Traffic Grooming: Balancing Choice and Service in Optical Networks

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Abstract: We articulate how the traditional optical networking research area of *traffic grooming* may be combined with recent advances in Internet architecture, specifically the proposed *ChoiceNet* Future Internet architecture, to create an agile system capable of reflecting both provider and customer interests on an ongoing basis as network conditions change.

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1. Introduction

Optical transport networks form the foundation of the planetary communication networks, whether voice or data, and this global infrastructure will be crucial to the operation of the Internet and its ability to support critical and reliable communication services indefinitely into the future. The optical transport must support an increasingly larger range of bandwidth needs, over more diverse time scales. Moreover, to allow a diverse and stable ecosystem of network operators and service providers, different niches for collaborating and competing businesses must exist, such that different business entities with different value proposition, business models, risk tolerance etc., can leverage each others offerings to present a rich set of offerings to the customer. The problem of providing an agile, energy-aware, flexible optical network architecture is one of the important problems in optical networking in the coming decade. However, the benefits provided by such a network are often not perceived by the end consumer. As a result, the economics, control signaling, and provisioning timescales, have all remained isolated and disconnected between backbone networks providing bulk bandwidth and commodity networks providing service to consumers.

2. Choice and Service in Optical Networks

2.1. *Traffic Grooming*

The art and science of converging available technologies, electronic and optical, for the access and core, for network-wide benefit, has been known as traffic grooming in the optical networking research literature [1, 2]. This area has generated a good deal of research in the past, largely focusing on optimizing various objectives including the number of wavelengths or OEO conversions, the (per-node or network-wide) power consumption, or elastic spectrum utilization, in keeping with the techno-commercial need of the time. Often, traffic grooming is narrowly defined as the act of multiplexing sub-wavelength flows into wavelength channels. However, the range of literature on grooming shows it to be a broad area, focused on multi-layer approaches to traffic engineering and resource placement/optimization, characterized by explicit representations of constraints and opportunities specific to optical layer technologies. More recent work that falls under the umbrella of grooming includes so-called "Green Grooming" that attempts to consolidate or distribute traffic over the network with an eye to reducing energy expenditure, either at individual points or network-wide. The disparate need for cooling system power required for differing choices that use different tradeoffs for electronic and optical technology provides an example of the input to such considerations.

As optical technology evolves, new devices or techniques bring new opportunities and constraints, and grooming approaches must be revisited to address them, say advances in elastic wavelengths. On the other hand, the need of the users whose data flows constitute the access network traffic that flows through the core also evolve, causing changes in the traffic demand characteristic, that have to be represented in such problems. The growing need for connection mobility is such an emergent change, prompted by (i) the rise in the volume of data representing individual users traffic, and (ii) the high degree of mobility that is becoming the norm for individual users even as they access high-bandwidth channels. The optical network of the future must be agile, and able to react quickly, on an ongoing basis, to changing user demands; it must also continually reconfigure itself and decide what services to offer so that they can be profitably aggregated or engineered in the network.

2.2. *ChoiceNet and Service Marketplace*

An operational framework that allows such dynamically changing demands to be communicated to the network, and service offers corresponding to computed optimal or near-optimal solutions to be offered to customers, is necessary. The ChoiceNet project [3], one of the NSF Future Internet Architecture (http://www.nets-fia.net) projects, provides a possibility for such a framework. The ChoiceNet architecture is based on the premise that exposing service choices explicitly to the end customer, not only for end-host services but also for network services such as different path providers, allowing the customer to make individual financial transactions with each provider individually, will reward reliable and high quality operation, and foster innovation. It proposes new entities in the Internet architecture. The first of these is an "economy plane.. (in contrast to existing architecture, which we refer to as the "use plane") with a common set of interactions that allow providers and customers to advertise choices, and pay for contracted service chosen. Economy plane interactions provide contracts that can be referred to in the use plane, to allow deliver of the service contracted for. Further, ChoiceNet proposes interactions to allow service providers to make verifiability claims, that can be used by specialized "measurement service" providers, who can contract with customers as a third-party to allow customers to know whether each service provider upheld their contract with the customer.

2.3. *Converged Ecosystem*

Figure 1 shows how the interactions provided by ChoiceNet can be utilized to serve as the framework in which dynamic user needs can meet dynamically optimized network service offers, computed by advanced dynamic grooming algorithms, to be presented in the network. The primary entities in this ecosystem are the customer, the provider, and the marketplace. In this view, service re-sellers and bundlers are represented as a combination of customer and provider entities. The customer and the provider are engaged in mutual value exchange; typically, the customer needs service that the provider has the bandwidth and switching infrastructure to produce, and the customer provides some consideration, often cash, that the provider values. The marketplace is an entity that serves as the rendezvous between provider capabilities and customer needs. Our key observation is that at every epoch, a provider can use traffic grooming algorithms to decide the most optimal set of service offerings to list in the marketplace, in light of its remaining network resources (bandwidth, electrical and optical switching capability, buffers).

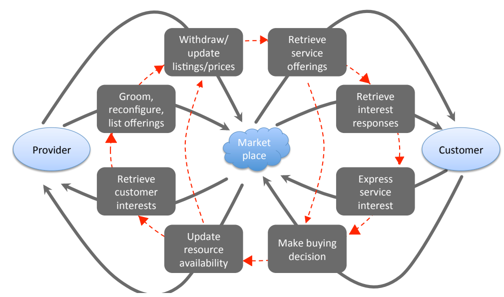

Fig. 1. Interactions in converged ecosystem

The successful demonstrations made by the GENI-Integration Measurement Framework team [4] provides confidence that such an approach, in which dynamically offered network alternatives are dynamically utilized by an end-host program, can be feasible. Though this demonstration pre-dated ChoiceNet, it involved optical layer measurements made at a GENI optical substrate, communicated to a stack protocol running inside a GENI slice, which dynamically exercised path choices as well as optical power choices to stabilize video quality in the face of wavering optical port power at an intermediate node.

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