# From Standalone to Collective Intelligent Route Control


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***Abstract*—In this paper we investigate the main limitations of the existing Intelligent Route Control (IRC) model at the AS-level. Among such limitations we found that all solutions available at present are standalone. As a side-effect, they can only provide one-way route control, i.e., they can intelligently control how traffic flows from an AS but not how it flows into the AS. Furthermore, all available solutions behave in a fully selfish way, that is, they operate without considering the effects of their decisions in the performance of the network. Based on these limitations, we propose to extend the existing IRC model from standalone and selfish to a collective and friendlier IRC model. Our evaluations confirm that when several route controllers compete for the same network resources, the standalone and selfish ones are outperformed by those using a *collective* and *friendlier* approach, and this becomes especially noticeable as the network utilization increases. A key advantage is that our extensions can be installed and used today, by simply performing software upgrades to any of the existing IRC solutions.**



***Keywords-component; Intelligent Route Control, end-to-end performance.***


## I. INTRODUCTION

Recent studies like [1] have shown that Intelligent Route Control (IRC) is a powerful method to improve end-to-end traffic performance. This has leveraged that several manufacturers are actively developing and offering IRC solutions targeting networks at the edge of the Internet [2-4].

Despite these advantages, all the solutions available at present have in common two drawbacks which are key motivations for the work we are developing. First, all solutions are standalone, so no cooperation exists between the ASs sourcing and sinking the traffic (clearly no cooperation exists with the ASs providing transit to the traffic). The consequences of this lack of cooperation are quite coarse route control over the outbound traffic of the ASs, and the inability to intelligently control part of their inbound traffic. Even though some recent proposals keep on trying to address this latter case in a standalone fashion [5], the problem of controlling how traffic flows into an AS, remains largely unsolved [6].

Without cooperation from upstream ASs, the only solutions an AS has in practice to control its inbound traffic are: i) reconfiguration of the BGP advertisements to the rest of the Internet, which it does not always work and is only feasible in rather large timescales [6]; ii) trust the autonomic decisions taken by several distant standalone route controllers.

The second drawback is that all available solutions behave in a fully selfish way. Therefore, it becomes quite unclear to foresee if these route controllers could still perform so well if several of them compete for the same network resources.

## II. TOWARDS COLLECTIVE AND FRIENDLY INTELLIGENT ROUTE CONTROL

Given the abovementioned limitations, we propose to extend the existing standalone and selfish IRC model in two different ways. First, we propose that the route controllers belonging to a pair of multihomed stub ASs that exchange large amounts of traffic become capable of cooperating between each other. This cooperation will allow these ASes to improve the end-to-end performance of the traffic they exchange either in a one-way or a two-way fashion, depending on their specific needs and the way in which the majority of their traffic flows. An appealing advantage is that either of the two ASs can challenge the other to start the cooperation, which can be exploited by an AS so as to intelligently control part of its inbound traffic (something which is unfeasible with the existing IRC solutions). Second, we propose to endow each controller with a friendly route control algorithm, which adaptively restrains its intrinsic selfishness by learning from and evolving together with the network dynamics.

Conversely to a previous work which claims that both the self-interference and the interactions between multiple route controllers introduce only slight performance penalties [7], our work shows that in practice the penalties can be considerable, especially, when the network utilization increases. In that previous work, the performance penalties were evaluated at traffic equilibria. Unfortunately, the existing IRC solutions focus on constantly improving the end-to-end performance of the traffic for a set of popular destination prefixes, but without actually seeking an optimal distribution of traffic or traffic equilibria. In our work the controllers are released from this constraint, which is at least at present, a more practical approach. The next section shows that in such conditions, collective and friendlier controllers supply significant improvements when compared with the current IRC model.


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## III. Performance Evaluation

Our simulation study uses an AS-level topology generated by the BRITE topology generator [8]. The topology was generated using the Waxman model with (α, β) set to (0.15, 0.2), and it is composed of 100 ASs with a ratio of ASs to links of 1:3 [9]. This simulated network aims at representing an Internet core composed by 100 ISPs. All ISPs operate PoPs (Points of Presence) for their customers through which they send and receive traffic. To emulate the multihomed stub ASs where the competing intelligent route controllers are located, we consider a set of twelve additional ASs uniformly distributed across the AS-level topology. These stub ASs are connected to the routers located at the PoPs of three different ISPs. We have considered triple-homed stub ASs because significant performance improvements are not expected from higher degrees of multihoming [10]. In this framework we have contrasted four different simulation scenarios:

(i) Default defined BGP routing, i.e., BGP routers choose their best routes based on the shortest AS-path length.
(ii) BGP combined with the conventional standalone and selfish IRC model at the stub domains.
(iii) BGP combined with a collective IRC model at the stub domains, but without running the friendly algorithm.
(iv) BGP combined with a collective and friendly IRC model at the stub domains.

We performed the simulations for three different load scale factors: i) f = 1 (low load corresponding to 45% of the egress links capacity); ii) f = 1.5 (medium load corresponding to 67.5% of the egress links capacity); and iii) f = 2 (high load corresponding to 90% of the egress links capacity).

The objectives of the simulation study are, first, to demonstrate how the social nature of the extended controllers contributes to reduce the performance penalties associated with frequent traffic relocations. To achieve this goal, we compared the average number of path shifts per second that occurred in the twelve competing stub ASs, for the scenarios (ii), (iii), and (iv). Our second objective is to assess how the different route control models aid to improve the end-to-end traffic performance. To achieve this goal, we assessed both the outbound and the inbound traffic performance. For the outbound traffic, we compared the average OWDs obtained at the twelve competing stub ASs for all scenarios. Due to space limitations we cannot show here the inbound traffic improvements.

The top of Fig.1 illustrates the average frequency of path shifts performed in all the stub AS for the three different load scale factors. Our results reveal that the collective and friendly IRC model drastically reduces the frequency of path shifts compared to both the conventional IRC model and a collective IRC model without exploiting the strengths of the friendly route control algorithm. The bottom of Fig. 1 reveals that the reductions in the penalties have actually no impact on the average end-to-end traffic performance.

## IV. Conclusions

The collective and friendly IRC model not only drastically reduces the performance penalties, but it also supplies slightly better end-to-end traffic performance for all the load scale factors assessed. This suggests that lots of the path shifts performed by the conventional route controllers are actually unnecessary in competing environments.

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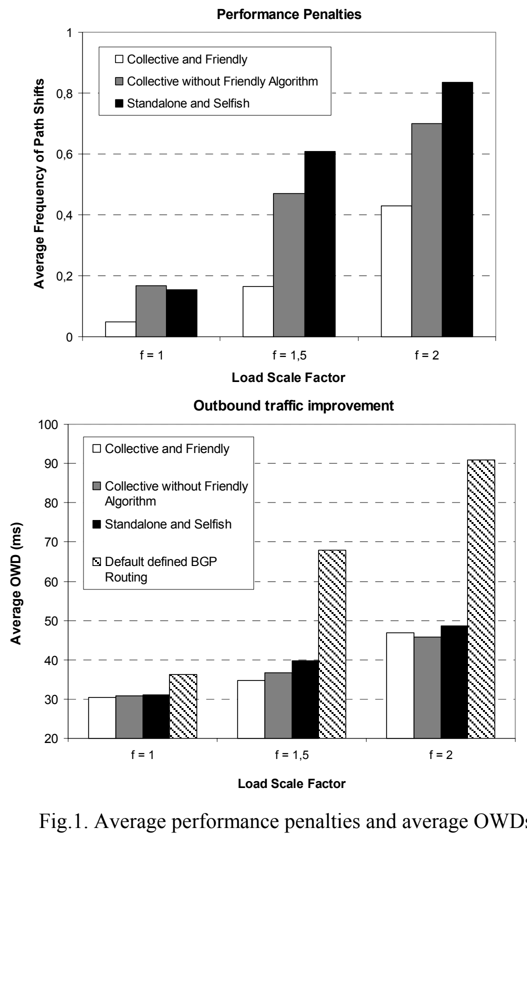


Fig.1. Average performance penalties and average OWDs