ENDEAVOUR: Towards a flexible software-defined network ecosystem

ENDEAVOUR

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Executive Summary

By leveraging SDN technologies at the core of the inter-domain ecosystem, ENDEAVOUR addresses fundamental limitations of the network interconnection model in the current Internet. To engage the Internet stakeholders, ENDEAVOUR targets the rich ecosystem of one of the largest IXPs, DE-CIX, which will be an ideal platform to implement new solutions and provide novel services to overcome the limitations of the present interconnection paradigm.

The ENDEAVOUR consortium organized two workshops to present the goals of the project, and explore the interest of the fundamental stakeholders of the IXP ecosystem, namely IXP *members*, i.e., ISPs, content delivery networks, access providers and IXP *operators*.

The first ENDEAVOUR workshop, "The Next Generation of Interconnection" [4], presented the project to a large audience of medium and small ISPs that are members of the decix IXP and surveyed their interest and expectations. The findings where unexpected and showed the slim understanding of SDN and its potential and thus the need to pursuit further dissemination efforts. This first workshop also revealed that the interest of medium and small sized ISPs on new solutions is accompanied by a limited perceived ability to invest resources to implement them. In particular, IXP members showed special interest in having better information on potential peers, improved traffic monitoring, application specific peering capabilities, and IP prefix hijacking detection.

At the Euro-IX industry meeting, the second ENDEAVOUR workshop addressed the other cornerstone of the IXP ecosystem, namely, the IXP operators. The workshop succeeded in helping the consortium to gain a deeper understanding of the operational challenges and limitations of today's IXP infrastructures. In particular, it showed that while there is interest in a breakthrough of the current interconnection paradigm, the ultimate constraint for operators is that their platform must remain highly available and neutral.

All in all, the two workshops showed that at this point the interest in SDN is not matched by a sufficient understanding of this technology, and hence further dissemination efforts by ENDEAVOUR are necessary. On the other hand, the findings of both workshops exposed the complexity of the Internet and the limitations and intricacies faced by the agents that compose it. To realize the benefits promised by SDN, ENDEAVOUR must develop a comprehensive and in-depth understanding of the particular problems of all relevant agents of the inter-domain ecosystem, especially in how they are affected by the adoption of SDN technology.

Contents

1 Introduction

ENDEAVOUR strives at impacting the Internet at large by improving connectivity at one of its most central elements, Internet eXchange Points (IXPs), with state-of-the-art (and beyond) Software Defined Networking (SDN) technologies.

The current interconnection paradigm is plagued with limitations that hamper Internet connectivity. With increasing demands of quality and performance, inflexibility due to static interconnection contracts [9] and suboptimal routing resulting from a limited topological visibility [14] are increasingly problematic. At the same time, routing nowadays focuses on reachability, with a very myopic view of the data plane [7], constraining the ability of networks to route their traffic in a more effective manner, e.g., by load balancing across multiple peerings. While SDN promises crucial advances to overcome those limitations, SDN benefits so far have been limited to the intradomain level, and just to a few large networks [13] with huge traffic volumes.

With a large number of networks exchanging a great volume of traffic, IXPs have mushroomed over the last decade and became central elements of the Internet interconnectivity fabric [5, 10] that is dynamic and willing to adopt innovative solutions [15, 8, 11]. Introducing SDN at IXPs is hence strategic, as it would benefit a diverse and extensive number of Internet stakeholders, including Internet Service Providers (ISPs) of all sizes, content delivery players, as well as IXP operators.

Introducing SDN at IXPs has a tremendous potential, not only because of the large number of networks and significant traffic volumes that will benefit from it, but also thanks to the fundamental advances that it can bring in terms of network management and applications, directly within the network interconnection fabric. Indeed, SDN potentially helps both network and IXP operators to simplify their management while enabling a whole new set of capabilities. SDN can help operators to make more informed decisions by providing fine-grained data plane analytics, e.g., for Distributed Denial of Service (DDoS) detection and Service-Level Agreement (SLA) monitoring. By making the control plane more dynamic and flexible, SDN enables novel services, such as application-specific peering or fine-grained load balancing.

To maximize the impact of the contributions of this research project, ENDEAVOUR must gain a detailed understanding of the current limitations faced at IXPs, as well as the needs of IXP members and operators. At the same time, ENDEAVOUR will disseminate its results to the IXP community. Because the ultimate goal of ENDEAVOUR is to have an impact on the

Internet community at large, if SDN is to be implemented at the IXPs, the technical contributions of the project must take into account as much as possible the interests and needs of both IXP members and operators.

To gain insights into IXPs operational practices and the interests of IXPs members and operators, ENDEAVOUR conducted two workshops targeting them separately. At the 26^{th} Euro-IX Forum in Marseille (France), ENDEAVOUR met with IXP operators to better understand the challenges they face and how SDN could benefit them. With more than 40 IXPs members, DE-CIX being one of its founding members as well as a partner of ENDEAVOUR, Euro-IX proved to be the right venue to engage with the IXP operator community. Furthermore, ENDEAVOUR organized a workshop in Cologne on the 19^{th} February 2015 to meet IXP members. During this workshop, ENDEAVOUR presented the project and surveyed the interests and expectations of small to medium ISPs.

The information gathered during the two workshops will help ENDEAVOUR to have realistic expectations about the practices as well as interests and concerns of the various stakeholders of the Internet ecosystem regarding SDN and its challenges. This deliverable presents the findings from both workshops and how they can help to shape the technical objectives of the project, as well as their impact on the Internet ecosystem. At the same time, by presenting the project to the community, ENDEAVOUR gained visibility, triggering discussions within the IXP community about the limitations currently faced at IXPs, what the potential avenues for solutions are, the role of SDN in making those solutions a reality, and more generally what the future of network interconnections in the Internet is. This effort will be further continued within WP5.

2 Workshop DE-CIX Customers

During the first workshop [4], ENDEAVOUR met with DE-CIX customers at Cologne on the 19^{th} of February 2015. With more than 600 customers, DE-CIX is one of the largest IXPs worldwide, and hence an ideal player for ENDEAVOUR. During this workshop, the ENDEAVOUR consortium presented the project to a group of ISPs and explored their interest and expectations on how to benefit from the outcomes of the project.

2.1 Audience

DE-CIX members are highly heterogeneous and representative of the diversity of the Internet ecosystem. Out of more than 600 IXP members

at DE-CIX, the audience of the workshop was mostly composed by small and medium sized ISPs and included a number of local access and service providers, enterprise network operators, sales representatives, and even two hardware vendors. As different networks have different interests and capabilities, addressing a variegated subset of the Internet ecosystem is important, as well as useful both to present the ENDEAVOUR project and to obtain feedback about it.

2.2 Agenda

With the main objective of surveying the potential interest of IXP customers in the project, we presented ENDEAVOUR at the Cologne workshop. During this first workshop, we explored the limitations faced by members in the current interconnection paradigm, their understanding of SDN and to what extent they perceive that it can be a breakthrough in the way they interconnect.

Our workshop started by introducing ENDEAVOUR, its funding and its sources, and the participating institutions and objectives. Motivated by the limitations of the current interconnection framework, ENDEAVOUR suggested to the attending networks a whole new set of services and capabilities at the IXP enabled by SDN.

The salient limitations mentioned during the workshop referred to the reduced ability of networks to cherry-pick how traffic is exchanged, and effectively load balance and establish new peering agreements. In turn, the workshop also discussed some of the novelties that could be enabled by ENDEAVOUR: namely, a better interface for an efficient management and monitoring of the peering operations at the IXP, suggestions of potential peers and path selection [12], and whether delegating these capabilities to the IXP would be desirable.

The workshop then collected feedback on how SDN could enhance their existing capabilities, which are their more urging concerns and probed their willingness to make changes to overcome the drawbacks currently faced.

2.3 Results

The workshop demonstrated that the complexity of the Internet ecosystem is a crucial factor to be taken into account. Small and medium sized networks face fundamental constraints that go beyond networking and must be accounted for. While all participants expressed an interest in new services, more flexibility and monitoring capabilities, they were generally risk-averse

and more interested in those solutions that did not imply any investment from their side (both in terms of Operating Expenses (OPEX) and Capital Expenditure (CAPEX)).

The workshop also demonstrated that the general understanding of SDN by small to medium ISPs was very immature. Therefore, by making IXP members reflect on the changes that SDN will bring in the near future, the ENDEAVOUR dissemination effort was a rather positive contribution on its own. Out of the new capabilities that SDN could bring, IXP members showed special interest in better ex ante information on potential peers, better traffic monitoring (for instance to prevent excessively asymmetric traffic exchanges), application-specific peering, and detection of Internet Protocol (IP) prefix hijacking [16, 6] among others [17].

While the advantages of an SDN-enabled IXP are significant, the IXP members approached in this workshop do not handle huge traffic volumes and the complexity of their routing policies is relatively low. Therefore, the contributions of ENDEAVOUR would result in limited individual benefits for this specific set of ISPs. Even though the aggregated benefit that ENDEAVOUR could bring to this whole part of the ecosystem is significant, very scarce manpower and limited individual benefits lessen the interest of small to medium ISPs in improving their connectivity capabilities at the IXP and therefore buying into SDN technology.

One important conclusion of this workshop is that while any improvement is rather welcome, to succeed in improving the current interconnection paradigm for small to medium-sized ISPs, these improvements must be brought without requiring significant investments on their side. This also implies that it is very unlikely that pro-active engagement from these stakeholders will happen during the lifetime of the ENDEAVOUR project.

3 IXP Operators Workshop

The Euro-IX Association [2] was formed to develop and strengthen the IXP community. Declared objectives are to promote open exchange of ideas and experiences, develop common procedures, gather information on regulatory issues affecting IXPs, and develop common procedures.

The Euro-IX Association organizes meetings for its members to contribute and benefit from the community's expertise and experience. The members meet twice a year at the Euro-IX Forums and gather a large and heterogeneous audience. While the Euro-IX meetings take place at different European locations it includes IXPs from all over the world. The 26^{th}

Forum took place in Marseille [1] and we seized this opportunity to present ENDEAVOUR in an interactive plenary talk. The audience we addressed during this meeting is shortly described within the next section.

3.1 Audience

At the 26^{th} Euro-IX Forum, 126 attendees from 68 organizations came together. Dominated by European IXP operators, the audience of this second ENDEAVOUR workshop, was highly complementary to the one of the previous workshop and benefited from the comprehensive scope of the Euro-IX Forum, bringing together IXPs from all over the world, but also IXP members such as Microsoft, Google or Schneider Electrics, and equipment vendors such as Alcatel Lucent or Cisco. The nature of the discussion reflects the heterogeneity of the audience, and while dominated by technical topics, non-technical ones such as regulation, are also within the scope of the forum.

3.2 Agenda

The goal of the workshop was to trigger interest on SDN at IXPs and engaging the audience in a discussion about its potential and their concerns. The workshop presented the ENDEAVOUR goals of addressing and overcoming the current limitations of Internet interconnections (the static nature of Border Gateway Protocol (BGP) peerings, limited topological visibility, reachability centric design, etc.) through an SDN-enabled IXP. Moreover, the workshop discussed the *additional services* that IXPs might be able to deliver thanks to ENDEAVOUR.

ENDEAVOUR presented some of the opportunities that SDN can deliver:

- The evolution of BGP peering, i.e., automated configuration of peerings, extended IXP path selection, or peerings at arbitrary granularities, e.g., application-layer peering.
- A programmable monitoring infrastructure at the IXP, including a simple Application Programming Interface (API) for IXP members that supports flexibility, e.g., multiple time and scope granularities.
- Traffic and port management such as port-redundancy, internal IXP path management, or extended MAC-IP mapping (ARP).

- Improved security, i.e., blackholing, peer blacklisting, or centralization of security services at IXPs.

On top of the aforementioned opportunities, we asked the audience to identify the most relevant IXP specific problems as well as potential use cases and concrete needs for adoption of SDN-enabled IXPs. The next section summarizes the discussion and the collected feedback.

3.3 Results

The audience responded almost unanimously to the need of improving the way BGP peering is done nowadays. A single member of the audience, and coincidentally not an IXP operator (Microsoft), expressed its explicit lack of interest in BGP-related improvements at the IXP, especially in the extensive use of BGP route servers leading to unnecessary duplication of their BGP peerings. This lack of interest is justified by the maturity of this large content delivery network. Differently from other ISPs, its concerns refer to the data plane rather than their already too large interconnection network and its correspondingly too large overhead.

There was a clear interest from the IXP operators to evolve their current infrastructure. Similarly to the case of the IXP members, IXP operators also had reservations regarding the consequences of such evolution on their OPEX and CAPEX. The reservations of IXP operators towards SDN-enabled changes highlighted the need for additional dissemination effort regarding the benefits of this technology.

The response of the audience regarding the programmable monitoring infrastructure was mostly negative. Indeed, IXP operators fear the implications of accessing the data plane with regard to data privacy and regulation. Network neutrality proved to be an important concern, with the IXP operators shying away from any advance in their infrastructure that could raise the issue of neutrality. Proof of the relevance of these concerns was that the Euro-IX Forum had a session specifically dedicated to the regulatory issues surrounding the topic of neutrality. The session showed the lack of awareness of IXP operators regarding the centrality of their role in the Internet, their misalignment with the views of the regulators, and more generally the unripe state of a debate that is likely to shape crucial aspects of the future Internet.

As for BGP, the topics of IXP infrastructure management and security were very positively received by the audience. However, the exact role that SDN should play was generally not well understood, and even more the

issue of the monitoring capabilities that are necessary to better manage and secure the IXP infrastructure. This again highlights that ENDEAVOUR must clearly explain to the IXP community how SDN can help to deal with specific challenges and potential use-cases. These elements are however out of scope of this deliverable, but will be initiated by the specific technical workpackages (WP2, WP3 and WP4) and the corresponding deliverables.

4 Direct Contacts

Going beyond the previously mentioned workshops, ENDEAVOUR also leveraged their contacts and other meetings such as RIPE to bring attention to the project and discuss opportunities and potential collaborations. This section list these contacts and briefly summarizes the discussions.

4.1 Contacts

- Luis M. Contreras, Technology and Planning, Transport, IP and Interconnection Networks, Telefónica (large ISP).
- Giacomo Bernardi, CTO, NGI SpA (medium ISP).
- Laurent Guerby, President of Tetaneutral.net a non-profit Regional ISP based in Toulouse and also board member of TouIX the Toulouse Internet Exchange.

4.2 Results

The discussion with Luis from Telefónica was fruitful and clearly showed that larger ISPs are truly interested in ENDEAVOUR. In particular, a potential integration or combination of the IXP control plane with an SDN network would be highly valued by Telefónica. As a matter of fact, Telefónica is already deploying SDN-enabled network segments within their own infrastructure.

During RIPE70 [3], which took place in Amsterdam in May 2015, we met with Giacomo and had a fertile brainstorming session. NGI operates a medium sized ISP in northern Italy that already utilizes SDN technologies. Given this background they will continue to support ENDEAVOUR by developing use cases with practical relevance in the future.

tetaneutral.net offers hosting services based on an Openstack cluster and Ceph for distributed storage over a 10G network and is also interconnected to the local Internet exchange TouIX, which recently became an SDN-based fabric. The aspects of SDN most valued by tetaneutral.net include the openness and flexibility given by SDN (to otherwise closed network equipment) to implement basic layer 2 control, monitoring, security and other routing features to be deployed in their production network. Additionally tetaneutral.net is also interested in hybrid SDN, which is already partially implemented on their servers Intel 10G network card with Data Plane Development Kit and the SDN switch, with OpenFlow as a unifying API.

5 Outlook

With the two first ENDEAVOUR workshops we seized the opportunity to involve small to medium IXP members as well as IXP operators. Additionally, our direct contacts enriched our perspective by reaching to other Internet stakeholders. This valuable input will be used to align our use cases even further to their needs and thus make them more relevant for practical application in the future. Notably, WP4 benefits directly from the workshops and will feed its outcomes directly into the desired SDN architecture of WP2.

Furthermore, we brought ENDEAVOUR widely to the attention of the IXP community. We arouse awareness of the benefits that SDN has to offer and got feedback on the concerns regarding its implementation. Our experience proves that it is important to keep the community in a close feedback loop to achieve the desired impact. The rather big players have not been in the focus of our dissemination yet, however this remains one goal for the near future.

6 Acronyms

SDN Software Defined Networking

BGP Border Gateway Protocol

ISP Internet Service Provider

IXP Internet eXchange Point

SLA Service-Level Agreement

ISP Internet Service Provider

IP Internet Protocol

DDoS Distributed Denial of Service

API Application Programming Interface

OPEX Operating Expenses

CAPEX Capital Expenditure

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