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Robust Resource Allocation in Resilient Overlay Routing Relay Node Networks

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ABSTRACT:

Overlay routing is a very attractive scheme that allows improving certain properties of the routing (such as delay or TCP throughput) without the need to change the standards of the current underlying routing. However, deploying overlay routing requires the placement and maintenance of overlay infrastructure. This gives rise to the following optimization problem: Find a minimal set of overlay nodes such that the required routing properties are satisfied. In this paper, we rigorously study this optimization problem. We show that it is NP-hard and derive a nontrivial approximation algorithm for it, where the approximation ratio depends on specific properties of the problem at hand.

We examine the practical aspects of the scheme by evaluating the gain one can get over several real scenarios. The first one is BGP routing, and we show, using up-to-date data reflecting the current BGP routing policy in the Internet, that a relative small number of less than 100 relay servers is sufficient to enable routing over shortest paths from a single source to all autonomous systems (ASs), reducing the average path length of inflated paths by 40%. We also demonstrate that the scheme is very useful for TCP performance improvement (results in an almost optimal placement of overlay nodes) and for Voice-over-IP (VoIP) applications where a small number of overlay nodes can significantly reduce the maximal peer-to-peer delay.

Index Terms:

Overlay network, resource allocation.

INTRODUCTION:

OVERLAY routing has been proposed in recent years as an effective way to achieve certain routing properties, without going into the long and tedious process of standardization and global deployment of a new routing protocol. For example, in overlay routing was used to improve TCP performance over the Internet, where the main idea is to break the end-to-end feedback loop into smaller loops. This requires that nodes capable of performing TCP Piping would be present along the route at relatively small distances. Other examples for the use of overlay routing are projects like RON and Detour where overlay routing is used to improve reliability. Yet another example is the concept of the "Global-ISP" paradigm introduced in where an overlay node is used to reduce latency in BGP routing. In order to deploy overlay routing over the actual physical infrastructure, one needs to deploy and manage overlay nodes that will have the new extra functionality. This come swith a non negligible cost both in terms of capital and operating costs. Thus, it is important to study the benefit one gets from improving the routing metric against this cost.

Existing System:

Using overlay routing to improve network performance is motivated by many works that studied the inefficiency of varieties of networking architectures and applications. Analyzing a large set of data, Savage et al. [6] explore the question: How "good" is Internet routing from a user's perspective considering round-trip time, packet loss rate, and bandwidth?

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They showed that in 30%–80% of the cases, there is an alternate routing path with better quality compared to the default routing path. In [7] and later in [1], the authors show that TCP performance is strictly affected by the RTT. Thus, breaking a TCP connection into low-latency sub connections improves the overallconnection performance. In [5], [8], and [9], the authors show that in many cases, routing paths in the Internet are inflated, and the actual length (in hops) of routing paths between clients is longer than the minimum hop distance between them

Proposed System:

In the authors study the relay placement problem, in which relay nodes should be placed in an intra domain network. An overlay path, in this case, is a path that consists of twoshortest paths, one from the source to a relay node and the other from the relay node to the destination. The objective function in this work is to find, for each source destination pair, an overlay path that is maximally disjoint from the default shortest path.

This problem is motivated by the request to increase the robustness of the network in case of router failures. In the authors introduce a routing strategy, which replaces the shortest-path routing, that routes traffic to a destination via predetermined intermediate nodes in order to avoid network congestion under high traffic variability.Roy et al.

were the first to actually study the cost associated with the deployment of overlay routing infrastructure. Considering two main cases, resilient routing, and TCP performance, they formulate the intermediate node placement as an optimization problem, where the objective is to place a given number intermediate nodes in order to optimize the overlay routing, and suggested several heuristic algorithms for each application.

Following this line of work, we study this resource allocation problem in this paper as a general framework that is not tied to a specific application, but can be used by any overlay scheme. Moreover, unlike heuristic algorithms, the approximation placement algorithm presented in our work, capturing any overlay scheme, ensures that the deployment cost is bounded within the algorithm approximation ratio.

MODEL AND PROBLEM DEFINITION:

Given a graph describing a network, let be the set of routing paths that is derived from the underlying routing scheme, and let be the set of routing paths that is derived from the overlaying routing scheme (we refer to each path in and in as the underlying and overlaying path sets, respectively). Note that both and can be defined explicitly as a set of paths, or implicitly, e.g., as the set of shortest paths with respect to a weight function over the edges. Given a pair of vertices , , denote by the set of overlay paths between and , namely , and , the endpoints of are and .

Definition 3.2: Given a graph $G = (V, E)$, a set of source–destination pairs $Q = \{(s_1, t_1), (s_2, t_2), \ldots, (s_n, t_n)\}$ (where $Q \subseteq V \times V$), a set of underlay paths P_u, and a set of overlay paths P_o, find a subset of vertices $U \subseteq V$ such that $\forall 1 \leq i \leq n$, U covers (s_i, t_i).

Definition 3.3: Given an instance of the *ORRA* problem, and a nonnegative weight function $W : V \rightarrow \mathbb{R}$ over the vertices, one needs to find a set $U_{opt} \subset V$ such that: 1) U_{opt} is feasible; and 2) the cost of U_{opt} is minimal among all feasible sets.

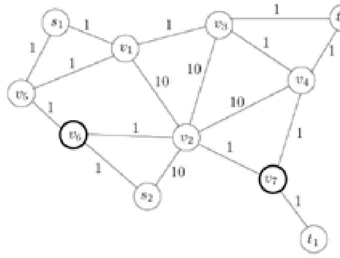

Fig. 1. Overlay routing example: Deploying relay server on v_6 and v_7 enables overlay routing.

Definition 3.4: Given an instance of the *ORRA* problem, a weight function $W : V \rightarrow \mathbb{R}$ over the vertices, and a positive number k, test if there is a feasible solution U such that $W(U) \leq k$.

ON THE COMPLEXITY OF THE ORRA PROBLEM:

In this section, we study the complexity of the ORRA problem. In particular, we show that the -ORRA problem is NP-hard, and it cannot be approximated within a factor of(where is the minimum between the number of pairs and the number of vertices), using an approximation preserving reduction from the Set Cover (SC) problem . We also present an -approximation algorithm where is the number of vertices required to separate each pair with respect to the set of overlay paths (a formal definition will be given later in this section).

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While the reduction and the hardness result hold even for the simple case where all nodes have an equal cost (i.e., the cost associated with a relay node deployment on each node is equal), the approximation algorithm can be applied for an arbitrary weight function, capturing the fact that the cost of deploying a relay node may be different from one node to another.

Theorem 1:

1) The *k-ORRA* problem is NP-hard.
2) The *MIN-ORRA* problem cannot be approximated within a factor of $(1-\epsilon)\cdot\ln(n)$ for any $\epsilon > 0$ unless $NP \subseteq DTIME(n^{\log\log n})$.

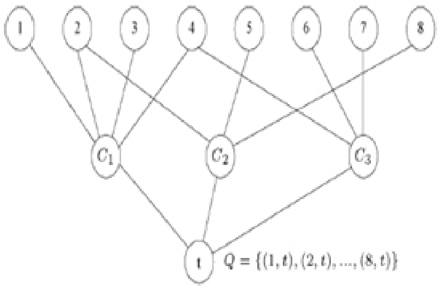

Fig. 2. Example: Set Cover—ORRA reduction.

Theorem 2: (Local Ratio): Given an instance of the *MIN-ORRA* problem and a feasible solution U. Let w_1 and w_2 be weight functions such that $w = w_1 + w_2$. If U is α-approximate with respect to w_1 and w_2, then U is also α-approximate with respect to w.

CASE STUDY AND EXPERIMENTAL RESULTS:

BGP Routing Scheme:

BGP is a policy-based interdomain routing protocol that is used to determine the routing paths between autonomous systems in the Internet. In practice, each AS is an independent business entity, and the BGP routing policy reflects the commercial relationships between connected ASs. customer–provider relationship between ASs means that one AS (the customer) pays another AS (the provider) for Internet connectivity, a peer–peer relationship between ASs means that they have mutual agreement to serve their customers while a sibling–sibling relationship means that they have mutual transit agreement (i.e., serving both their customers and providers). These business relationships betweenASs induce a BGP export policy in which an AS usually does not export its providers and peers routes to other providers and peers . In [21] and [22], the authors showed that this route export policy indicates that routing paths do not contain so called valleys nor steps. In other words, after traversing a provider–customer or a peer–peer link, a path cannot traverse a customer–provider or a peer-peer link This routing policy may cause, among other things, that data packets will not be routed along the shortest path.

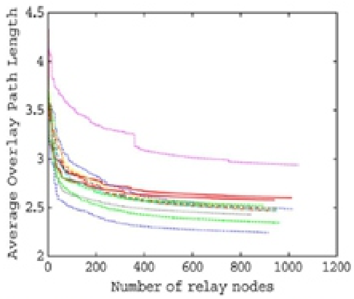

Fig. 5. Average path length versus number of relay nodes, BGP scenario. Each line represents a single BGP source.

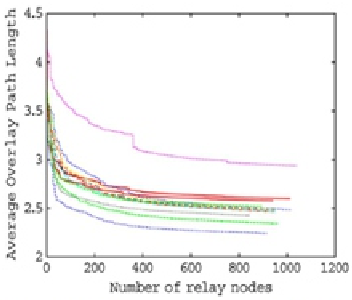

Fig. 5. Average path length versus number of relay nodes, BGP scenario. Each line represents a single BGP source.

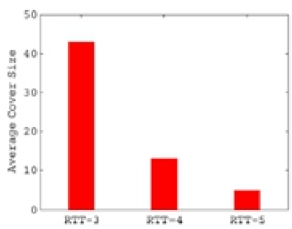

Fig. 8. Algorithm coverage for different RTT values.

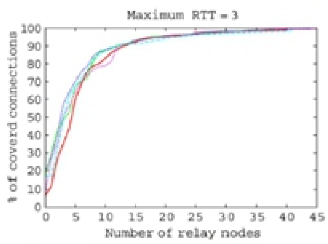

Fig. 9. Covered connections versus number of relay nodes, $RTT_{max} = 3$.

Since the performance of the algorithm is tightly coupled with the size of the Overlay Vertex Cut, increasing the value of the maximum RTT increases the average cut size.

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While the average cut size for is two, indicating that the approximation ratio in the case is bounded by two, it is increased to 2.2.

CONCLUSION:

While using overlay routing to improve network performance was studied in the past by many works both practical and theoretical, very few of them consider the cost associated with the deployment of overlay infrastructure. In this paper, we addressed this fundamental problem developing an approximationalgorithm to the problem. Rather than considering a customized algorithm for a specific application or scenario, we suggested a general framework that fits a large set of overlay applications. Considering three different practical scenarios, we evaluated the performance of the algorithm, showing that in practice the algorithm provides close ptimal results. Many issues are left for further research. One interesting direction is an analytical study of the vertex cut used in the algorithm. It would be interesting to find properties of the underlay and overlay routing that assure a bound on the size of the cut. It would be also interesting to study the performance of our framework for other routing scenarios and to study issues related to actual implementation of the scheme.

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