Final publishable summary report

A. Introduction

There is no doubt that Internet is a key pillar of the society today and tomorrow, providing an easy and worldwide access to knowledge, entertainments and open communications, as well as a fertile compost for innovation and growth for the Information and Communications Technology market. Internet represents a complex interconnection of network operators, service providers and users, and the basic Internet service, i.e. the reachability, is not sufficient anymore: indeed, interconnection rules need to be more flexible to cope with the divergent interests of the various stakeholders.

To meet users' expectations, investments are required in new network infrastructures and/or technologies to enhance the end-to-end Quality of Experience (QoE). Disputes amongst stakeholders (between Network Service providers -NSPs, or between NSPs and Content and Application Providers –CAPs) on who has to pay for such investments arise. To not endanger the stable operation of the Internet, it is mandatory to rethink how global ICT revenues and costs are shared amongst all actors of the value chain: the ones who create the services, the ones who transport the traffic, the ones who build equipment, and finally end-users who consume the services. There is no reason to question the openness, low entry barrier and universality properties of the current Internet. However, the current best effort data transport model does not provide enough incentives for users and CAPs to pay attention to the way they consume network infrastructure resources. The ETICS project was created to investigate complementary technical solutions and business models. It will not replace the Internet rules, but will allow the development of applications and services with more stringent requirements, while ensuring a fairer distribution of generated revenues amongst participating actors.

This paper summarizes main results and impacts of the **FP7 ETICS (Economics and Technologies for Inter-Carrier Services) project**. Section B first recalls the motivations and objectives of the project, while section C presents the project results in terms of business models, technical architecture, and feasibility demonstration. Section D concludes highlighting the wide dissemination towards various stakeholders and decision makers to influence future networks and the future of Internet.

B. Motivations and objectives

Recognizing above the benefits of the Internet on our society, we also challenged its revenue sharing mechanisms amongst involved actors. Hereafter, we sum up current limitations, briefly explain why current solutions may not be sufficient, and introduce the main objectives of the ETICS project.

a. An observation of the current Internet

The increasing activities on the Internet led to a tremendous traffic increase over the last decade. To support such evolution, network equipment vendors and NSPs have innovated and deployed new technologies in every network segment (mobile & fixed access, aggregation/metropolitan networks, and core networks) to progressively increase the bandwidth offered to every citizens and service providers. Such evolutions were made possible in a healthy competing market where the increasing number of users and revenues from classical telecom services allowed funding new deployments with a certain network over-provisioning to maintain the end-to-end Quality of Service (QoS). With a stagnating number of users and a transformation of Telecommunication networks into converged IP infrastructures, despite technological progresses decreasing the cost to transport bits, investments in new network infrastructures slowed down due to uncertainties on the return on investments for NSPs.

Internet is composed of interconnected network domains (Autonomous Systems, ASes) managed by different NSPs, and governed by traditional peering (money-free) and transit (paid) interconnection agreements. The huge decrease of transit prices over the last decade [1] combined with the increasing traffic have created tensions between interconnecting parties, due to business threats in the form of backbone free riding and business stealing situations. In addition, the provided basic reachability service is independent of the nature of the traffic and lacks Quality of Service (QoS) properties. Hence, it is not possible to convey the relative importance or value of the IP packet when transported over the Internet. This reduces incentives to invest in network infrastructure such as interconnection links. Disputes have been emerging between NSPs, or between NSPs and CAPs, resulting in a degradation of the service for end-customers, thus demonstrating that the current Internet funding and management rules may have reached their limit.

b. Why existing solutions may not be sufficient

As inter-domain routing is service-agnostic, the per-domain network effort to provide quality is hidden and not rewarded (nor punished). Thus, inter-domain network quality is uncertain, undermining the market potential of incentive-compatible and efficient management of off-net traffic flows on top of the Internet infrastructure. Content Delivery Networks (CDN) only partially address inefficiencies of the current Internet for a fraction of services. Furthermore, over-provisioning has ceased to be a sustainable option over large parts of the network (e.g. peering links). This results in **unmet market needs for a) End-users**, who both lack choice for differentiated service quality levels and experience unpredictable performance; **b) NSPs** that cannot differentiate their product offerings and suffer from continuous erosion of their profit margins in a saturated market; c) **CAPs,** which have to limit their product offerings due to the lack of true end-to-end guarantees.

c. ETICS objectives

Observing these current inefficiencies, the ETICS project took as a fundamental assumption that Quality of Service and business models for assured quality interconnection could be the gear of a sustainable ecosystem with fairer revenue sharing for all actors participating in the delivery of an end-to-end value-added service. Indeed, QoS creates both the business and technical opportunities to better manage future network infrastructures. The ETICS project therefore had three major objectives:

- Propose new business models based on QoS product exchanges amongst NSPs,
- Design and specify an architecture allowing QoS interconnection, taking into account heterogeneous technologies used by NSPs in their domains,
- Demonstrate the feasibility of the system on a large-scale interconnected test bed.

C. ETICS main results

Figure 1: ETICS portal to sell and manage ASQ path to customers

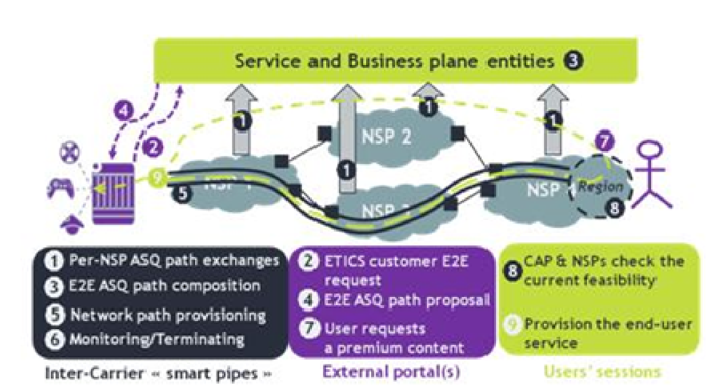

Figure 2: Inter-carrier ASQ path establishments (traffic aggregates) enhanced with QoS-enabled end-users' services

In this section, we present ETICS results with respect to these major objectives according to the following vision: as a solution to the aforementioned problems, NSPs collaborate to offer end-to-end **assured service quality (ASQ)** paths, and accordingly, exchange information on possible ASQ paths each NSP can provide (Fig. 1 and 2). Thus, customers can request an ASQ path to deliver aggregated traffic with QoS constraints (availability, delay, packet loss rate, etc.) or routing constraints (to maintain traffic in a geographical region, avoid certain countries, etc.). The customer can be an NSP, a CAP, or an Enterprise. Figure 2 also shows two main service categories: ***ASQ Paths***, for services at the aggregate network resource level, and ***End-user ASQ connectivity***, for retail sessions at the end-customer demand time scale. ASQs paths can be between two physical points of interconnects (PoI, between two NSPs or between an NSP and an enterprise), thus forming an ***ASQ tunnel***, or from a PoI to an open set of destination end-points called a *region* (e.g. a geographical area and/or a group of business customers or mobile customer end-points), which is a ***PoI2Region (***termination) service.

a. Business models and charging principles

Through a market quantification for different types of services (multimedia communication, off-net premium content delivery, VPNs, etc.), ETICS has demonstrated possible economical benefits in the use of ASQ paths and has analyzed the related possible socioeconomic, legal and regulatory impacts.

In particular, to provide more incentives for NSPs to invest in network infrastructure and for CAPs to use the bandwidth efficiently, ETICS investigated revenue models based on the principle that **the Sending Party Network Pays (SPNP)** for traffic at the interconnection point. Under this principle (Fig. 3), while carrier B sends the traffic to Carrier A, it also financially compensates carrier A for the IP packet transport. Thus, the receiver of the traffic is mandated for delivering the traffic to the destination, with the requested level of QoS. Indeed, the sender best knows which IP-packets shall be sent with premium quality.

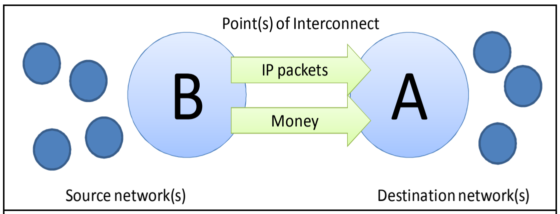

Figure 3: The Sending Party Network Pays principle

However, SPNP does not address all the issues challenging the Internet and should simply be considered as a baseline element contributing to enhance the eco-system. As examples, the following charging models could be used as an extension or on top of SPNP for further improvements:

- At the wholesale level, the **Destination-based principle** would allow a receiver carrier to charge different destination regions within and also beyond his network independently, reflecting costs to transport traffic in different areas, or taking into account the PoI from where the traffic enters his network. This differentiated pricing model takes distance-related costs into account as opposed to the current practice.
- At the retail level, the **Initiating Party Network Pays** on top of SPNP may solve the problem of distributing the total value received by the end-user's value of content and services. Under this charging principle the initiating party network (assumed to contain the end-customer) is paying for return traffic from a specific end-point in addition to SPNP charges. Typically, the agreement between two carriers will include a method to exchange IPNP usage data over all such end-customer cases, and a settlement process where the net effect is charged and billed.

b. Technical solutions

The ETICS core system aims at describing how NSPs can exchange information to build such end-to-end ASQ paths, with various modes of collaboration amongst them. It relies on the introduction of a **Network Service and Business Plane (NSBP)** on top of the classical Control, Management and Data planes of each NSP, which allows maintaining confidentiality on NSPs' infrastructures. At this level, only ASQ path connectivity services (with QoS attributes) are exchanged between NSPs (step 1 in Fig. 2): **these services can be either pre-defined in advance**, supposing a good knowledge of the network status and of customer demands, **or created on-demand**, to best fit with a specific customer demand. This dual approach is described in the core system architecture as the ***push*** and ***pulls*** options: pre-built offers are "pushed" into a catalogue and are composed with other NSPs' offers when receiving a request for an edge-to-edge ASQ path. On the contrary, if NSPs exchange only "network capabilities", i.e. rough QoS information per domain to allow for a first selection of the NSP chain, precise offers will be built on-demand ("pulled") based on an up-to-date network view.
The other important dimension is to whom the information of each NSP is sent, i.e. how the NSBP entities of the figure 2 are implemented. For each mode of collaboration, multiple scenarios have been envisaged, either **exchanging information only with neighbouring NSPs** (bilaterally, possibly in cascade), **with all others NSPs of the community**, **or with a neutral third party** acting as a facilitator for the whole community. These models have pros and cons, from the business and technical viewpoints, which are described in ETICS deliverables. An important point is that each is suitable and adapted to a given context and phase in the **QoS interconnection market roadmap** proposed by the project. Currently, a QoS interconnection market is immature: NSPs cannot precisely estimate QoS demands before the market is kicked off with first products; and, customers would not know precisely what they are buying, an issue related to the so-called "lemon market" theory [2]. To progressively increase the trust amongst actors, recommended options are summarized in figure 4, but these models can also live in parallel according to business interests and trust among NSPs.

- **Bilateral ASQ path creation**: in the short term, an *open-association* type of community, with limited trust amongst participants, is expected. Offers will be rough, essentially built manually and exchanged exclusively with neighbouring NSPs, which have then to agree on generic forwarding principles (e.g. simple DiffServ forwarding) and with only bilateral commercial discussions. In order to bootstrap ASQ services into the market, the primary deployment would happen with simple bilateral agreements addressing the traffic to/from the two NSPs' own customers. Later on, each "offer" received by an NSP can be bundled with the NSP' own resources and "resold" to its upstream NSPs, thus allowing to cascade the ASQ traffic for an enlarged reach of ASQ services (Figure 4.a).
- **Distributed on-demand ASQ path creation (distributed pull)**: With increased trust, a sub-set of the NSPs can agree to share more technical information, or "network capabilities", and forms a more integrated community, a *federation*. With distribution of aggregated QoS information amongst NSPs, more precise offers can be provided dynamically to relevant NSPs, to build more adapted end-to-end services for their customers (Figure 4.b).
- **Per-NSP ASQ path creation (per-NSP centralized push)**: Finally, in a more mature market, the federation could evolve into a business *alliance*, where NSPs agree to share more information within deeper commercial agreements. Offers are built in advance by each NSP, which then pushes their offers into other NSPs' catalogues, so that they can quickly compose end-to-end services (Figure 4.c). The alliance represents a "coopetition" model with a trade-off between competition when NSPs push competing offers in order to be selected by other NSPs and cooperation when they are sharing more information to increase the alliance revenues (and in return, their own revenues).

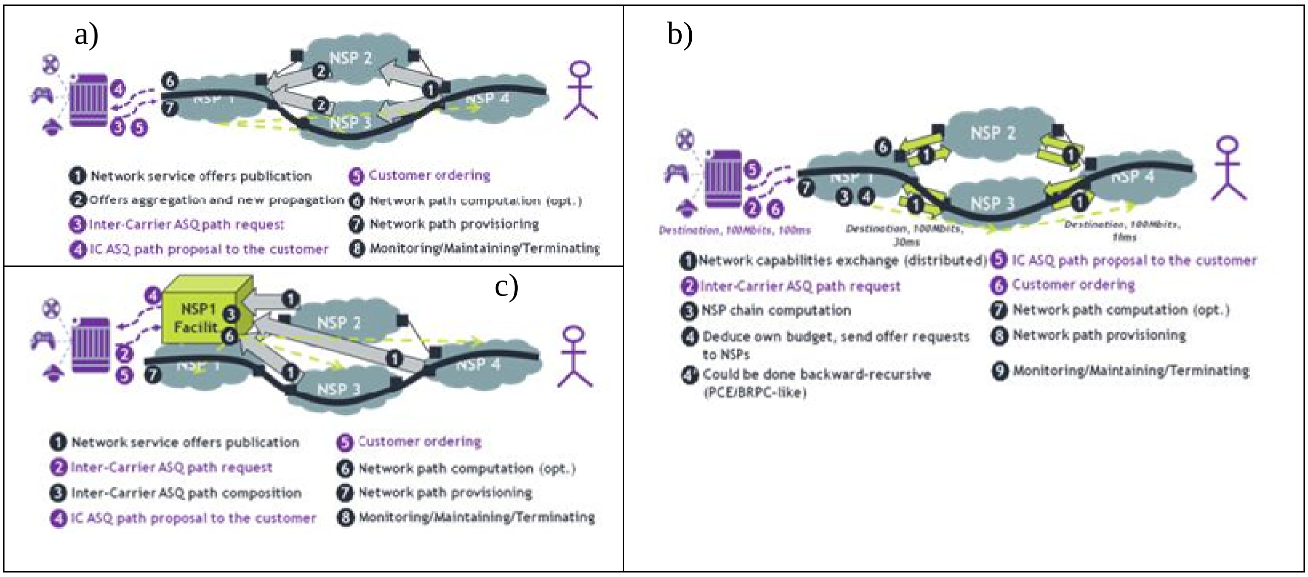

Figure 4: Roadmap of the ETICS architecture deployment modes: a) bilateral ASQ path creation, b) Distributed on-demand (pull) ASQ path creation and c) per-NSP ASQ path creation (push)

Once the offer for a service is accepted by the customer, the service is materialized in each domain through the provisioning of network resources for the ASQ path. Once established, an ASQ path is monitored, to check that QoS metrics are respected, and terminated when it reaches its time limit or on the demand of the customer.

As mentioned earlier, once ASQ paths are in place, it is important for both the NSPs and the CAPs to translate the ASQ quality properties into tangible premium or differentiated services for residential, mobile, and business end-users. From the ETICS framework point of view it is not possible to describe all imaginable services and business models that possibly would be developed in the future. Due to this, ETICS has introduced in addition to the ETICS core system the Service Enhancement Functions Area (SEFA) for the management and support of end-user ASQ connectivity services. SEFA provides the space for developing new and actor specific services and functionality on top of ASQ path services (e.g. added value services) that complements the ETICS core system architecture (steps 7 to 9 on figure 2). Examples of SEFA use cases could be application service related QoS/QoE monitoring enabling quality indication feedback to users, or derivation of context information to enhance application service quality delivery to customers in conjunction with application service control functionalities (e.g. media adaptation). Moreover, such functionalities could be related to policy and accounting entities in order to enable charging principles and/or business models. SEFA features could be added on top of the ASQ core system, and therefore could apply at any step of the aforementioned roadmap, starting with simpler features at short term.

In addition, optimizations for Inter-Carrier VPN services on top of ASQ paths have been studied in order to provide QoS-enabled services to business customers. Enabling inter-domain VPN services opens the way for new types of services going beyond the mere limits of traditional private, QoS enabled networking, e.g. in a cloud service domain targeting the provision of assured quality, secure access to remotely located public data centres. Finally, enhanced Congestion Exposure (ConEx) features have been proposed and implemented as an end-to-end control mechanism, e.g. when several users share a link to a common destination with varying capacity demands like in a video-on-demand use case. ConEx in ETICS thus complements the ETICS core system architecture with the ability to police capacity sharing on shared ASQ paths according to the service provider's policies.

c. Prototyping

To demonstrate the features of the ETICS core system, most building blocks and protocols have been implemented in an interconnected lab-environment, involving multiple partners. The control and data planes in the test bed are representative of a multi-vendor/-carrier environment, validating the NSBP concept. In particular, both centralized push and distributed pull models have been implemented relying as much as possible on stable and mature technologies. Bilateral ASQ path creation is left to commercial agreements amongst NSPs, outside the scope of the ETICS project.

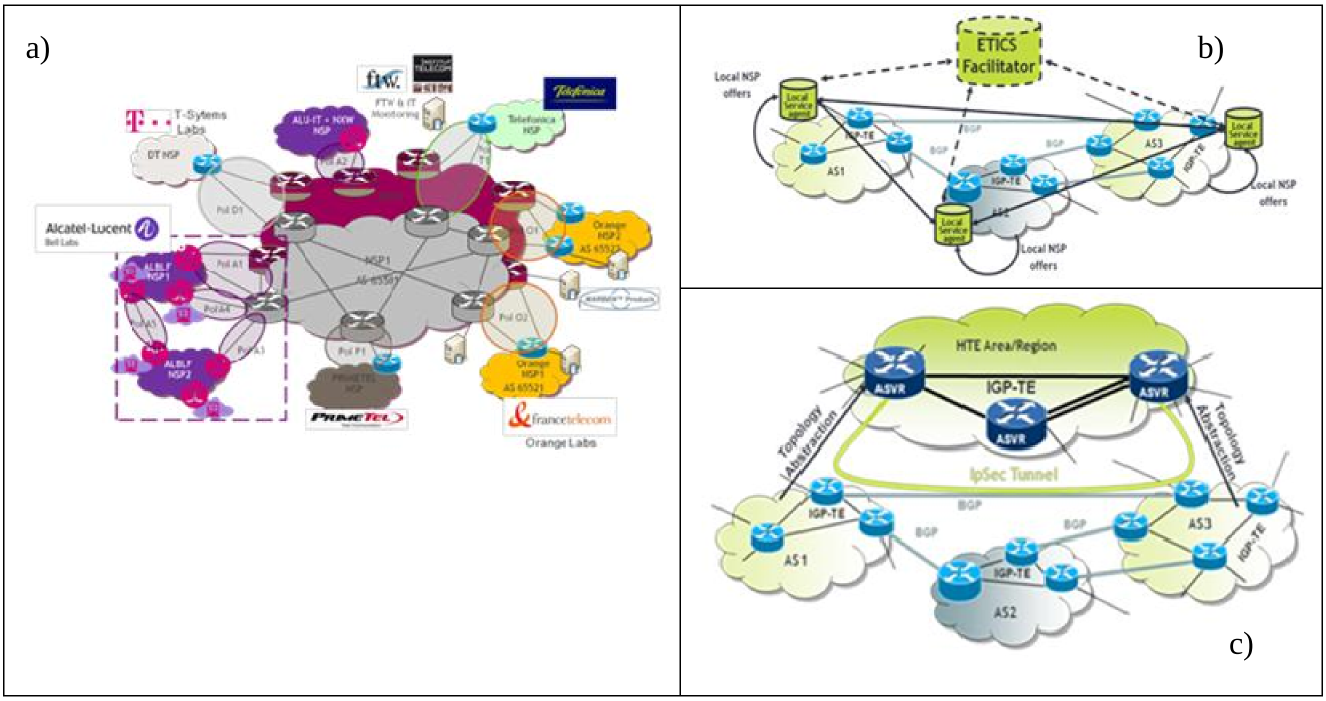

Figure 5: a) ETICS interconnected test-bed, b) REST-based centralized push implementation c) HTE implementation of the distributed pull model

- A Service Oriented Architecture framework based on the REST (Representational State Transfer) paradigm for the push model, comprising local service agent and facilitators according to web service design using HTTP methods.
- Principles of Hierarchical Traffic Engineering (H-TE) for the pull model: each NSP domain is abstracted as an Autonomous System Virtual Router (ASVR) exposing the network capabilities of the domain. Communications amongst ASVRs use an Internal Gateway Protocol (IGP) capable to transport TE information.
- A lightweight passive monitoring system for multi-domain environments: the monitoring is focused on preserving privacy requirements of participating domains, and is based on a protocol (EMONIT) reducing the bandwidth consumption and the processing overhead.

D. Conclusions

Inter-domain QoS management has been a preoccupation for the last decades, but no global impact has been reached so far. By studying existing limitations and proposing jointly new business models and a flexible architecture capable to adapt to a QoS interconnection market gaining in maturity, ETICS has set-up important pillars for the future of the network interconnection and Internet.

ETICS members widely disseminated these results in the scientific community **-more than 50 papers have already been published**, including some in prestigious conferences (INFOCOM, GLOBECOM), journals (IEEE Communication Magazine) and workshops linked to major conferences (Sigmetric 2012, Networking 2012, CoNEXT 2012), in the technical community (**around 20 contributions in standardization bodies**, in particular at the IETF), and **to regulators** (answer to the BEREC's consultation on the Net Neutrality, promotion of results towards several national regulation bodies).

Business model proposals and technical solutions were promoted to main European carriers, through regular meetings with operational representatives, public workshops and a demonstration at the MPLS Congress 2013. Furthermore, basic concepts on inter-NSP ASQs and the service models defined for NSP collaboration (open association, federation, and alliance), has become a relevant use case in IETF- Software Driven Network (SDN) and ETSI Network Function Virtualisation (NFV) contexts,

The concept of Sending Party Network Pays, promoted by the majority of ETICS carriers, **has also been endorsed by the European Telecommunications Network Operators (ETNO) association**.

At the end of the project, ETICS Network Service operators are analysing opportunities to redefine their peering strategies, but also how ETICS collaboration principles could help them manage multiple domains in their own infrastructure. The possibility to conduct QoS field trials (3) has been announced by Deutsche Telekom., and different product lines of equipment and stack vendors are analyzing exploitation opportunities from ETICS technological realizations.

Eventually, and thanks to ETICS, the issues and solutions for enabling end-to-end assured service quality across actor domains are now perceived as a fundamental challenge for future networks and the sustainability of the future Internet. The ETICS tool kit with various charging principles and technical deployment scenarios makes us confident that "ETICS-like" solutions will become a reality in the coming years.

Project Information:

FP7 ETICS project, grant agreement 248567, www.ict-etics.eu

Partners & contacts:

1. Alcatel-Lucent Bell Labs France (Project/Technical Managers: Nicolas Le Sauze/Richard Douville, {nicolas.le_sauze; richard.douville} @alcatel-lucent.com
2. Alcatel-Lucent Italy (WP4 leader: Giorgio Parladori, giordio.parladori@alcatel-lucent.com)
3. RAD Data Communication (Yuri Gittik, Yuri_g@rad.com)
4. Marben Products (Philippe Cuer, philippe.cuer@marben-products.com)
5. Nextworks (Nicola Ciulli, n.ciulli@nextworks.it)
6. British Telecommunications plc (Carla Di Cairano Gilfedder, carla.dicairano-gilfedder@bt.com)
7. Deutsche Telekom (Isabelle Korthals, Isabelle.Korthals@telekom.de)
8. France Telecom Orange Labs (WP6/7 Leader: Olivier Dugeon, olivier.dugeon@orange.com)
9. Telefonica I+D (WP5 Leader: Diego Lopez, diego@tid.es)
10. Telenor (WP2 Leader: Hakon Lonsethagen, hakon.lonsethagen@telenor.com)
11. Athens University of Economics and Business (Costas Courcoubetis, courcou@aueb.gr)
12. Forschungszentrum Telekommunikation Wien GmbH (Hannes Weisgrab, Hannes.Weisgrab@ftw.at)
13. Institut Telecom (Jean-Louis Rougier, rougier@TELECOM-PARISTECH.FR)
14. Politecnico di Milano (WP3 leader : Filippo Renga, filippo.renga@polimi.it)
15. Université de Versailles – UVS (Dominique Barth, dominique.barth@prism.uvsq.fr)
16. Israel Institute of Technology Technion (Ariel Orda, ariel@ee.technion.ac.il),
17. Primetel Plc (Michael Georgiades, michaelg@PRIME-TEL.COM)
18. University of Stuttgart (Mirja Kuehlewind, mirja.kuehlewind@IKR.UNI-STUTTGART.DE)

References:

[1] http://drpeering.net/white-papers/Internet-Transit-Pricing-Historical-And-Projected.php

[2] Akerlof, G. A.: "The Market for Lemons: Quality Uncertainty and the Market Mechanism". The Quarterly Journal of Economics 84:3, pp. 488-500, August 1970.

[3] Von Bornstaedt, F.:"Deutsche Telekom Group Quality-of-Service (QoS) for IP-Transit / Peering", October 2012. *https://bscw.ict-etics.eu/pub/bscw.cgi/d44579/DT%20QoS%20White%20Paper.pdf*