Network Federation as a Provider Concept: From Today's Measurement to Tomorrow's Architecture

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I. Introduction

In this contribution we link the lack of service quality to the current concept of *network providers*. We advocate for *Network Federation* [1]–[3] and *Network Selection* [4], [5] as mechanisms to provide service quality, which might serve as new building blocks and operation concepts for future network providers or for transforming today's providers.

To build the case for *Network Federation*, we first outline why today's provider concept fails to provide service quality in the access and across domains, and discuss the need to empower users and applications to select networks on short timeframes to address service quality issues. We highlight the existence of differences between current providers through parallel measurements in three independent Austrian3G mobile networks. Next, we implement *Network Selection* using off-the-shelf components and on-board tools of existing operating systems. Finally, we extrapolate available network selection capabilities into the architecture of the Future Internet by combining *Network Selection* with the paradigm of Network Federation.

II. Today's Provider Paradigm and its Deficiencies

Network providers supply wired or wireless communications services to end users. Typically, providers own or control *all* elements necessary to sell and deliver their services [6]. The facilities and tasks of providers include access lines and radio spectrum, backhaul and core network infrastructure, billing, customer care, marketing, and repair.

Typically, providers are responsive for their service towards the end user in a comprehensible way: Users have contracts to a single provider, and that provider takes care for maintaining the quality of the contracted services. This paradigm is a result of how the technical features and ownership of networks developed: The original technical characteristic of networks used to be providing *connectivity*, and most public communication networks were owned by state-run monopolists until the late the 1980s, governing network design and technologies for decades.

It was only the proliferating Internet usage that started to reveal the deficiencies of the traditional provider concept in the inter-domain case. The Internet is a network of networks, each under different control. Hence, no single provider governs the quality of communications services on the Internet.

Moreover, albeit many current providers apply similar base technologies in the last mile, core networks, and peering, their traffic management concepts might differ. This way, providers can set themselves apart from competitors, but overall, sub-par solutions can emerge [7]. Under certain conditions, users and applications would benefit from temporarily choosing another network to improve service quality. While Network Selection across providers is achievable with current technology, differences in provider service quality can yield ambiguous choices. In the next section, we exemplarily show the differences in performance among three Austrian 3G provider networks.

III. 3G Mobile Network Provider Comparison

The measurement setup comprises a laptop and three identical USB dongle 3G modems, each equipped with a SIM card for one of three independent Austrian mobile operators in 2011. The network quality was measured by the round-trip time to our university's web server using ICMP probes, spaced 0.5 seconds, from each of the interfaces.

The upper part of Figure 1 shows a detail of a time series of a measurement run that concurrently observes the operators. One can observe two main aspects of the latency series: First, the values seem to form descending "lines" over time. We attribute this to the specifics of radio access scheduling in 3G. Second, and even stronger in effect, the latency suddenly decreases or increases, and then remains low (or high). This can be due to the reception conditions and access channel assignments changing.

The bottom part of Figure 1 depicts the empirical cumulative distribution functions for the three time series ($n \approx 2,700$ per graph). We conclude that using operator B yields both adequate latency and little variation, while operator C has similar average latency but at the cost of higher variations. In this measurement run, operator A's latency lags by 50%.

IV. Implementing Network Selection

Given the hardware setup described in the previous section, we develop configurations that leverage multi-homing. One possibility is to route each packet flow (identified by its address-port-protocol quintuple) through a different interface, thus balancing the load while not breaking transport-layer semantics. This is easily accomplished using standard OS tools such as `iptables` on Linux or `bpf` on BSD systems, without any programming effort.

Multi-path is another possible setup: Flows are striped across multiple interfaces to aggregate bandwidth. In this case, a remote inverse (de)multiplexing proxy or specialized protocols such as MPTCP are required. Finally, flows (or packets) can be routed dynamically depending on connectivity,

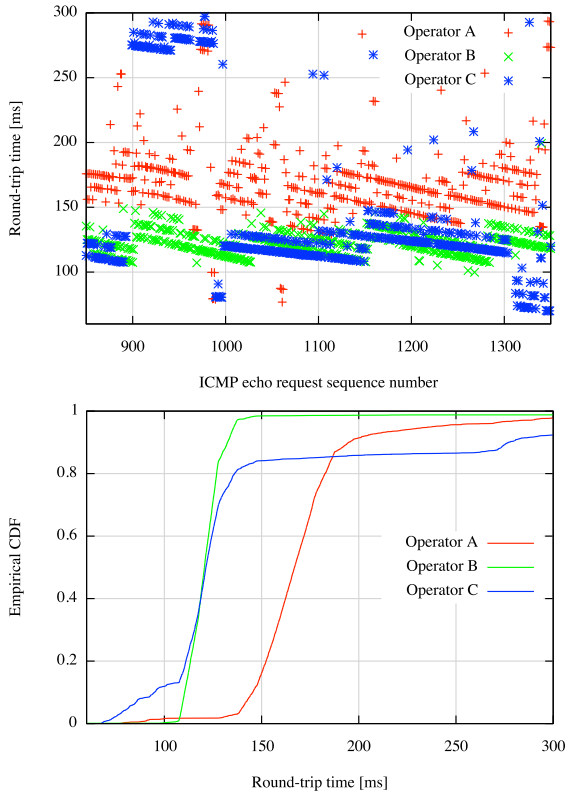

Fig. 1. Parallel 3G latency measurements

latency, available bandwidth, packet loss etc. For this, the link and connection quality must be monitored, and routes and packet filters modified on the fly.

The solutions in this section have been achieve with no or limited programming requirements. They show that Network Selection is easily implemented by today's means. In this way, sophisticated users can already undermine the longterm contracts of today's operators; at the same time, operators might instantly profit from attracting new customers.

V. From Network Selection to Network Federation

The last two sections sketched both the potential and ambiguity of Network Selection. If it were to become a building block in network architectures, where should the function be placed? Conventional wisdom answers with the ISO/OSI model. On application layer, service or content selection techniques exist, e.g., in P2P filesharing networks [8]. On transport layer, protocols like MPTCP and SCTP have similar goals. On network layer, source routing can choose paths for packets through the network. Finally, selecting access technologies on the MAC layer, e.g. between 3G or WLAN, may improve quality [5]. However, the concepts outlined above are limited to acting on information available to their respective network layers, and might disregard cross-layer information such as the trade-off between throughput (transport layer) and power consumption (MAC layer).

To help standardize the way information is exchanged both between layers and between associated networks, consider the concept of *Network Federation* [1], [3]. Network Federation combines willingly cooperating network resources, achieving horizontal convergence of diverse technical and administrative domains [9]. This way, providers can share resources across their domains in a deeper cooperation than *Service Level Agreements (SLAs)* or peering contracts [10].

Network Selection can be combined with Network Federation by placing users and their applications in the most appropriate federation, e.g. by selecting the correct access network in order to provide the appropriate service quality. A future provider can take care of maintaining the service quality in the whole federation or in parts of it. The federation concept enables the provide to (re)define their scope of responsibility, potentially extending or reducing it based on their approach to traffic management. In this way we think that *Network Federation* and *Network Federation* might enable new provider concepts that contribute to generating quality for services in the Future Internet.

VI. Conclusion

We build the case for *Network Federation* as new concept for future network providers. For this, *Network Selection* plays an important role. We show how users can already implement Network Selection using current technology, but also point out its ambiguity. Network Selection might be both disruptive and beneficial for today's providers, especially when combined with Network Federation. With it, providers might place users and their applications in the best federation.

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