On the creation of Network Planes

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Abstract

The IST project AGAVE aims to develop a simple and scalable approach for effective Quality of Service (QoS) deployment in IP networks. The key element of the AGAVE proposal is the Network Plane (NP), which must be designed to be an effective way to transport, within a given domain, traffic from services with common connectivity provisioning requirements. Moreover, it will be possible to engineer different Network Planes over the same physical network topology by means of Differentiated Services (DiffServ), Differentiated Routing (DiffRout) or a combination of both. End-to-end QoS will be achieved by means of the interconnection of NPs belonging to different domains, thus creating parallel networks called Parallel Internets (PIs). This paper will introduce these novel concepts and four different strategies to realise both Network Planes and Parallel Internets.

Introduction

The AGAVE project, which stands for “A liGhtweight Approach for Viable End-to-end IP-based QoS Services” and began on December 2005 and will conclude on May 2008, has the main objective of developing a simple and scalable solution to deploy effectively and in a lightweight way end-to-end QoS in IP networks in order to support added-value IP-based services. The key element of this proposal is the “lightweight” aspect, as it means that the solutions to be proposed need to be efficient, simple, scalable and it will be possible to deploy them gradually across IP networks, with small incremental additions to the existing best-effort Internet.

Consequently AGAVE proposals (Network Planes and Parallel Internets) are based both on differentiated forwarding (DiffServ) and on the principles of Differentiated Routing (DiffRout), which can introduce load balancing and resilience capabilities, without requiring a universal deployment.

AGAVE considers a framework where there is a clear separation between the roles of Service Providers (SPs) and IP Network Provider (INP), aiming to support a multi-provider environment where network infrastructure and the services provided over it are not managed by a single provider. Thus, it is facilitated a vertical cooperation of SPs with INPs intra-domain (introducing Vertical Traffic Engineering) and horizontal cooperation between INPs and between SPs for inter-domain service provisioning.

Therefore, another goal of AGAVE will be the specification of an open connectivity service provisioning interface to allow SPs to interact with underlying INPs regarding network resources provisioning in order to provide added-value services across IP based networks.

The remaining of this paper is structured as follows: first both Network Planes and Parallel Internet definitions will be introduced. Then general strategies to implement and realize Network Planes and Parallel Internets will be described, followed by the description of four proposed mechanisms to achieve tasks and finally the conclusions and future work will be presented.

Network Planes and Parallel Internets

Network Planes are set up to transport traffic, inside a given single domain, from services with common connectivity provisioning requirements.

In order to achieve effective service differentiation, Network Planes are engineered by INPs over the same physical network topology, differing mainly in the differentiated forwarding and diverse path selections.

As such, Network Planes are logical partitions of a single network domain, each of which may have dedicated resources allocation, such as network elements (nodes and links), available bandwidth, routing/forwarding tables etc. Physical resources assigned to them may either be shared, soft or hard reserved.

In this way, the different network resource provisioning paradigms that support end-to-end QoS differentiation and Traffic Engineering (TE) in a single domain can be used.

That is, Network Planes are the basic tool for managing the resources from an intra-domain perspective, and hence are internally implemented by the INP to support external QoS-aware services from SPs or final users.

Network Planes are primarily designed in a proactive way; that is, with clear and concise provisioning targets in mind, being the reactive behaviour against potential problems, such as congestion ones, the result of their autonomous operation.

Traffic flows are assigned to Network Planes by means of classification mechanisms in the domain ingress nodes.

The concept of Parallel Internets is also introduced by AGAVE as an innovative way to enable end-to-end service differentiation in terms of network QoS, resilience and availability. Specifically, Parallel Internets are coexisting parallel networks, composed of interconnected Per-Domain Network Planes.

Parallel Internets are constructed from the perspectives of each INP, by configuring for each Network Plane different inter-domain routes to certain destinations, based on local criteria. In addition, within a domain, the different Network Planes themselves, in general, use different intra-domain routes. For each Network Plane, traffic may exit the INP domain through a different AS Border Router (ASBR), or through different portions of the same inter-domain link e.g. based on DiffServ capabilities. The result of traffic classification at ingress domain nodes is that flows assigned to different Network Planes may be delivered through dedicated intra- and inter-domain routes.

In this way, INPs would be able to support different levels of availability, resilience and QoS to remote destinations by using the inter-domain routes more appropriate to the service connectivity requirements of the supported NP.

Network Plane creation and realisation

AGAVE is currently studying a wide range of techniques to achieve Network Planes and Parallel Internets realisation, defining the under-laying mechanisms that will allow the existence of Network Planes and their interconnection to produce Parallel Internets.

Network Planes can be created by means of different mechanisms. Hitherto, two main strategies have been identified to achieve the required end-to-end QoS differentiation: DiffServ and DiffRout, meaning that NPs can be realised using each one of them individually, or a combination of both.

DiffServ [1][2][3][4] has been identified as one of the strategies to be used to provide service differentiation through differentiated forwarding mechanisms (Per Hop Behaviours - PHBs) and PDBs.

In addition to this type of service differentiation based in packet forwarding, Differentiated Routing (DiffRout) is also under consideration as a complementary paradigm to realise Network Planes. An example is to route traffic with different QoS requirements through distinct paths that are able to satisfy their own demands. From the viewpoint of INPs, this type of routing differentiation not only supports heterogeneous QoS requirements, but it is also a useful tool for resource optimization purposes such as load balancing, meaning that traffic flows may follow different paths to reach the same destination.

The basic idea of this approach is that traffic belonging to different Network Planes is delivered through distinct paths such that individual QoS requirements can be satisfied. In effect, DiffRout can be regarded as a set of diverse routing mechanisms (e.g., IP routing, MPLS explicit routing, overlay routing, etc.), each of which can be used for realising specific Network Planes for individual QoS requirements.

As mechanisms such as DiffServ and Multi-topology routing protocols are not deployed ubiquitously in the Internet, Network Plane realisation should be flexible enough to accommodate various scenarios. On the other hand, INPs may also adopt a more sophisticated strategy of realising Network Planes with more than one mechanism.

Strategies for NP and PIs realisation

As DiffServ mechanisms are well known, most effort is being carried on in the field of DiffRout and NPs interconnections. Two different approaches to Network Plane realisation (MRDV and Multitopology Routing) by means of intra-domain DiffRouting and two strategies to bind Network Planes to build Parallel Internets (q-BGP and Virtual Peerings) will be introduced.

MRDV

Multipath Routing with Dynamic Variance (MRDV) [5][6] algorithm has been proposed as an improvement to current IGP protocols, introducing the possibility of using multiple paths to carry on the traffic while maintaining the simplicity and the compatibility with the traditional IP protocols. Although the main concepts could be valid for any IP routing protocol, the proposal assumes that routers use a link-state routing algorithm in order to know all the possible paths between any two nodes and the associated bottleneck-based costs.

MRDV combines multipath routing with variance and distributed dynamic routing protocols, in order to get the advantages of both techniques without their inconveniences. This algorithm uses a variable number of alternative paths towards a destination depending on the link loads. Meaning that, as the traffic load increases, the number of paths used to carry it will increase consequently, following the expressions introduced in [5] and [6]. Thus traffic will be distributed among several paths, reducing congestion and leading to a better use of network resources. Additionally, this mechanism is decentralized as routers directly measure load in links, being compatible with current IP intra-domain routing algorithms, and allowing a scalable and gradual deployment.

Nevertheless, this distribution does not take into account the different QoS requirements of the different types of traffic. Thus, to implement NPs, a modification in MRDV algorithm [7] is currently under development so that the variance parameter is not common for all types of traffic, but instead, there is a variance parameter for each traffic class and each output interface. These parameters are adjusted in a dynamic way, according to the average load that the router detects in the next hop of the optimal path towards a destination, so that the most loaded links are unloaded automatically. Thus, each traffic class considers its load and the load of the traffic classes that have higher priority to calculate their variance parameter. Therefore, under high local load conditions, lower priority classes would have a higher variance parameter and their traffic would be routed among more paths. This way, higher priority classes would have more bandwidth in paths with lower cost, and higher cost paths would be left for lower priority classes.

Every MRDV-enabled router monitors its adjacent links loads and supplies the algorithm with these data, modifying the variance of those interfaces according to their load. Therefore, traffic will be distributed properly even when not all the interfaces are overloaded. In this case, only these overloaded links overflow traffic to other interfaces.

Multitopology Routing

Another approach considered in the AGAVE project for implementing Network Planes is to apply multi-topology aware IP routing. Existing intra-domain multi-topology IP routing protocols include Multi-topology OSPF (MT-OSPF) [8] and Multi-topology IS-IS [9]. In order to provide the original IGP protocols with additional ability of viewing the physical network into multiple logical IP topologies independently, each network link is associated with multiple link weights, each identified by a specific Multi-topology Identifier (MT-ID). The design of these protocol extensions is originally for the purpose of routing different types of traffic such as unicast/multicast and IPv4/IPv6 traffic with dedicated intra-domain paths.

In the AGAVE project, multi-topology IGP is adopted for supporting routing differentiation across multiple Network Planes. The basic idea is to configure specific routing logic, i.e., dedicated IGP link weights to enforce specific routing decisions within each Network Plane. In order to achieve specific service differentiation and Traffic Engineering purposes, the link weights within each routing topology is carefully optimised. Figure 1 shows a simple example of Network Plane implementation with multi-topology IGP based routing for supporting end-to-end delay differentiation across Network Planes, and also for Traffic Engineering purposes such as load balancing.

First of all, traffic from the source S to the destination D can be delivered through dedicated Network Planes, so that individual flows using different Network Planes have different delay bounds in terms of hop counts. Another benefit of applying multi-topology IP routing is load balancing, as the traffic from the source to the destination can be split strategically, either online or offline, into multiple IGP paths by assigning individual flows to different routing topologies. It is worth mentioning that the mapping between IGP routing topologies and Network Planes is flexible. A typical scenario is that the INP may have the option to use multiple IGP topologies within one single Network Plane, e.g., for Traffic Engineering and resilience purposes.

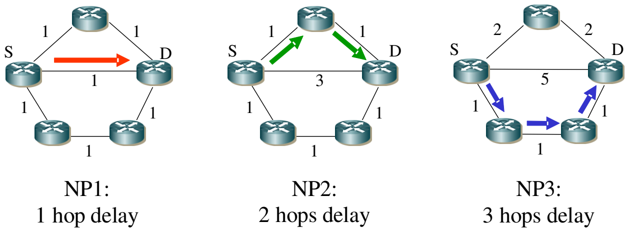

Figure 1. A simple example of Network Plane implementation with multi-topology IGPs

Q-BGP

QoS-Inferred BGP (q-BGP) is the enhanced version of BGP proposed to support QoS requirements for allowing the deployment of QoS-based services. The QoS-related information and their characteristics that are required to exchange between domains can occur either at the service plane during the interconnection agreement negotiation phase or at the routing level using q-BGP. In the first option, an identifier agreed at the interconnection agreement negotiation phase specifying a Network Plane is exchanged via q-BGP messages. QoS performance metrics and their target values are negotiated and agreed in the interconnection agreement; they are not exchanged in the routing level by q-BGP. In the second option, the Network Plane identifier and the QoS performance metrics target values are exchanged by q-BGP. Here, the QoS performance metrics to be exchanged are agreed during the interconnection agreement negotiation phase.

Therefore, q-BGP provides a number of features. We introduced a new optional attribute called QoS_NLRI described in [10] to implement the following features:

1. QoS service capabilities: since peering entities need to know about each other's QoS service capabilities, q-BGP allows negotiating the capabilities that a peer domain provides, and indicates what information can potentially be carried by the q-BGP messages.
2. QoS Class identifier: it is used to distinguish the Network Planes that can be used by/from service peers.
3. QoS performance characteristics: these are a set of QoS characteristics values, such as one-way packet loss and delay and inter-packet delay variation. q-BGP supports a set of QoS performance characteristics to be sent in one single q-BGP UPDATE message.

q-BGP can carry QoS performance characteristics that could be advantageously taken into account by the q-BGP route selection process to select an optimal path. This would enable to tune the route selection process in order to select routes according to more sophisticated routing policies (e.g., route with highest available rate and lower delay). The QoS information inserted in q-BGP messages could be of different nature. It could be (1) administratively enforced. In that case it would not change too frequently. Or, it could be (2) much more dynamic (result of an active measurement for instance). In that case the frequency of changes could be much higher.

Administrative setting of QoS values could be achieved either statically (i.e., long term validity) or periodically (i.e., mid term validity). If these values are set statically, the behaviour of q-BGP will be static and the route selection process will choose the same route. The QoS-related information does not bring major added value to the final behaviour of the route decision-making process and freezes the state of the inter-domain routing. Nevertheless, in case of periodically or dynamically changing QoS performance characteristics values, providers will deploy mechanisms that monitor the Network Plane and then guide the setting of these values. q-BGP will be provided with accurate information in order to select the optimal path. The frequency between two q-BGP router configuration operations in an administrative scheme should not be too small and could be very small in the dynamic scheme. In case of dynamic setting scheme, the risk is to impact routing table stability and probably introduce oscillation phenomena.

In order to interconnect the domains of two adjacent providers, two alternatives are valid for the activation of q-BGP so as to extend the Network Planes beyond the boundaries of a single provider: the first alternative consists of configuring several q-BGP sessions, each dedicated to a given Network Plane. And the second alternative consists in activating a single q-BGP session that will multiplex reachability information of all involved Network Planes.

Virtual Peering

A common method used by ASes to engineer the flow of their inter-domain traffic is to establish peering relations with other ASes [11]. Until recently, those peering relations were established either through direct private links between the two ASes or over an interconnection point. An eBGP session was used over the peering link to advertise the prefixes that are reachable via each AS. In addition to this, BGP peering is established manually by changing the routers configurations on both ends by hand. However, manual operations are error-prone and slow. In addition, the time of establishment of a new peering is often on the order of magnitude of several days or weeks.

In the framework of the AGAVE project, we consider the extension of such peering mechanisms to non-adjacent ASes, through the utilization of Virtual Peering. A *Virtual Peering* is a peering built on dynamically established uni-directional IP tunnels between two cooperating, but non-adjacent, ASes. These IP tunnels are used by the source AS to send packets to the destination AS via chosen ingress routers in the destination AS. The only requirement to be able to deploy such IP tunnels is that the remote ingress routers IP addresses be routable separately. Today, an increasing number of ASes already establish peering relations with non-adjacent ASes by relying on L2VPNs (see [12], for instance). Emulating such point-to-point links using tunnels is currently investigated by the IETF in the PWE3 working group [13].

In AGAVE, we investigate the utilization of Virtual Peering as a means to better engineer the inter-domain traffic of ASes. We envision several applications of Virtual Peering. A first example would be to use Virtual Peering to balance the load of traffic received by an AS over its access links. Another example would be to forward traffic towards a remote destination along a path which has a better quality than the default BGP-learned routes. A typical use case would be to engineer a lower latency path between two SIP proxies. Using Virtual Peering in this way would allow the provision of *better than best-effort services* without the need for end-to-end signaling and reservation as proposed with MPLS/RSVP-TE solutions.

The advantage of using IP tunnels for inter-domain traffic engineering is a twofold one. First, IP tunnels allow the leverage of Internet path diversity. With BGP, only a small subset of the available paths is learned by the ASes, due not only to the routing policies enforced by the intermediate ASes but also to the BGP protocol itself. Indeed, BGP routers currently only allow a single best route to be propagated to their neighbors. Second, the cooperation of intermediate ASes is not required to deploy IP tunnels. The forwarding decisions are taken by the cooperating ASes at the endpoints of the tunnel only. For this reason, IP tunnels can readily be deployed without the need for the whole Internet infrastructure to be updated.

Though Virtual Peering does not allow the provision of strict QoS guarantees, they make possible the provision of better than best-effort services. Virtual Peering is a more lightweight approach than solutions relying on end-to-end signaling such as MPLS/RSVP-TE mechanisms. They do not need the cooperation of intermediate transit ASes and most of the technologies underlying Virtual Peering are readily available. For this reason, their deployment could be faster than the provision of strict end-to-end QoS and it could be envisioned in only a few years.

Conclusions and Future work

In this paper we have presented a few strategies to realise and interconnect Network Planes. These mechanisms, which are currently under study in the IST project AGAVE, will provide an effective way to achieve service differentiation and satisfy the end-to-end QoS requirements of both Service Providers and final users.

Network Planes can be built by means of DiffServ DiffRout, or a combination of both. Given that DiffServ has been studied thoroughly during last years, AGAVE efforts lay on DiffRout, which provides service differentiation employing routing mechanisms and Traffic Engineering techniques. Namely, we have presented MRDV and Multitopology Routing as strategies to build Network Planes and q-BGP and Virtual Peering as means to interconnect them.

During the following months, AGAVE project will concentrate on further developing the presented strategies and in the identification of other alternatives.

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References

1. Blake, S., et al, “An Architecture for Differentiated Services”, December 1998. Internet RFC 2475.
2. Heinanen, J., F. Baker, W. Weiss, J. Wroclawski, “Assured Forwarding PHB Group”, June 1999. Internet RFC 2597.
3. Davie, B., et al, “An Expedited Forwarding PHB (Per-Hop Behavior)”, March 2002. Internet RFC 3246.
4. Nichols, K., and B. Carpenter, “Diffserv per Domain Behaviors”, April 2001. Internet RFC 3086.
5. Ramón-Salguero, F.J., J. Enríquez-Gabeiras, J. Andrés-Colás, A. Molíns-Jiménez: “Multipath Routing with Dynamic Variance”, COST 279 Technical Report TD02043 (2002).
6. Callejo-Rodríguez, M.A., J. Andrés-Colás, G. García-de-Blas, F.J. Ramón-Salguero, J. Enríquez-Gabeiras: “A Decentralized Traffic Management Approach for Ambient Networks Environments", in Proceedings of the Ambient Networks: 16th IFIP/IEEE International Workshop on Distributed Systems: Operations and Management, DSOM 2005, Barcelona, Spain, October 24-26, (2005) 145-156. Springer.
7. Elizondo, A.J., M.L. Garcia-Osma, J. Rodriguez Sanchez, “The AGAVE Framework for QoS: Extending DiffServ by means of Differentiated Routing”, in Proceedings of the 2006 International Workshop "Towards the QoS Internet" To-QoS'2006, Coimbra, Portugal, May 2006.
8. Psenak, P., et al., “Multi-Topology (MT) Routing in OSPF,” IETF Internet-draft, draft-ietf-ospf-mt-06.txt, February 2006.
9. Przygienda, T., N. Shen and N. Sheth, “M-ISIS: Multi Topology (MT) Routing in IS-IS,” IETF Internet-draft, draft-ietf-isis-wg-multi-topology-11.txt, October 2005.
10. Boucadair, M., “QoS-Enhanced Border Gateway Protocol”, Internet-Draft, draft-boucadair-qos-bgp-spec-01.txt, July 2005.
11. Bartholomew, S., “The Art of Peering”, 2000.
12. LINX, Pseudowire / Layer-2 Connect, 2006, https://www.linx.net/www_public/our_services/layer2_connect/?searchterm=martini
13. Bryant, S., and P. Pate, “Pseudo Wire Emulation Edge-to-Edge (PWE3) Architecture”, March 2005. Internet RFC 3985.

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