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Achieving high robustness and performance in QoS-aware route planning for IPTV networks ☆

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A B S T R A C T

Quality of Service (QoS)-aware network planning in internet protocol television (IPTV) networks becomes increasingly important for network operators and Internet Service Providers (ISP) alike as different components of IPTV traffic have different and stringent QoS requirements. Proposing a routing algorithm to meet individual QoS parameters is a tedious task, since providing guarantee of meeting individual parameters in a stochastic system is impossible. Therefore, we propose optimum allocation of bandwidth where bandwidth requirements are evaluated based on accurate empirical effective bandwidth estimation for different classes of traffic by simulating a path as a First-in–First-out (FIFO) queue [2], whereby meeting the individual QoS requirements of each class of traffic. The route planning problem was formulated as a residual bandwidth optimization problem and solved using Genetic Algorithm–Variable Neighborhood Search (GA–VNS) hybrid algorithm. Although the standard evolutionary algorithms do not perform well on constrained optimization problems [4], GA–VNS was found to perform well on this particular problem [9]. This paper proposes new and novel adjustments and parameter settings to best suit the problem in terms of robustness and performance. The use of dynamically switching between two cost functions to meet the above requirements, the reduction of the difficulty of the problem in the initial generations to find a feasible solution and the use of a variation of the original VNS algorithm, besides the use of specific operators and general parameter settings are some of the recommendations of this paper. The proposed recommendations are based on extensive experiments on the performance and analysis carried out on different network topologies including Abilene topology. The proposed algorithm performed better than the recently proposed specialized constrained handling algorithms proposed in the literature, i.e. problem specific solutions are more desirable than black-box optimization for this problem. The proposed route planning mechanism was also found to produce good results even under dynamic traffic conditions.

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1. Introduction

Recent years have seen explosive growth in the number and range of services provided over the Internet, as well as increase in the number of access networks and devices accessing these services. These factors have contributed to a progressively more complex, interconnected networking infrastructure. However, these complexities are not only contributed from the growing communication infrastructure, but also new forms of services for end users. An example of this new service is internet protocol television (IPTV), which is provided as a bundle of three services consisting of video, audio and data (this is usually referred as triple play). The video component of IPTV triple play consists of Video on Demand (VoD) and broadcast TV, the audio component consists of Voice over IP (VoIP), and the data component consists of standard HTTP based applications. Triple play and Internet traffic are routed using uni-cast routing, while broadcast TV traffic is routed using multicast routing [17]. IPTV traffic, in particular VoD constitutes a significant proportion of the network traffic and has very stringent QoS requirements and Quality of Experience (QoE) requirements. In this context, QoS-aware network route planning remains critically important to network operators and ISP, especially when resources must be fairly and efficiently shared by IPTV services and other high resource demand services used by standard Internet users (e.g. peer-to-peer multimedia streaming). There have been many research efforts to address the route planning problem.

Kodialam and Lakshman [15] proposed an integer programming formulation to find two disjoint paths for each demand pair during route planning. One path is used as the primary and the other as secondary. The secondary paths are selected in such a way they share the link capacity when their corresponding primaries do not have any links in common. They showed through experiments that the complete information regarding the allocated paths is not necessary to find a near optimal bandwidth allocation. Riedl and Schupke [20] proposed a routing algorithm that takes into account a concave link metric in addition to an additive one, showing that better utilization can be achieved when both metrics are used to perform the routing. They presented a mixed integer programming model to work on the metrics for small networks and a GA based technique for large networks. Applegate and Cohen [1] proposed a routing model based on Linear Programming (LP). The maximum link utilization was taken as the metric to optimize routing. They further showed that a perfect knowledge of the traffic matrix was not required to perform robust routing under dynamic traffic conditions.

Kodialam et al. [14] proposed an on-line multi-cast routing algorithm which minimizes a cost function. Their heuristic algorithm uses the knowledge of the ingress and egress points which are potential future demands to avoid the use of the loaded links that may be required for future demands. They also presented results that showed reduction in call rejection rate. The solution proposed by Yaiche et al. [23] for optimal bandwidth allocation of elastic demands is based on a game theoretic framework. The Nash equilibrium is used as the bargaining point of the bandwidth requirement. The solution was presented in both centralized and distributed manners. In previous work [11] we proposed a heuristic solution based on a GA to support bandwidth guaranteed routing for clustered topologies. We showed through experiments that the proposed algorithm, which is distributed in the sense that individual clusters are treated in parallel outperformed similar algorithms that do not take cognizance of the clustered nature of the topology.

However, the above problem formulations of the well-known routing problem do not produce optimum desirable route plans always. For example, choosing to minimize maximum link utilization [1] does not guarantee minimal load on each link in the network. We had formulated the said routing problem as maximizing the residual bandwidth of all links in a network in our previous work [9], which we have presented in Section 2. This is a significant multi-modal constrained optimization problem that deterministic heuristic techniques are incapable of addressing. We used GA [8] as a means of addressing the above bandwidth optimization problem in network planning. GA have been proposed for various non-linear optimization problems in communication networks [20,10,3,21], where deterministic optimization techniques such as linear programming are not applicable. However, it is well known that standard GA approaches often do not guarantee converging to feasible solutions in the context of constrained optimization problems [4]. Failure to guarantee convergence is an important limitation, especially in the context of route planning for large networks, where application of these techniques can be computationally expensive. However, the research results have established that hybrid algorithms obtained by combining GA with heuristic techniques improve the performance of GA [13,9]. Hence, we used a novel algorithm (denoted GA–VNS) to maximize the residual bandwidth of links for route planning that is based on augmenting a standard GA approach with the variable neighborhood(VNS) approach proposed by Tasgetiren et al. [18]. In Section 5, we provide details of the above algorithm.

In this paper, we propose a variation of the GA–original VNS algorithm that best suits the residual bandwidth optimization in terms of robustness and performance through examining and analyzing different parameter settings, different cost functions including hybrid functions and variations of the GA–VNS. Since we are at the juncture where substantial effort has been put into the lookout for reduced energy consuming options to make green technology a reality, it is vital to reduce the time taken to execute different applications by improving their performances. The input to our algorithm is a demand matrix for the network that is QoS-aware in the sense that the estimated demand for a given source–destination pair takes cognizance of the effective bandwidth [12] of the traffic expected to flow from that source to that destination. We describe the processes involved in the preparation of the demand matrix and applying the proposed GA–VNS algorithm to solve the said problem in Sections 3 and 4 respectively. We further present extensive performance evaluations carried out to evaluate the performance and robustness on different parameter settings, variations of the above algorithm and other popular