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## On the weal and woe of internet traffic management in Europe: A critical appraisal from a network economic perspective

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# On the Weal and Woe of Internet Traffic Management in Europe

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A Critical Appraisal from a Network Economic Perspective

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## Abstract

The *Body of European Regulators for Electronic Communications* (BEREC) has recently proposed a framework to assess the reasonableness of traffic management (TM) practices. This paper discusses BEREC's proposal from a network economic perspective focusing on the underlying concepts of congestion, application-agnosticism and layer separation. It can be shown that within the current European regulatory framework the adverse use of TM by network operators is no cause for concern as long as regulatory objectives are fulfilled and significant market power is adequately disciplined. Furthermore, entrepreneurial search processes for optimal price and quality differentiation may require the implementation of TM practices which deviate from strict application-agnosticism and thus violate BEREC's layer separation principle. They may according to BEREC be labeled unreasonable. Instead of the complex case-by-case assessment inducing regulatory micro-management necessary in BEREC's framework, an alternative from a network economic perspective is proposed. Based on an economic understanding of congestion, a market-driven interpretation of application-agnosticism and a corresponding layer separation constitute the main pillars of a resilient and dynamic understanding of TM.

JEL: L51, L86, L96

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## 1. Introduction

The debate on network neutrality has regained momentum; in particular the use and abuse of traffic management (TM) practices is a subject of controversy. In analogy to John Stuart Mill's example of the sale of poison (cf. Mill 1859, pp. 171ff.; Orbach 2012), TM is considered a complex 'product'. From the perspective of the *Body of European Regulators for Electronic Communications* (BEREC), TM practices exhibit both 'useful' potentials (above all an increase in economic efficiency via congestion management) and 'poisonous' ones (e.g. blocking or targeted degradation leading to ad hoc discrimination). Ideally, useful effects would be exploited while the poisonous ones would be restricted; a problem that complex requires a complex solution. The question is how to reliably assess whether or when TM practices are harmful. For such an assessment a consistent and reliable framework is urgently needed. Complementary to basic regulation in telecommunications markets as described in the European Regulatory Framework, BEREC has recently presented a first proposal. The assessment is conducted along four assessment criteria: 1) *non-discrimination between players*, 2) *end-user control*, 3) *efficiency and proportionality* and 4) *application-agnosticism* (BEREC 2012c, p. 4). The aim and scope of this paper is to critically appraise BEREC's proposal from a network economic perspective. In particular, the underlying concepts of congestion, application-agnosticism and layer separation are discussed and a modification is proposed. In doing so, the concept of market-driven network neutrality (cf. Knieps 2011a) serves as a normative reference point.

The paper is structured as follows. Section 2 discusses the issue of why network operators might have incentives to deviate from TCP/IP-based best effort networking principles. For this, the evolution of the Internet is briefly explained and the benefits of TM are derived. In section 3, the normative reference point of the disaggregated regulatory approach for network industries is presented and contrasted with the current regulatory framework for electronic communications markets in Europe. Based on the opportunities and benefits that TM provides, it is discussed whether or when it is incentive compatible for network operators to impose ad hoc discrimination in order to maximize profits. Section 4 then presents the BEREC approach towards the assessment of TM and contractual restrictions. A critical appraisal of the underlying concepts of congestion, application-agnosticism and layer separation from a network economic perspective is conducted in section 5. From this, an alternative framework from a network economic perspective is developed in section 6. Section 7 closes with a conclusion.

## 2. Why do Network Operators have an Incentive to deviate from TCP/IP-based Best Effort?

Before discussing the nature and occurrence of TM practices, it is imperative to illustrate the network operators' incentives to deviate from TCP/IP-based best effort Internet.<sup>1</sup> The evolution of the Internet ecosystem plays an important role in the analysis. It has come a long way from ARPANET, the Internet's early 'ancestor', to current increasingly broadband Internet.<sup>2</sup> This evolution has taken place both within and reciprocally between different

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<sup>1</sup> For simplicity, we use the terms network operator and Internet service provider as synonyms.

<sup>2</sup> For the purpose of a network economic analysis, a disaggregated representation of the Internet seems useful as it enables the identification of relevant submarkets. Following Knieps and Zenhausern (2008, pp. 122f.)

components which as an entity represent the Internet. Physical network capacities, i.e. local as well as long distance telecommunications infrastructures have been changing continuously over time. Whereas fiber has already become the first choice technology for long distance telecommunications infrastructure, it is increasingly used in local telecommunications infrastructures. Internet traffic services (Internet access and Internet backbone services; specialized/managed services)<sup>3</sup> have evolved alongside the underlying infrastructure components. As a result, transmission capacities and data traffic have steadily been growing over the last decades. Technological progress in terminal equipment (e.g. PCs or smartphones) has led to higher processing power and/or storage capacities. All these developments have eventually paved the way for new generations of innovative Internet application services like telemedicine or video conferencing. The Internet's components constitute interdependent catalysts, which by interaction stimulate the spontaneous evolution of the Internet as a whole. Beyond technological considerations, from a network economic perspective two issues are most appealing with regard to the status quo Internet ecosystem: First, the fundamental heterogeneity between different kinds of Internet application services with respect to their sensitivity to the quality and bandwidth intensity of data transmission. And second, to date, the persistent endurance of the Internet's traffic rules determined by the TCP/IP-based best effort principle.

In the very beginnings of the commercialized Internet – due to the prevalence of relatively homogeneous narrowband Internet access technologies – there was not much of a variety in Internet application services. In fact, application services exhibited rather homogenous sensitivity to variations in the timeliness and stability of data transmission, i.e. traffic quality.<sup>4</sup> The emergence and gradual adoption of broadband access technologies affiliated with the innovation in Internet application services has led to a fundamental change in the Internet. In addition to the existing homogenous 'narrowband application services', innovative and increasingly complex 'broadband application services' like video conferencing had emerged. As a consequence, the heterogeneity between and the spectrum of different application services had widened considerably. Especially real-time application services deviate from narrowband application services in that they require comparably high and stable levels of traffic quality. In order to achieve full functionality, different application services a priori pose different requirements to traffic quality. Heterogeneity in Internet application services induces heterogeneous traffic quality requirements, which translate into a differentiated demand for traffic qualities (cf. e.g. Knieps and Zenhausern 2008, pp. 124ff.).

Although the evolution towards increasingly heterogeneous demands for traffic quality is a well-known phenomenon, it is not systematically taken into account by the Internet's 'traffic rules'. The fundamentals of TCP/IP-based best effort Internet are the end-to-end principle and the normative maxim of non-discrimination between data packets. In order to create 'fair'

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different components, which as an entity represent the Internet, can be described. Peripheral components of the Internet comprise physical network capacities, i.e. local as well as long distance telecommunications infrastructure components, terminal equipment and content. Core services of the Internet comprise Internet traffic services (Internet access and Internet backbone services) and Internet application services (e.g. search machines or voice over IP [VoIP]). Internet traffic services use upstream network capacities and serve as input for downstream Internet application services.

<sup>3</sup> Although subject to recent discussions, the topic of proprietary specialized/managed services (based on strict admission control) is beyond the scope of our paper.

<sup>4</sup> For example, sending an e-mail or downloading a file is both rather 'robust' and tolerant to distortions in data transmission. In our context, traffic quality is described by the network performance parameters delay, jitter and packet loss rate.

sharing of network resources, TCP endogenously provides an average traffic quality depending positively on available capacity and negatively on levels of traffic flows. Nevertheless, a necessary condition for TCP's 'flow-rate fairness' is an environment of relatively homogeneous application services. Whereas in the narrowband era this was satisfied, the broadband-related increase in the degree of heterogeneity between Internet application services has changed the fairness situation fundamentally. Consider the case for rivalry in consumption of scarce network resources between a peer-to-peer file sharing application which is tolerant to losses in traffic quality and a VoIP application which is rather sensitive to quality losses.<sup>5</sup> While the file sharing application produces huge volumes of data traffic and consumes a huge bulk of the available bandwidth by using multiple TCP flows – hence degrading average traffic quality – the VoIP application suffers from it. In the end, TCP/IP-based non-discrimination between data packets unfolds discrimination potentials between application services; quality-sensitive application services may even be victim to crowding-out effects (e.g. Briscoe 2009; Knieps 2011a; Berger-Koegler and Kruse 2011). As a result, the persistent endurance of TCP/IP has led to an outcome clearly contradicting its purpose.

In addition to such qualitative considerations, quantitative challenges are thwarting supply-side capacity extension strategies in network infrastructure. Especially when network capacities are 'heavily' used, any marginal increase in demand for data traffic can cause (additional) losses in traffic quality and consequently in application functionality. The root causes are manifold: First and foremost, it can be observed that more people access the Internet, a fact further emphasized by increasing broadband availability and penetration rates. Empirical results show that higher data rates in Internet access are correlated with an increased demand for data (cf. e.g. OFCOM 2012, pp. 21f., OECD 2013). Second, there is a trend towards all-IP networks, enabling providers to offer voice, data and TV-services over IP-based network architectures (cf. e.g. Vogelsang 2009; BEREK 2012b, p. 50). Third, the emergence, growth and future role of cloud computing services have already shifted capacity and processing power resources from the edges into the core of the Internet. To make use of cloud-services, edges exchange data with nodes in the cloud.<sup>6</sup> This not only creates additional data traffic but also changes traffic patterns (cf. e.g. Kundra 2011; Mell and Grance 2011). Fourth, flat rate-based end-user pricing models lead to inefficient levels of bandwidth consumption by end users according to their saturation points. In this case, prices cannot fulfill their function of signaling scarcity (cf. Berger-Koegler and Kruse 2011, p. 6).<sup>7</sup>

To summarize, as a result of the transition from narrowband to broadband Internet, heterogeneity in access products, application services and content has crystallized. Different application services – a priori posing different requirements for traffic quality – increasingly translate into heterogeneous demand for traffic services. At the same time, the Internet's traffic rules determined by the TCP/IP-based best effort principle and the resulting homogenous average traffic quality create discrimination potentials between different application services whenever capacity is scarce. Best effort-compliant solutions to scarcity

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<sup>5</sup> The example is based on Briscoe (2009).

<sup>6</sup> From this, asymmetries between downstream and upstream data flows are very likely to follow. In the example of web storage upstream exceeds downstream traffic, while in the case of web-based applications downstream data volumes exceed upstream data (cf. Faratin et al. 2007).

<sup>7</sup> Faratin et al. (2007/2008) emphasize the evolution in Internet interconnection markets and highlight that growing asymmetries in data traffic flows between autonomous systems have caused an evolution in interconnection agreements.

problems are economically inefficient over-provisioning strategies, i.e. excessive investment in network capacities such that demand peaks can be processed without losses in traffic quality or user restrictions (e.g. introduction of non-optional volume caps for all users). Efficiency-enhancing overlay networks may also be installed.<sup>8</sup> Still, they can neither mend the root-causes of congestion problems nor discrimination potentials.

In contrast, TM practices can mend these. They provide means to implement efficiency-enhancing capacity allocation mechanisms in response to increasing heterogeneity.<sup>9</sup> As they require a deviation from TCP/IP-based best effort principles, the solution to the complex problem of finding the ‘optimal deviation’ is a complex task – a task so complex that only a solution driven by the market can yield optimal results. Only then can the dynamic and evolutionary market forces be incorporated into the search processes for optimal solutions.

### 3. Why should Network Operators implement ad hoc Discrimination?

Although the benefits of TM are obvious, TM can also be used to discriminate between content or application services. The purpose of TM practices may thus range from the benevolent intentions to increase social welfare to inefficient adverse practices such as targeted degradation of competitors’ data traffic. Also, blocking and the curtailment of freedom of speech by governments may represent potential threats (cf. Solum and Chung 2003). Crucial to the analysis of the weal and woe of TM practices is the institutional framing of the markets. The question is when and to what extent market forces can prevent market participants from acting in a discriminatory manner and exploiting the ‘poisonous’ side of TM.

From a normative point of view, regulation in network industries comprises technical regulation, universal service regulation and market power regulation which must be considered complementary to the ex post application of the general competition law. A division of labor between competition policy and regulatory interventions is necessary. Aiming at the universal availability for end-users to access certain services (e.g. traditional voice telephone services) at a minimum quality at politically desirable prices, universal service regulation is the proper measure. Prior condition for workable competition is technical regulation. It shall ensure the functioning of the networks (e.g. interoperability, number portability, spectrum policy etc.) and also includes measures for consumer protection (e.g. transparency, switching).<sup>10</sup> Transparency is of vital importance for competition to work efficiently, since switching costs largely depend on the technical and contractual ability to

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<sup>8</sup> In our context, overlay networks are virtual networks located on top of the basic Internet infrastructure enhancing the Internet’s basic functionality. They may increase efficiency by subtle routing algorithms (routing overlay networks [RONs]) or by distributed caching of content leading to increased load balancing (content delivery networks[CDNs]). They can be used to bypass best effort Internet’s inefficiencies, but are also limited in their impact as they still rely on the basic Internet as an infrastructure. For an overview see Clark et al. (2006). Moreover, CDNs are considered complementary to best effort Internet but only partial substitutes for priority schemes (cf. Berger-Koegler and Kruse 2011, p.15).

<sup>9</sup> Traffic management is defined in RFC 3272: “[T]raffic management includes (1) nodal traffic control functions such as traffic conditioning, queue management, scheduling, and (2) other functions that regulate traffic flow through the network or that arbitrate access to network resources between different packets or between different traffic streams” (Awduche et al. 2002).

<sup>10</sup> In our paper, we consider general consumer protection such as information on tariff pricing and quality characteristics as part of technical regulation.

switch operators and on the information about the operator's TM practices in a way understandable for end-users. A market can only unfold its full potential if market participants are able to make informed decisions. Corresponding efforts towards technical regulation must be made to enable workable competition but must be differentiated from regulation of network-specific market power. Insufficient technical regulation may cause both significant switching costs and lock-in effects and thus lend market power to network operators. Still, the adequate response is technical regulation. Likewise, perfect information cannot prevent or discipline network-specific market power.

Following the disaggregated regulatory approach, market power regulation aims at disciplining monopolistic bottlenecks. Monopolistic bottlenecks endow the corresponding firm with network-specific market power, which can neither be disciplined by active nor by potential competition. In contrast to global regulation, only those components in the value chain exhibiting both the characteristic of a natural monopoly in the relevant range of demand and irreversible costs –i.e. monopolistic bottlenecks – form the minimum regulatory basis and are subject to tailor-made market power regulation. The precise localization and periodic revision of the regulatory basis is highly important. A misled regulatory basis leads to massive distortions to competition by false positive or false negative regulatory fallacies<sup>11</sup> and may trigger interventionist chain reactions (cf. Knieps 1997; Knieps and Zenhausern 2013).

Put simply, causes of market inefficiencies must be localized and tackled at their roots. As in the case of monopolistic bottlenecks in local telecommunications infrastructure, proper regulation serves as a substitute for active and potential competition and prevents network operators from transferring market power into downstream service markets. Concerns of undue discrimination by network operators in service markets can thus be widely eliminated as ad hoc discrimination in these markets is not incentive compatible for network operators (cf. Knieps 1997; Blankart et al. 2007).

The 'Regulatory framework for electronic communications in the European Union' was issued in 2002 and revised in 2009 in order to create harmonized community-wide markets for electronic communications.<sup>12</sup> With respect to market power regulation, the framework is widely consistent with the disaggregated regulatory approach. The 'three-criteria test' as the relevant tool to identify firms with dominant positions ('significant market power') in the markets is closely related to the theory of monopolistic bottlenecks.<sup>13</sup> Complementary efforts towards technical and universal service regulation shall ensure transparency and low switching costs. In addition, national regulatory authorities (NRAs) may even impose

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<sup>11</sup> False positive regulatory fallacies occur if the regulatory basis is too wide, i.e. there is over-regulation. In contrast, false negative regulatory fallacies occur if the regulatory basis is too narrow, i.e. there is a lack of regulation.

<sup>12</sup> For a discussion of the 2009 revised framework see Knieps and Zenhausern (2010). For a disaggregated localization of monopolistic bottlenecks and its application in European markets for telecommunications see Blankart et al. (2007) and Knieps and Zenhausern (2010).

<sup>13</sup> Commission Recommendation of 11 February 2003 on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation in accordance with Directive 2002/21/EC of the European Parliament and of the Council on a common regulatory framework for electronic communications networks and services (notified under document number C(2003) 497) (2003/311/EC), OJ, 8.5.2003, L 114/45–49.

minimum quality standards.<sup>14</sup> This especially is considered as a measure of last resort to prevent discriminatory behavior by network operators culminating in what is known as the ‘dirt road’ argumentation.<sup>15</sup> However, within the European market framing, such ad hoc discrimination can only be incentive compatible for network operators if regulation fails to meet its objectives.

Although the cases of Madison River and Comcast<sup>16</sup> often serve as examples of ad hoc discrimination by using adverse TM practiced, it is important to notice that broadband access in the U.S. has been subject to considerable deregulation efforts (cf. Bauer 2005). As an assessment of incentives for ad hoc discrimination by network operators crucially depends on the corresponding market framing, the fundamental differences between the U.S. and European regulatory frameworks must be taken into account. Lessons and experiences from the U.S. cannot easily be transferred to European communications markets. As cases similar to Madison River or Comcast have not been discovered in Europe, there is currently no evidence for negative regulatory fallacies or requirements to implement measures beyond basic regulation to prevent discriminatory behavior. Any further regulatory interventions in service markets must be considered detrimental and superfluous (cf. Knieps and Zenhausern 2008).

#### 4. The BEREC Approach

BEREC note that TM practices are neither good nor bad per se. As TM may potentially increase or decrease welfare, they emphasize the necessity of a consistent reference point for

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<sup>14</sup> E.g.: Directive 2002/19/EC of the European Parliament and of the Council of 7 March 2002 on access to, and interconnection of, electronic communications networks and associated facilities (Access Directive), OJ, 24.4.2002, L 108/7–20, Article 9(1);

Directive 2002/22/EC of the European Parliament and of the Council of 7 March 2002 on universal service and users’ rights relating to electronic communications networks and services (Universal Service Directive), OJ, 24.4.2002, L 108/51–77, Article 22;

Directive 2009/136/EC of the European Parliament and of the Council of 25 November 2009 amending Directive 2002/22/EC on universal service and users’ rights relating to electronic communications networks and services, Directive 2002/58/EC concerning the processing of personal data and the protection of privacy in the electronic communications sector and Regulation (EC) No 2006/2004 on cooperation between national authorities responsible for the enforcement of consumer protection laws, OJ, 18.12.2009, L 337/11-36, Recital 34 and Article 21.

Although universal service debates in the context of broadband Internet are quite prominent and certainly important when it comes to the comprehensive provision of high-speed access to end-users, it is beyond the scope of this paper. Interesting however is Recital 34 of Directive 2009/136/EC stating: “In order to meet quality of service requirements, operators may use procedures to measure and shape traffic on a network link so as to avoid filling the link to capacity or overfilling the link, which would result in network congestion and poor performance.”

<sup>15</sup> Along this line of argumentation, in a scenario of price and quality differentiation (via prioritization), a network operator has incentives to implement ad hoc discrimination in order to maximize his revenues by degrading free best effort traffic quality in such a way that users are forced to choose ‘higher’ traffic classes which cost them positive prices (cf. Knieps 2011a).

<sup>16</sup> *Madison River Case*: a U.S. telecommunications provider that blocked VoIP applications and was fined by the Federal Communications Commission (FCC) in March 2005. *Comcast Case*: a U.S. cable access provider that interfered with BitTorrent-related peer-to-peer data traffic and was sanctioned by the FCC in 2008 (cf. Kahn 2007, p. 3; FCC 2008; Lee and Wu 2009, p. 61).



case-by-case assessment. In order to evaluate the reasonableness of contractual restrictions and TM practices, BEREC (2012c, p.4) has proposed four criteria which can be considered complementary to basic regulation and general competition policy: 1) *Non-discrimination between players*, 2) *End-user control*, 3) *Efficiency and Proportionality* and 4) *Application-agnosticism*. A TM practice must fulfill all four criteria to be considered reasonable.

Criterion 1) shall ensure that network operators do not discriminate between different providers of content or application services on an ad hoc basis. In 2) BEREC highlights that the use of TM practices by network operators should be requested by end-users who should also be able to deactivate it. Criterion 3) is straightforward and implies that TM practices shall be targeted and restricted to specific objectives. Oversized TM interventions may lead to significant distortions. In 4) BEREC's preference for application-agnostic TM practices is highlighted. BEREC defines the underlying concept as follows:

“A function that is application-agnostic is treating all applications similarly (e.g. IP packets from all applications put in the same forwarding queue) while application-specific functions treat individual applications differently (e.g. VoIP is blocked or P2P is throttled while other applications are not)” (BEREC 2012a, p. 29).

Although BEREC's preference for homogeneous treatment of (possibly heterogeneous) applications and contents is expressed, they allow for deviations from a strict interpretation of application-agnosticism:

“Application-specific differentiation involving *preferential treatment* needs to be evaluated based on the effect this may have on the rest of the traffic. [...] Providing access with *application-agnostic traffic classes* (priority levels) needs to be evaluated based on the effect that higher-priority traffic classes may have on lower-priority classes. As in the application-specific category above, decreasing performance over time for lower-level classes may indicate that the existence of higher-level classes effectively constitute a *degradation* of these lower-level traffic classes.” (BEREC 2012a, pp. 49f.).

Further, compliance with application-agnosticism is considered equivalent with the principle of layer separation of the network layer<sup>17</sup> and the application layer.<sup>18</sup> As layer separation has played an important role in the evolution of the Internet's open architecture it is a concept worth being safeguarded by appropriate means.<sup>19</sup> In the context of the status quo Internet, BEREC proposes a layer separation based on the OSI reference model.<sup>20</sup> In order to fulfill the criterion of layer separation TM practices by network operators must be located in the network layer. Whenever TM practices require the integration of network and application layer, these practices violate the criterion.

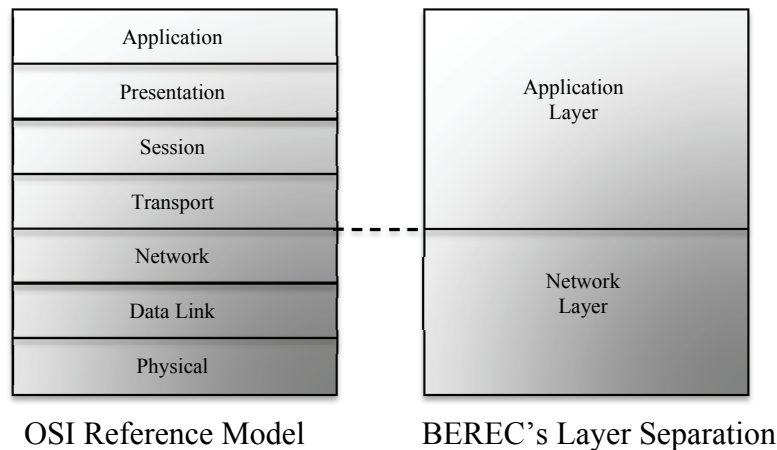
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<sup>17</sup> In our paper, BEREC's network layer is terminologically equivalent to what we later label transport layer.

<sup>18</sup> “This parallels the fact that the decoupling between network and application layers is a characteristic feature of the open Internet” (BEREC 2012c, p. 4).

<sup>19</sup> The Internet once started out as an overlay network on top of the public switched telephone network (PSTN); adding enhanced functionality and using existing infrastructure. In PSTN, traditional telephone calls were circuit-switched and designed to deliver end-to-end service level guarantees. Transport and application layers were integrated and end-to-end services were offered and provided by telephone companies. Nowadays, there is a convergence of network architectures culminating in next generation networks including high-speed fiber-based broadband access technologies. In contrast to circuit-switched voice telephony, within the packet-switched TCP/IP-based Internet, the separation of transport and application layers is desired.

<sup>20</sup> The OSI reference model consists of physical layer (Layer 1), data link layer (Layer 2), network layer (Layer 3), transport layer (Layer 4), session layer (Layer 5), presentation layer (Layer 6) and application layer (Layer 7). While routing of data packets through the network is attributed to the network layer, the transport layer functions include e.g. end-to-end based re-transmission requests and packet-flow management (cf. Valdar 2006, pp. 187f.).

**Figure 1: BEREC's Layer Separation Proposal**

Source: Author; based on Valdar 2006, pp. 187f. and BEREC 2011, p. 16

Figure 1 illustrates their proposal. According to their definition, the network layer consists of OSI layers 1 to 3 while the application layer comprises OSI layers 4-7. Within this framework they classify TM practices in three distinct categories (cf. BEREC 2011, pp. 18ff.). The first category of TM (TM type I) includes techniques implemented by the network operator within the boundaries of its own network/autonomous system.<sup>21</sup> Basically, these interventions are executed in OSI layer 3 or below and are consequently attributed to the network layer. Category 2 (TM type II) embraces TM practices that are typically executed in the end nodes (e.g. TCP congestion control), meaning outside the network operator's genuine competency and responsibility. Here, OSI layer 4 plays an all-important role; by BEREC's definition this is part of the application layer. The last category of TM (TM type III) consists of measures taken by network operators within their networks/autonomous systems executed above OSI layer 3 (e.g. deep packet inspection [DPI]). It is also mentioned that in the provision of different priority levels or traffic classes both TM type I (forwarding) and TM type III (tagging/classification) are involved (cf. BEREC 2012c, pp. 1f.). In this case, the layer separation principle is violated and according TM practices are threatened being labeled unreasonable.

Increasing efficiency by means of congestion management is a major cause to deviate from best effort TCP/IP and to implement TM. In order to assess according TM practices and to evaluate their welfare effects, a thorough understanding of Internet congestion consistent with the applied assessment criteria is necessary. BEREC defines Internet congestion as follows:

“Congestion is the situation met in IP networks when traffic increases to a level where routers run out of buffer space and are forced to start dropping some IP packets. By default, this is done randomly. Congestion in IP networks can occur caused by unpredictable/unavoidable situations or caused by a failure of the ISP to provide sufficient capacity.” (BEREC 2012a, p. 6).

BEREC's interpretation of congestion stems from networking theory and is equivalent to the TCP-based congestion concept. The relevant congestion signal for the well-known 'additive

<sup>21</sup> Examples are techniques à la differentiated services (DiffServ) or multiprotocol label switching (MPLS) that are performed at a set of nodes inside the network or packet-by-packet-based queue management (e.g. weighted fair queueing [WFQ] or random early detection [RED]) (cf. BEREC 2011, p. 18).

increase multiplicative decrease' congestion control policy to take effect is a packet loss (cf. Jacobson 1988, pp. 319ff.).

## 5. A Critical Appraisal from a Network Economic Perspective

As will be shown in this section, a rigorous analysis of the BEREC proposal from a network economic perspective reveals interesting insights. In the course of our critical appraisal, three aspects are emphasized: BEREC's understanding of Internet congestion, the concept of application-agnosticism and the proposed layer separation.

### The Concept of Internet Congestion

Despite its potential downsides, from a social welfare perspective TM is a 'useful' tool to internalize externalities. Externalities in the usage of scarce network resources result from congestion and very much resemble those in traditional transportation networks. Hence, normative insights can be gained from the field of transport economics (cf. Knieps 2011a, p. 28). On these grounds – preliminary to further discussion of the reasonableness of TM – Internet congestion and resulting negative externalities are briefly explicated.

Problems of Internet congestion constitute local phenomena. Hence, congestion problems in the access service networks cannot be reduced by capacity extension 'somewhere' in the backbone where fiber is cheap. As BEREC's interpretation of congestion considers a packet loss as the relevant congestion signal, those situations in which delay and jitter in data transmission occur due to queues building up at the nodes with queue length not exceeding buffer capacity are not considered as congestion. In contrast, a network economic perspective reveals that whenever a marginal increase in data traffic – i.e. one additional data packet traverses a cable or arrives at a link – affects any other data packet in that cable or that link in that it creates externality costs, the cable or link is congested.<sup>22</sup> The negative effects (increase in delay, jitter *and* potentially in packet loss rate) on any other individual are reflected in reduced average traffic quality (cf. Knieps 2011a). Simply put, increased usage of fixed network resources increases scarcity, decreases TCP/IP-based average traffic quality and produces externality costs. As this makes clear, the economic definition of congestion differs fundamentally from the definition provided by networking theory used by BEREC. So, whenever congestion externalities occur, differentiation with respect to traffic quality may serve as a proper means to increase social welfare. The technical interpretation of congestion cannot serve as an adequate basis for grasping the idea of negative externalities and the resultant opportunity costs of network usage. Thus, an adequate assessment on the weal and woe of TM practices should rather be based on an economic understanding of congestion.

### The Concept of Application-Agnosticism

In section 3 we concluded that incentives for ad hoc discrimination crucially depend on the market power situation of the network operators. Any analysis of the weal and woe of TM practices must consider the institutional framing of the relevant markets. Under the current regulatory regime, significant market power is disciplined by tailor-made ex ante market

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<sup>22</sup> "[W]hen an increase in the use of a facility or service which is used by a number of people would impose a cost (not necessarily a monetary cost) on the existing users, that facility is said to be 'congested'" (Pearce 1992 in Bauer *et al.* 2009, p. 11). In our case, a situation of partial rivalry exhibits the following characteristics: consumption of transmission services by one individual does not exclude other individuals from consuming transmission services. Notice that at the physical infrastructure level, there exists direct rivalry between data packets at the link (e.g. as it is the case with first-in-first-out [FIFO] queueing at the routers). As a result, at the complementary data traffic service level there is partial rivalry in consumption which indicates congestion (cf. Kruse 2011, p. 11).

power regulation often comprising unbundling obligations and incentive regulation ensuring that the market power transfer chain is broken; in other words, there is no possibility of transferring upstream market power into complementary downstream service markets. If adequately applied, the combination of basic regulation (market power regulation, technical regulation and universal regulation) and general competition law ensures that competitive forces in service markets prevent network operators from implementing ad hoc discrimination. Hence, additional regulatory interventions are not necessary. On this basis, BEREC's proposed four criteria for the assessment of reasonableness of contractual relations and TM practices are critically appraised. Before turning to the actual concept of application-agnosticism, we briefly discuss criteria 1) to 3).

*Non-Discrimination between players* as expressed by BEREC in criterion 1) is only relevant in an environment where market power exists, i.e. if a false negative regulatory fallacy is in place. As mentioned above, if market power is disciplined at its roots, it cannot be transferred to downstream service markets and ad hoc discrimination is therefore not incentive compatible. The same line of argumentation is applied to criterion 2) with respect to *End-user control*. In a competitive environment, switching enables end-users to choose from a variety of tariff schemes provided by several operators. The tariffs differ in service characteristics and prices so that end-users choose the tariff best suiting their demand. Criterion 3) *Efficiency and Proportionality* is straightforward and implies that TM measures shall be targeted and restricted to specific objectives. Tailor-made TM practices shall minimize distortions.<sup>23</sup>

In criterion 4) *Application-agnosticism*, BEREC's preference for homogeneous treatment of (possibly heterogeneous) applications and contents is expressed. To grasp the meaning of application-agnosticism, briefly consider the example given in section 2. It was shown that in case of rivalry in consumption of scarce network resources between a peer-to-peer file sharing application and a VoIP application, the TCP/IP-based non-discrimination between data packets unfolds discrimination potentials between heterogeneous application services. So, in the context of broadband Internet, a strict interpretation of application-agnosticism as a concept very much related to technical neutrality between data packets (i.e. strict network neutrality) shall not be misunderstood as a fairness criterion. Rather, deviations from strict application-agnosticism and strict neutrality principles may well be desirable.

As a normative reference point for an optimal deviation from strict application-agnosticism, the concept of market-driven network neutrality according to Knieps (2011a) is introduced. In a competitive environment, entrepreneurial search processes for optimal price and quality differentiation strategies lead to an endogenous capacity allocation such that there is no incentive for network operators to discriminate between different application services or content. The approach is based on quality differentiation via prioritization and a complementary price differentiation<sup>24</sup> scheme based on the opportunity costs of capacity usage. However, such a market-driven approach most likely represents an outcome in which strict application-agnosticism is violated. But, as the prioritization decision is at least indirectly<sup>25</sup> made by end-users, the sole task of the network operator is the implementation. In

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<sup>23</sup> If for technological reasons, only coarse-grained and thus suboptimal TM is applicable, deviations from the normative recommendations are to be minimized.

<sup>24</sup> The pricing strategy is based on congestion pricing. A fact further emphasizing the importance of a proper understanding of congestion.

<sup>25</sup> It may be indirect through the purchase of an application service, which at the retail level is 'bundled' by the network operator with a corresponding traffic service. Here, a self-selection mechanism ensures that end-users can reveal their willingness to pay for different application services.

contrast to targeted degradation by some ‘practicable mark’<sup>26</sup> resulting in a network operator-driven discriminatory capacity allocation, a self-selection process ensures a decentralized and endogenous capacity allocation between traffic classes reflecting the heterogeneity in demand for traffic quality. Depending on end-user preferences, heterogeneity of application services within the traffic classes may result.<sup>27</sup> In a competitive environment, such a deviation from application-agnosticism is no need to intervene since it only reflects the outcome of an endogenous, market-driven optimization process determined by an inherent heterogeneity. As a result, it is obvious that deviating from strict application-agnosticism is no reliable signal for unreasonableness per se. Rather, the outcome of an endogenous, market-driven search process deviating from strict application-agnosticism has in any case to be considered optimal since it is the natural outcome reflecting heterogeneity in demand.

BEREC’s preference for strict application-agnosticism turns out to be a fallacy. In broadband Internet, strict application-agnosticism cannot be considered as a major goal of TM since it only curtails search processes within the markets to find superior solutions. It only holds in a homogeneous narrowband best effort context. Prohibition of (a subset of) TM practices by regulatory interventions constitutes a false positive regulatory fallacy (cf. Knieps and Zenhausern 2008). It not only deprives network operators of means to improve efficiency within their networks, it also curtails the possibility to meet end-users’ heterogeneous demands for traffic quality. Instead, from a network economic perspective, a market-driven interpretation of application-agnosticism deviated from the concept of market-driven network neutrality as an abstract concept is desirable.

### **BEREC’s Layer Separation**

BEREC’s delineation proposal for a separation of network and application layer is consistent with a strict interpretation of application-agnosticism. But, as a mere deviation from strict application-agnosticism is no reliable signal for unreasonableness of TM practices per se, the question arises if the proposed layer separation by BEREC is compatible with the network economic concept of a market-driven interpretation of application-agnosticism.

In section 4 it was shown that BEREC’s layer separation proposal sharply differentiates between what they label network layer and application layer. According to their framework, any practice that integrates application and network layer violates the layer separation principle and is threatened to be considered unreasonable. As an example, their delineation concept labels ad hoc discrimination by network operators based on some ‘practicable mark’ (TM type III, e.g. based on DPI) unreasonable. Although this is comprehensible, we have shown that if markets are regulated properly, such behavior is not incentive compatible. As their delineation concept is derived from the rigid concept of strict application-agnosticism and the technical OSI reference model, it lacks a network economic foundation.

The restrictiveness of BEREC’s proposal can be shown in the case of prioritization. According to Knieps (2011a/b) the adequate mechanism to achieve market-driven network neutrality comprises the implementation of adequate price and quality differentiation based on

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<sup>26</sup> Network operators may use information either in the IP/MPLS or transport layer protocol header or in the packet payload as a ‘practicable mark’ in a Pigouvian sense for targeted differentiation.

<sup>27</sup> A ‘natural outcome’ to be expected from this is that end users will have comparable high willingness to pay for (some) application services which are sensitive to traffic quality while application services which are non-sensitive to traffic quality will probably not exhibit high willingness to pay. Hence, end-user preferences endogenously determine differentiation between different application services by assigning them to different traffic classes.

the implementation of the DiffServ<sup>28</sup> architecture. As the underlying TM is based on a combination of TM type I and TM type III it would violate BEREC's layer separation and be labeled unreasonable. This is consistent with a violation of strict application-agnosticism. If a market-driven interpretation of application-agnosticism shall serve a reference point for layer separation, BEREC's delineation cannot hold as it labels desirable differentiation strategies unreasonable.

Although BEREC (2012a, pp. 49ff.) relaxes its argumentation in this case<sup>29</sup>, the framework is not sufficiently consistent. In the context of BEREC's framework, a deviation from strict application-agnosticism and thus a violation of the layer separation principle is necessary in order to exploit efficiency potentials by market-driven, innovative capacity allocation mechanisms. This is neither consistent with BEREC's preference for application-agnosticism nor with their layer separation principle. Exemption rules are required and complex case-by-case assessments may induce undesirable regulatory micro-management.

## 6. An Alternative Framework from a Network Economic Perspective

As demonstrated with respect to BEREC's delineation proposal, layer definitions too wide or too narrow may lead to a distorted delineation hence curtailing the authority and competency of network operators to find adequate allocation mechanisms for its scarce network resources on the basis of a market-driven entrepreneurial search process. Any restrictions of such an entrepreneurial search process prevent network operators from exploiting efficiency potentials. In order to analyze TM practices from a network economic perspective, an alternative delineation between transport and application layer has to be developed. The focus is on the network operators' competency for TM.

According to the maxim of end-to-end communication in the Internet, congestion control and avoidance implemented by TCP constitute passive TM. Algorithms implemented in the intelligent edges determine average traffic quality. According to the Jacobson algorithms, a packet loss along the path signals congestion and induces a resubmit of the lost data window and leads to a multiplicative adjustment of the device's sending rate. But, whenever end-user devices execute TCP congestion control on an end-to-end basis over the Internet, it is in the competency of the involved network operators to interfere with this practice or to accept it. Both, accepting and interfering constitute active TM decisions made by network operators. While accepting means that data packet transmission inside the 'dumb' cores of the networks is executed on a best effort basis, interfering means to override the end-to-end TCP mechanism. By installing intelligence inside its network core, it is in the competency of each network operator involved in the data transmission process to overrule the intelligence situated in the edges/end-user devices. Hence, the network operator can substitute or complement end-to-end TCP flow and congestion control with active TM practices (e.g. DiffServ) available to him. If active TM is implemented, intelligence is shifted into the core of the network making passive TM in the edges obsolete. Depending on demand from the

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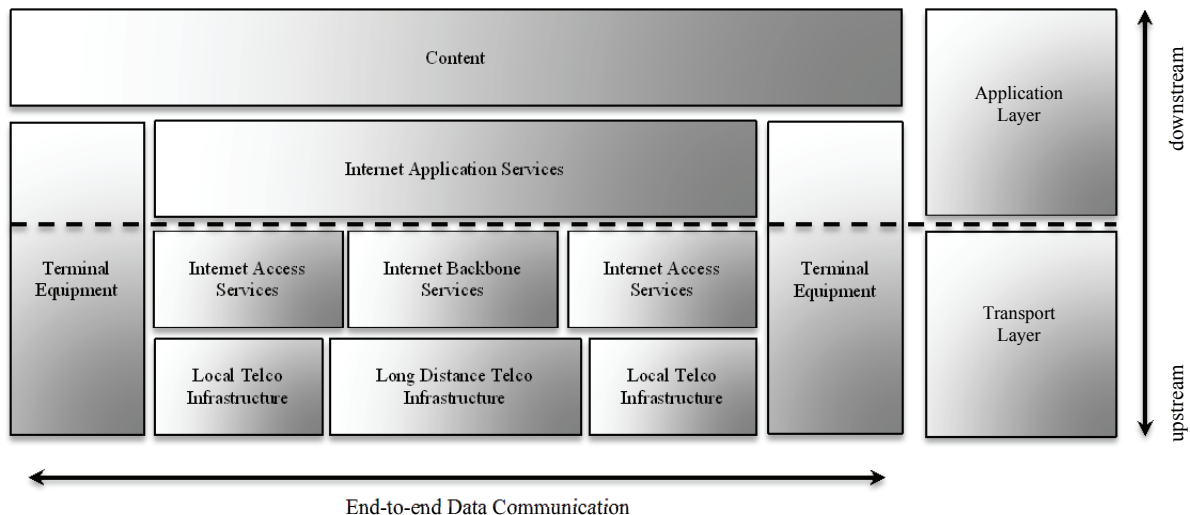
<sup>28</sup> By means of the Differentiated Services (DiffServ) architecture, network operators are able to assign different application services different priorities. In this case, the corresponding data packets are marked, assigned to traffic classes and then forwarded according to preconfigured priorities and drop precedences. In case network operators arbitrarily discriminate on an ad hoc basis, application-agnosticism is violated. Notice however that such behavior is not incentive compatible in a competitive environment but only if the network operator possesses market power.

<sup>29</sup> See section 4, p. 7.

application layer, network operators must be able to adjust the transport layer accordingly. There is a feedback from application layer with an impact on the upstream transport layer. Network operators must be endowed with the competency to react, i.e. to implement adequate traffic quality differentiation by means of active TM. Moreover, incentive compatibility can only be ensured if quality differentiation is supplemented by a complementary pricing scheme. Discriminatory pricing as mentioned in the course of the dirt road debate is neither incentive compatible nor stable since competitive forces discipline any deviations from competitive price structures. As pointed out by Knieps (2011a), endogenous pricing schemes based on the opportunity costs of data transmission prove stable. According price and quality differentiation strategies are both monotonously decreasing in traffic quality and prices and incentive compatible.

As a result, a proper delineation between transport and application layer must reflect the full competency of the network operator. Even the acceptance of end-to-end flow control (passive TM) and thus not to interfere can be considered as ‘active’ decision. The transport layer must include all TM practices feasible for the network operator based on network logistics and data traffic services, i.e. which are in the realm of his autonomous system, including its possibilities to interfere with TCP. Hence, the residual – i.e. the subset of TM practices not included in the transport layer – must be attributed to the application layer. Any TM practices beyond the network operator’s genuine competencies – e.g. in the case of overlay networks via CDNs or RONS or practices – are attributed to the downstream application layer. As a result, a network economic delineation into transport layer and application layer can be described as follows: the aggregate of telecommunications capacities and transmission services (including logistics) constitute the transport layer. Downstream, the application layer consists of Internet application services which are based on upstream traffic services and convey content. The resulting layer separation is illustrated in figure 2.

**Figure 2: Layer Separation in the Public Internet**



Source: Author

While the principle of layer separation is still desirable, the analysis now fundamentally differs from BEREC’s. Within our framework, TM practices type I, II and III are analyzed. Being less restrictive, it is obvious that TM practices considered as legitimate by BEREC are also considered legitimate in our framework. On the one hand, TM type I clearly is consistent with the claim of layer separation since it completely is executed in the realm of the network operator, i.e. within the boundaries of its autonomous system. On the other hand, TM type II,

i.e. TM executed outside the network operator's realm does not raise any concerns with respect to violations of the layer separation principle and market power. Even TM III can be attributed to the transport layer. In a competitive environment, whenever a network operator decides to discriminate, i.e. to adversely affect traffic from specific applications or application providers, end-users will switch to competitors. So the market's intrinsic threat potential towards network operators is sufficient to prevent such anticompetitive behavior.

As a result, layer separation in our framework does not constrain entrepreneurial search processes for innovative solutions to scarcity problems. Rather, our delineation allows these beneficial workings to unfold while still not violating the basic principle of layer separation.

## 7. Conclusion

BEREC's proposed framework requires a network economic foundation. This is evident when it comes to assessing market-driven TM practices.

*First*, BEREC's definition of congestion according to networking theory lacks a network economic foundation. In fact, the economics of congestion are fundamental for grasping the idea of negative externalities and the resultant opportunity costs of network usage. From this, the network operators' incentives to deviate from best effort and to implement an adequate price and quality differentiation strategy based on TM are derived.

*Second*, the market framing in European (sub-)markets for electronic communications is crucially important. The regulatory regime in Europe is based on ex ante regulation of monopolistic bottleneck components; i.e. network-specific market power is disciplined at its roots. Paired with adequate technical regulation, the market power transfer chain is broken. Network-specific market power cannot be transferred into complementary downstream service markets. Hence, competitive forces can unfold and ensure that TM practices enforcing ad hoc discrimination between application services become unstable and are not incentive compatible. There is also no justification for restricting contractual freedom between Internet application providers and network operators (cf. Knieps 2011b, p. 19). In the context of BEREC's framework, a deviation from strict application-agnosticism and thus a violation of the layer separation principle is necessary in order to exploit efficiency potentials by market-driven, innovative capacity allocation mechanisms. A market-driven interpretation of application-agnosticism is crucial. This is not consistent with BEREC's preference for strict application-agnosticism and requires exemption rules or regulatory micro-management in the course of complex case-by-case assessment.

*Third*, from a network economic perspective a slight reorganization, i.e. a modification of the delineation between transport layer (terminologically equivalent to BEREC's network layer) and application layer provides a consistent foundation for a thorough assessment of the reasonableness of TM in compliance with the concept of market-driven application agnosticism. With respect to network operators, the aggregate of telecommunications capacities and traffic services (including logistics) constitutes the transport layer, which covers the network operators' unconstrained competencies to manage traffic within the boundaries of their autonomous systems. Hence, optimal deviations from strict application-agnosticism no longer violate layer separation and are not considered unreasonable. Network operators must be endowed with the competency to implement quality differentiation by means of TM. Moreover, in order to prevent arbitrage between traffic classes in a scenario where pricing is absent, incentive compatibility can only be ensured if quality differentiation



is supplemented by a complementary pricing scheme which reflects the opportunity costs of capacity usage.

In conclusion, the disciplining effect of competition can only unfold if adequate ex ante market power regulation paired with the application of the general competition law and technical regulation is implemented. Hence, criteria 1), 2) and 4) of the BEREC proposal are only relevant in an environment with inadequate market power regulation and insufficient technical regulation. Whenever competition is workable, only the useful properties of TM are exploited. In the context of Mill's example of the sale of poison, it is not incentive compatible to use TM in a poisonous way (i.e. to introduce ad hoc discrimination) – rather TM is poised to be a remedy.

## References

- AWDUCHE, D., CHIU, A., ELWALID, A., WIDJAJA, I. AND XIAO, X. (2002) 'RFC 3272: Overview and Principles of Internet Traffic Engineering', available at: <http://tools.ietf.org/pdf/rfc3272.pdf> [accessed: 08.08.2013].
- BAUER, J. M. (2005) 'Unbundling policy in the United States: Players, Outcomes and Effects' *Communications & Strategies*, 57(1), 59-82.
- BAUER, S., CLARK, D. AND LEHR, W. (2009) 'The Evolution of Internet Congestion', 37<sup>th</sup> *Research Conference on Communication, Information and Internet Policy*, TPRC, Arlington, USA, August 25-27, available at: [http://mitas.csail.mit.edu/papers/Bauer\\_Clark\\_Lehr\\_2009.pdf](http://mitas.csail.mit.edu/papers/Bauer_Clark_Lehr_2009.pdf) [accessed: 05.09.2013].
- BEREC (2011) 'A framework for Quality of Service in the scope of Net Neutrality', *BoR (11) 53*, 8 December 2011.
- BEREC (2012a) 'BEREC Guidelines for Quality of service in the scope of net neutrality', *BoR (12) 131*, 26 November 2012.
- BEREC (2012b) 'Differentiation practices and related competition issues in the scope of net neutrality', *BoR (12) 132*, 26 November 2012.
- BEREC (2012c) 'BEREC response to EC questionnaire on specific aspects of transparency, traffic management and switching in an Open Internet', *BoR (12) 145*, rev. 1, 19 December 2012.
- BERGER-KOEGLER, U. AND KRUSE, J. (2011) 'Net neutrality regulation of the internet?', *International Journal of Management and Network Economics*, 2(1), 3-23.
- BLANKART, C. B., KNIEPS, G. AND ZENHAEUSERN, P. (2007) 'Regulation of New Markets in Telecommunications: Market Dynamics and Shrinking Monopolistic Bottlenecks', *European Business Organization Law Review*, 8(3), 413-428.
- BRISCOE, B. (2009) 'Internet: Fairer is Faster', *BT Whitepaper TR-CXR9-2009-001*, available at: <http://bobbriscoe.net/projects/refb/FairerFasterWP.pdf> [accessed: 05.09.2013].
- CLARK, D.D., LEHR, B., BAUER, S., FARATIN, P., SAMI, R., AND WROCLAWSKI, J. (2006) 'Overlay Networks and the Future of the Internet', *Communications & Strategies*, 63(3), 109-129.
- FARATIN, P., CLARK, D., GILMORE, P., BAUER, S., BERGER, A. AND LEHR, W. (2007) 'Complexity of Internet Interconnections: Technology, Incentives and Implications for Policy', 35<sup>th</sup> *Research Conference on Communication, Information and Internet Policy*, TPRC, Arlington, USA, September 29-30, available at: [http://people.csail.mit.edu/wlehr/Lehr-Papers\\_files/Clark%20Lehr%20Faratin%20Complexity%20Interconnection%20TPRC%202007.pdf](http://people.csail.mit.edu/wlehr/Lehr-Papers_files/Clark%20Lehr%20Faratin%20Complexity%20Interconnection%20TPRC%202007.pdf) [accessed: 05.09.2013].

- FARATIN, P., CLARK, D., GILMORE, P., BAUER, S., BERGER, A. AND LEHR, W. (2008) 'Complexity of Internet Interconnections: Technology, Incentives and Implications for Policy', *Communications & Strategies*, 72 (4), 51-71.
- FEDERAL COMMUNICATIONS COMMISSION (FCC) (2008), In the Matter of Formal Complaint of Free Press and Public Knowledge against Comcast Corporation for Secretly Degrading Peer-to-Peer Applications, File No. EB-08-IH-1518 (FCC 08-183), Memorandum Opinion and Order, Adopted: August 1, 2008
- JACOBSON, V. (1988) 'Congestion Avoidance and Control', *Applications, Technologies, Architectures, and Protocols for Computer Communication - Symposium proceedings on Communications architectures and protocols*, Stanford, USA, August 16-18, New York, USA: ACM, 314-329.
- KAHN, A. E. (2007), 'Network Neutrality', *AEI-Brookings Joint Center Working*, Paper No. RP07-05, Washington.
- KNIEPS, G. (1997) 'Phasing out Sector-Specific Regulation in Competitive Telecommunications', *Kyklos*, 50(3), 325-339.
- KNIEPS, G. (2011a) 'Network neutrality and the Evolution of the Internet', *International Journal of Management und Network Economics*, 2(1), 24-28.
- KNIEPS, G. (2011b) 'Market driven network neutrality and the fallacies of Internet traffic regulation', *International Telecommunications Policy Review*, 2(1), 1-22.
- KNIEPS, G. AND ZENHAEUSERN, P. (2008) 'The fallacies of network neutrality regulation', *Competition and Regulation in Network Industries*, 9(2), 119-134.
- KNIEPS, G. AND ZENHAEUSERN, P. (2010) 'Phasing out sector-specific regulation in European telecommunications', *Journal of Competition Law & Economics*, 6(4), 995-1006.
- KNIEPS, G. AND ZENHAEUSERN, P. (2013) 'Regulatory Fallacies in global Telecommunications: The Case of International Roaming', *International Journal of Economic Policy*, forthcoming.
- KRUSE, J. (2011) 'Net Neutrality: Should Internet neutrality be regulated?', *EFNE - European Forum for Sustainable Development*.
- KUNDRU, V. (2011) 'Federal Cloud Computing Strategy', available at: <http://www.dhs.gov/sites/default/files/publications/digital-strategy/federal-cloud-computing-strategy.pdf> [accessed: 05.09.2013].
- LEE, R. S., AND WU, T. (2009) 'Subsidizing Creativity through Network Design: Zero-Pricing and Net Neutrality', *Journal of Economic Perspectives*, 23(3), 61-76.
- MELL, P. AND GRANCE, T. (2011) 'The NIST Definition of Cloud Computing', *Recommendations of the National Institute of Standards and Technology*, NIST Special Publication 800-145, available at: <http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf> [accessed: 05.09.2013].

MILL, J. S. (1859) *On Liberty*, 2<sup>nd</sup> ed., London: John W. Parker and Son.

OECD (2013) *OECD Broadband Portal* [online], available at: <http://www.oecd.org/sti/broadband/oecdbroadbandportal.htm> [accessed: 05.09.2013].

OFCOM (2012) Infrastructure Report, updated version: 20 December 2012, available at: <http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/infrastructure-report-2012/> [accessed: 05.09.2013].

ORBACH, B. Y. (2012) ‘What Is Regulation?’, *Yale Journal on Regulation Online*, 30(1), 1-10, available at: <http://ssrn.com/abstract=2143385> [accessed: 04.09.2013].

SOLUM, L.B. AND CHUNG, M. (2003) ‘The Layers Principle: Internet Architecture and the Law’, University of San Diego School of Law, *Public Law and Legal Theory Research Paper No. 55*, available at: [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=416263](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=416263) [accessed: 05.09.2013].

VALDAR, A. (2006) *Understanding Telecommunication Networks*, Series 52, London: The Institution of Engineering and Technology.

VOGELSANG, I. (2009) ‘Convergence and Net Neutrality’, in: Krämer, J. und Seifert, S. (eds.) *Communications Regulation in the Age of Digital Convergence – Legal and Economic Perspectives*, Karlsruhe: Universitätsverlag Karlsruhe, 19-27.