Robust and scalable software defined networks

Keywords : Computer networks; Routing protocols.

Olivier Bonaventure, Renaud Hartert, David Lebrun, Pierre Schaus, Olivier Tilmans, Stefano Vissicchio

Abstract* – *Software Defined Networking (SDN) is a new paradigm in computer networks where network operators write or compose software tools to manage their network. SDN promotes better manageability by relying on a logically centralized controller that exposes high-level configuration interfaces and network abstractions. We describe our effort in developing SDN based on the Segment Routing architecture and the recently proposed Fibbing approach.

Managing enterprise and service provider networks is a hard task for operators, regularly resulting in outages and often hampering the deployment of new services. Despite their huge (economical and technical) impact, configuration errors causing large-scale outages, unexpected behaviour and sub-optimal performance are common and hard to prevent in current networks, especially ISPs. Indeed, ISP operators have to manage huge, geographically distributed networks and high traffic volumes. To this end, they must configure each of the thousand devices in their networks, using low-level, vendor-dependent and platform-specific languages.

Such configurations fine-tune the behaviour of distributed protocols, hence providing an *indirect control* on the final network behaviour. Even worse, to offer a competitive set of services to their customers, operators have to fine-tune a large number of subtly interacting protocols (from IGP to MPLS, BGP and often RVSP-TE, VPLS, etc.), which makes both configuration correctness and optimality hard to be guaranteed.

For ISPs, Software Defined Networking (SDN) represents a unique opportunity to mitigate all those concerns, by improving both manageability and flexibility. SDN promotes better manageability by relying on a logically centralized controller that exposes high-level configuration interfaces and network abstractions. For example, the centralized controller enables *declarative network management*, according to which the operators can express management objectives (the *what*) rather than the low-level device settings (the *how*). Also, SDN allows operators to easily deploy new services (without the need of yet another distributed protocol), by leveraging the possibility to arbitrarily program devices - a feature often referred to as data-plane programmability.

Unfortunately, naive SDN solutions hardly work for ISPs and their strict robustness and scalability requirements. Beyond being not yet mature, SDN indeed collapses the control-plane into a single logic element, the controller, which therefore tends to be a performance bottleneck and a single point of failure.

ICTEAM researchers are exploring two parallel directions to enable the realisation of Software Defined Networks that are both robust and scalable: Segment Routing [1,3] and Fibbing [7].

Segment Routing (SR) is a modern source routing technique currently being standardized [1,2] by commercial vendors and network operators through the IETF. Segment Routing enables to steer packets through an ordered list of instructions, which can be topological or service-based. These instructions are called *segments*. There are two types of topological segments: *node segments* and *adjacency segments*. The presence of a node segment means that the packet must be forwarded through a specific network node. Conversely, the presence of an adjacency segment means that the packet must be forwarded along a specific link. This type of segment is often local to the node on which the link is connected to. An additional type of segment, the *service segment*, which is local to a node, represents a service to apply to the packet. This type of segment is important in order to support Service Function Chaining. Two dataplanes for Segment Routing are currently being standardized : MPLS and IPv6 [2].

We believe that the IPv6 extension for Segment Routing has the highest potential in the long term since it can be used both on endhosts and on routers. The first open-source implementation of IPv6 Segment Routing in the Linux kernel is developed within ICTEAM [3]. ICTEAM researchers have also worked on the design, optimization algorithms and implementation of a controller for SR networks. The resulting DEFO controller [4,5,6] enables network operators to express their objectives in a high level language and automatically translates those requirements into SR paths to be installed in the network.

The second SDN approach being pursued by ICTEAM researcher consists in centrally controlling the output of distributed protocols. We called this approach Fibbing [7]. Fibbing allows network operators to influences the paths used for specific sources-destinations pairs in a network by injecting carefully chosen information in an underlying link-state routing protocol. Fibbing is both more effective and easier to deploy than Openflow and Segment Routing. Indeed, Fibbing is scalable and robust, since forwarding-entry computation and installation are kept distributed (despite the decisions of the routing paths is centralized). Moreover, Fibbing does not require any modification to the dataplane since it is fully compatible with existing protocols (e.g., OSPF) ; Hence, it can be deployed in existing networks without any hardware change. The paper that proposed Fibbing [8] received the best paper award at SIGCOMM, the most prestigious networking conference.

References

[1] C. Filsfils et al. Segment Routing Architecture. Internet draft, draft-ietf-spring-segment-routing-07, work in progress, Dec. 2015.

[2] S. Previdi et al. IPv6 Segment Routing Header (SRH). Internet draft, draft-ietf-6man-segment-routing-header-00, work in progress, June 2016.

[3] D. Lebrun, Implementation of IPv6 Segment Routing in the Linux kernel, http://www.segment-routing.org

[4] R. Hartert, S. Vissicchio, P. Schaus, O. Bonaventure, C. Filsfils, T. Telkamp, P. Francois. A Declarative and Expressive Approach to Control Forwarding Paths in Carrier-Grade Networks. In Proc. SIGCOMM, 2015.

[5] R. Hartert, P. Schaus, S. Vissicchio, and O. Bonaventure. Solving Segment Routing Problems with Hybrid Constraint Programming Techniques, CP 2015, Cork, 2015.

[6] R . Hartert, Declarative and Expressive Forwarding Optimizer, http://sites.uclouvain.be/defo/

[7] S. Vissicchio, O. Tilmans, L. Vanbever, and J. Rexford., Fibbing, http://www.fibbing.net

[8] S. Vissicchio, O. Tilmans, L. Vanbever, and J. Rexford. Central Control over Distributed Routing. In Proc. SIGCOMM, 2015. **Best paper award**.

[9] F. Aubry, D. Lebrun, S. Vissicchio, K. M. Thanh, Y. Deville, O. Bonaventure, SCMon: Leveraging Segment Routing to Improve Network, Prof. INFOCOM'16, April 2016.