioned in collaboration with Switch) to gain empirical insight into the frequency of route updates exchanged between neighbor ASes. This chapter, thus, is the methods section.
- Based on the outcome of the methods part, implement the respective chosen candidates (including potential combinations) in prototypical form. Pursue simulations, document your experiments, and depict effects. In case experiments on route stability are conducted too, draw conclusions on assumptions of how often a route change is to be expected if no mechanism to guarantee a path to be taken is applied. This chapter, thus, is the results section.
- Evaluate your work and especially the results gained by drawing conclusions on overall feasibility, reliability, performance, and scalability of the implemented candidates. Evaluate also clearly reached and missed objectives as well as advantages and drawbacks of the chosen approach.

## 5. General Notes

- Provide a proposed schedule for your steps within the first two weeks of your work. Clarify details with your supervisor and finalize the schedule of tasks, basically in a bi-weekly fashion. Prepare an intermediate report and a short internal presentation after half time (date to be set) and discuss this with your supervisor. At the thesis' end a final public presentation has to be given.
- The final written report will document all work undertaken and remember that this report must be self-contained. Major technical basics are to be included and detailed knowledge obtained during the work must be documented. Assumptions, design decisions, configuration choices, and results are part of the report as well as implementation details and usage information. Correct bibliographic references and a list of papers, recommendations, and descriptions used must be added, including those ones given below.
- Establish weekly meetings with the supervisor to report on progress and problems.
- Students involved are required to read and answer e-mails related to this project at least twice a week.

- The sheet on hints for diploma/semester thesis work is required to be known.

## 6. Formal Results

Besides an oral presentation of your work in exactly 20 min plus 10 min for questions and answers during the public presentation, the following written documents are part of your work and need to be handed in to the supervisor in time:

- A report in a soft cover binding, printed double-sided, and in 3 copies (in English, preferred): It covers the problem to be solved, the discussion of the design choices, a set of arguments on the final design choice, a list of solved and open issues, a table of content and figures (including tables), a valid list of bibliographic references, and optional appendices as required. A critical consideration of the task, the work, and the result will conclude the report. The official acknowledgement section is mandatory, a personal one optional, however recommended, as usually a number of people took part in the process of finalizing the thesis. The text processing shall be done in FrameMaker (preferred).
- A documentation of the implemented/configured system, covering the systems view point, an implementation description, a use and installation manual, a documentation of all program and data structures developed or utilized. All of this may be part of the report below, however, in case it will not be included, it must exist in a separate document.
- A dedicated CD has to be produced: (1) a collection of all program sources, software components, protocol implementations utilized, hardware/product documentation in PDF, related work papers in PDF or full HTML pages, and a directory description; (2) the written thesis (report) in source files, figures in source file and gif or eps, and a full printable PS as well as PDF file, the set of slides for the final presentation in PowerPoint, and all further material used, if available in electronic form, such as all existing and documented test scenarios, testing plans, and test results.
- A German (or English, in case of a German report) summary of maximum 2 pages, which will enable a quick and clear survey of this work's tasks and results. This summary will be part of the bound report, and is included after the front page and before any other text will follow. It includes four short sections on: 1. Introduction, 2. Aims and Goals, 3. Results, and 4. Further Work.
- The complete set of copies of the report, the CD, and the talk must be completed and handed in to the supervisor in time before the diploma thesis will change into "submitted" status.

## 7. References

The following list of references addresses key points. Further paper, scenario, and document research is a must:

- [1] S. Hares, D. Katz: *Administrative Domains and Routing Domains. A Model for Routing in the Internet*; IETF RFC 1136, pp. 1-10, December 1989.
- [2] J. Hawkinson, T. Bates: *Guidelines for Creation, Selection, and Registration of an Autonomous System (AS)*; IETF RFC 1930, pp. 1-10, March 1996.
- [3] IETF MPLS working group: *Multiprotocol Label Switching (MPLS)*; <http://www.ietf.org/html.charters/mpls-charter.html>, March 2006.
- [4] M. Karsten, J. Schmitt, B. Stiller, L. Wolf: *Charging for Packet-switched Network Communication – Motivation and Overview*; Computer Communications, Vol. 23(3), pp. 290-302, 2000.
- [5] C. Morariu, M. Waldburger, B. Stiller: *An Integrated Accounting and Charging Architecture for Mobile Grids*; Third International Workshop on Networks for Grid Applications (GridNets 2006), pp. 1-10, San Jose (CA), USA, October 2006.

- [6] Y. Rekhter, T. Li, S. Hares: *A Border Gateway Protocol 4 (BGP-4)*; IETF RFC 4271, draft standard, pp. 1-104, January 2006.
- [7] E. Rosen, A. Viswanathan, R. Callon: *Multiprotocol Label Switching Architecture*; IETF RFC 3031, pp. 1-61, January 2001.
- [8] SWITCH: *SWITCH – The Swiss Education & Research Network*; <http://www.switch.ch>, 2007.
- [9] M. Waldburger, B. Stiller: *Legal Compliance in Commercial Service Provisioning Across Administrative Domains*; 13th EUNICE Open European Summer School and IFIP TC6.6 Workshop on Dependable and Adaptable Networks and Services (EUNICE 2007), pp. 1-8, Enschede, The Netherlands, July 2007.