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Bailout forward contracts for edge-to-edge internet services ☆

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ABSTRACT

Despite the huge success of the Internet in providing basic communication services, its economic architecture needs to be upgraded so as to provide end-to-end guaranteed or more reliable services to its customers. Currently, a user or an enterprise that needs end-to-end bandwidth guarantees between two arbitrary points in the Internet for a short period of time has no way of expressing its needs. To allow these much needed basic services, we propose a single-domain edge-to-edge (g2g) dynamic capacity contracting mechanism, where a network customer can enter into a bandwidth contract on a g2g path at a future time, at a predetermined price. For practical and economic viability, such forward contracts must involve a bailout option to account for bandwidth becoming unavailable at service delivery time, and must be priced appropriately to enable Internet Service Providers (ISPs) manage *risks* in their contracting and investments. Our design allows ISPs to advertise point-to-point different prices for each of their g2g paths instead of the current point-to-anywhere prices, allowing discovery of better end-to-end paths, temporal flexibility and efficiency of bandwidth usage. We compute the *risk-neutral prices* for these g2g *bailout forward contracts* (BFCs), taking into account correlations between different contracts due to correlated demand patterns and overlapping paths. We apply this multiple g2g BFC framework on network models with Rocketfuel topologies. We evaluate our contracting mechanism in terms of key network performance metrics like fraction of bailouts, revenue earned by the provider, and adaptability to link failures. We also explore the tradeoffs between complexity of pricing and performance benefits of our BFC mechanism.

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1. Introduction

The Internet is a commercial environment embodying multiple service providers competing with each other. Provisioning end-to-end (e2e) quality-of-service (QoS), thus relies on the viability and flexibility of single-domain edge-to-edge (g2g) contracting capabilities. Current single-domain contracts or service level agreements (SLAs) are typically *point-to-anywhere* settlements happening in peer-to-peer or customer-provider ISP relationships. This point-to-anywhere nature of SLAs carry all the way to the end users, and thus the current Internet services are packaged in a typically flat-rate and point-to-anywhere deals without any specific end-to-end performance guarantees, except the access bandwidth guarantees. Though such best-effort point-to-anywhere contracting has the convenience of making the customer not worry about per-destination prices (i.e., different prices for the traffic destined to different locations instead of a single price for all possible destinations), the tradeoffs are (i) lack of e2e QoS and (ii) the lost opportunity for discovering potentially better value flow paths both economically (e.g., cheaper) and technically (e.g., higher capacity).

Another key characteristic missing in the current SLAs is the economic flexibility to manage risks involved in the inter-ISP settlements. For example, the time-scale of SLAs is too long (e.g., months to years) and there is typically no way of bailing out of an SLA if the ISP finds a better deal. Further, SLAs are arranged for immediate service (or in the very near future such as a few days/weeks) and an ISP typically cannot easily close deals for its future investments to reduce risks involved in its investment. It is a pressing need to have such economic instruments for enabling the ISPs to *manage risks* in their investments.

We consider an Internet architecture that allows flexible, finer grained, dynamic contracting over multiple providers. We propose a new family of single-domain contracting mechanisms based on edge-to-edge (g2g) dynamic capacity contracting [2] involving

☆ An initial version of this work appeared in IEEE IWQoS [1]. On top of this conference publication, we have extended the paper with a large amount of work. Our extensions are mainly in Section 7 and include (i) revenue analysis of bailout forward contracts (BFCs) concept, (ii) exploration of simplifying the pricing complexity of BFCs, and (iii) the potential benefit of predictable future demand on the robustness of BFCs.

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forward contracts with bailout options, also called *g2g bailout forward contracts* (BFCs). Our design allows ISPs to advertise point-to-point different prices for each of their g2g paths instead of the current point-to-anywhere prices. Such g2g contracts enable composition of end-to-end higher quality paths given that inter-domain relationships are made over such g2g contracting [3]. Breaking the point-to-anywhere contracts into point-to-point g2g contracts allows more tussle points [4] (between multiple network service providers and content providers) in the system and thus opens the door for discovering better end-to-end paths [5]. This phenomenon is also illustrated in Fig. 1, where end-to-end QoS paths can be composed by concatenating single-domain g2g contracts.

A forward contract for a g2g path, as the name suggests, offers a service on that g2g path which will be delivered at a future time, but at a predetermined price, called the "forward price". We enhance this forward contract with a bailout clause and establish a bailout forward contract (BFC). BFCs allow the provider to bail out from offering the service at a future time, if the available capacity or resources on the g2g path is not sufficient to support the service. Offering such g2g BFCs on all the chosen g2g paths in a domain increases the *spatial tussle* by enabling point-to-point economics rather than the current pure point-to-anywhere approach, and this provides mechanisms for more efficient use of bandwidth. Further, such g2g BFCs create *temporal tussle* points for network management where risks involved in future investments can be tackled better. Taking this to the inter-domain level, multiple g2g BFCs between multiple network service providers will create a platform for higher spatial and temporal flexibility and efficiency for end-to-end bandwidth services.

The forward contracting mechanism introduces a time frame between the time of agreement and the time of actual service delivery. In that sense, a bailout forward contract term can be separated into three stages. The first stage represents the current time (now) where the forward contract advertisements and consequent agreements are made. An important distinction that comes with the forward contracting approach is that there is no payment taking place now within the first stage. The second stage is the time period between the time when the customers lock in the deal and the actual service delivery time. During this period, the provider may bail out of the deal if the conditions arise as long as they

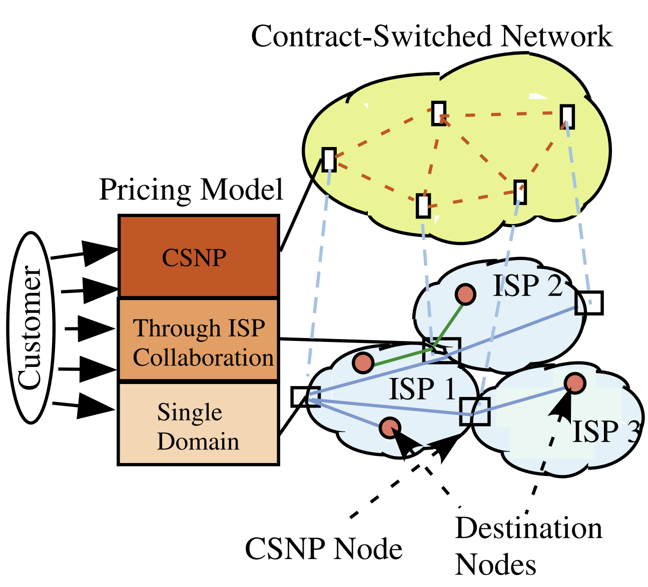

Fig. 1. Major components of an inter-network leveraging edge-to-edge (g2g) contracts. An overlay network provider (called Contract-Switched Network Provider (CSNP)) can concatenate several g2g single-domain contracts to compose an end-to-end path. Distributed end-to-end path composition is also possible with appropriate updates to inter-domain protocols [3].

are specified (and also agreed) with the bailout clause of the forward contract. This bailout mechanism provides a means to exit from the contract when troubles of extra-ordinary network conditions emerge. However, such bailouts, if frequent, will adversely affect the providers' reputation and the customers' demand for BFC in future. Since *the main innovation behind the bailout forward contracting depends on sharing the risk of unpredictable future between customers and providers of Internet services*, the robustness and reliability of such contracts are crucial for building the trust for wide-acceptance of these tools. In this work, we develop mechanisms for the robustness of BFC definitions so as to minimize the frequency of bailouts. Finally, the third stage of the BFC begins when the delivery of the contract initiates. Once the actual delivery of the service starts, the bailout terms become irrelevant and the main contract terms should be honored. If they are not met, then it will be a breach of the contract and a penalty must apply similarly to the case of today's SLA practices. One can attach penalties to the bailout terms as well; however, that is not a typical practice.

It is worth emphasizing that contracting mechanisms studied in this paper are discussed and analyzed mainly from the perspectives of ISPs selling and buying edge-to-edge services to/from each other. Thus in this context, the terms 'provider' and 'customer' both refer to ISPs. Also, an ISP can be a provider on some BFCs and a customer on other BFCs. Analysis of the contracting between end users and their provider ISPs, which is a major topic in itself, is beyond the scope of this work. As argued above, BFCs will allow ISPs better manage their risks individually, as well as enable better sharing of risk among ISPs. It is conceivable however that use of BFCs between ISPs would also lead to more flexible terms of service, and better risk sharing, between end users and ISPs. In particular, use of BFCs may help in the realization of differentiated services for end users, offered at different price points. End users who desire guaranteed services would pay more, and their ISPs would have to ensure that their services are least affected in a bailout scenario (often a result of unexpected congestion). On the other extreme, end users that desire best effort service will pay a low price, but would be the first to be affected in a bailout scenario.

The rest of the paper is organized as follows: We first detail a few motivating scenarios and our contributions in the rest of this section. We, then, discuss architectural considerations and implementation issues for BFCs in Section 2. Next, we cover the related literature in Section 3. In Section 4, we formally define bailout forward contracts (BFCs). Section 5 details our proposed method of composing edge-to-edge prices for multiple BFCs for an ISP domain. In Section 6, we build our experimental setup using Rocketfuel topologies and describe our network performance analysis methodology on the robustness of BFCs under stress and link failures. Later in Section 7, we make an economic performance analysis of BFCs in comparison with two other pricing alternatives with specific focus on the ability to manage risks and derived benefits. We summarize our findings in Section 8.

1.1. Motivating scenarios and use cases

To explain how the BFC mechanism works, we now describe a particular market case involving a local ISP and a regional ISP. Golden Gate Telecommunication (GGT), which is a San Francisco-based local ISP, investigates the feasibility of offering value-added IPTV services to its subscribers (end users) in addition to commodity data services. To offer this service, GGT has to embark a risky investment project and upgrade its connection to its Chicago hub, where most of the IPTV broadcast channels are headquartered. The advertisement and high-speed data connection costs are the two big components of this investment project.

During the same period, West Side Telecom (WST), which is a regional ISP, is exploring and evaluating various options to upgrade

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