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Self-Adaptation in Next Generation Internet Networks: a Traffic Aware Approach

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The main requirements for Next Generation Networks (NGN), i.e. flexibility with respect to traffic variability, QoS satisfaction while effectively using network resources call for a "self-adapting" approach. An example of smart (self-adaptive) networks capable of coping with traffic changes and QoS requirements are the so called "cognitive packet networks" (CPN) [1] [2]. CPNs adaptively select paths so as to offer a QoS as near as possible to the end users' dynamic requests, thanks to on-line monitoring and measurements coupled with monitoring-driven intelligent adaptive behavior. Since NGNs should handle all service types, including the guaranteed QoS ones, they should be capable of optimizing network resources and react to traffic changes, while providing the desired QoS and reliability levels, by self-adapting to traffic changes through a traffic engineering approach.

The Multi-Protocol Label Switching (MPLS) technique provides the means for addressing these issues, by coupling the advantages of flexibility and performance of layer 3 and layer 2, respectively [3]. The challenge for NGN consists in extending such flexibility and efficiency to other layers of the network, like SDH/SONET and WDM, considering even non packet-based forwarding planes. The extension of MPLS to Generalized MPLS (GMPLS) allows to perform efficient traffic engineering for different technologies [4]. However, a feasible solution able to use such ingredients is not consolidated yet.

The present paper deals with self-adapting network in NGNs based on the MPLS/GMPLS paradigm and discusses one of the key issues to be addressed: how traffic models can be used to enable a self-adaptive behaviour.

Self-adaptation envisages the capability to react automatically to traffic demand fluctuations and network availability changes, while meeting the tight QoS objectives required of NGNs. The difficulties associated to the automation of the network control require the synergies of different traffic engineering solutions, e.g. routing, pre-emption mechanisms, bandwidth management techniques, traffic measurement and forecasting, and protection and restoration mechanisms.

The concept of self-adaptive network may be better explained by using the metaphor of TE as a closed loop control system, where two loops can be envisaged. The network characteristics, namely the physical topology and the link capacities, are known to all the TE system elements. Such system is capable to identify the network state and take actions to drive the network to a desired operational state, which corresponds to a nearly optimal utilization of network resources. The outer loop operates on longer timescales. A key block is the master traffic engineer (MTE). It has the role of examining two main input information: i) the traffic demand derived from the whole set of contracts, which provide the traffic demand (bandwidth and QoS attributes) for each O-D couple; ii) the traffic statistics observed on long timescales. Such statistics would have been derived, typically by the network management system, through traffic measurements achieved over long time scales. The distributed measurement collection system enables the MTE, possibly after a suitable processing, to obtain the multi-layer traffic matrices, since a multi-layer view of the traffic is necessary for a smooth and effective traffic management [5]. The availability of such traffic matrices in a continuous fashion and therefore of their time series allows the MTE to formulate traffic forecasts and to decide "when" actuating the "global path-provisioning" function, acting as a trigger. In fact the monitoring and forecast functions incorporated in the MTE enable it to detect a significant change in the traffic demand, leading to re-run the global path-provisioning. A global approach, i.e. where the resources of the whole network and their status are known, is required for an effective optimization and is better achieved by a centralized approach. However, a global optimization could require moving the traffic already accommodated in the network, so that it should be carried out sparingly.

On the other hand, the inner control loop is essential to handle single relevant traffic variations occurring on a short timescale. In fact, regular, even if unpredicted, traffic changes lead to appreciable traffic load variations that need to be handled by a dedicated module, named the Dynamic TE (DTE). This module perform two basic functions: i) selecting the dynamic operations to be carried out based on short-term measurements data and/or the individual traffic reservations, and ii) accomplishing the required dynamic operation. The latter may include: 1) dynamic routing of new unpredicted requests when they arise; 2) possible preemption of lower priority data flows at the advantage of higher priority ones; 3) possible re-routing of data flows, 4) variation of bandwidth attributes when specifically requested. A DTE can therefore take some decisions on specific data paths such as set up, tear down, re-routing and so forth, to drive the network to a more efficient network status. The role of measurements is crucial in both loops, since the information about the status of the link and of the other network resources should be at the same time accurate and updated, also to avoid the false triggering of the automated global provisioning facility

While the MTE and the global path-provisioning modules operate “off-line”, and could easily be accomplished in a centralized way, the DTE must operate “on-line”, to react “on demand” to individual requests, and could reasonably achieved in a “distributed approach”. In other words, DTE functions can be implemented directly on local nodes.

The information needed by both MTE and DTE, in addition to the traffic measurements, is the current quantitative availability of links and nodes on the different network layers. This information can be made obtained through routing protocols such as OSPF-TE as specified in the MPLS and the GMPLS paradigm. The network status information must be recorded and continuously updated in proper databases, which could be located in a centralized network management system and/or distributed in all the network nodes that can take actions.

In this way, the system as a whole is able to both optimize network resources and react to traffic changes. The utilization of off-line routing approach in the global path-provisioning phase and the on-line dynamic routing approach to react to dynamic traffic changes characterize the hybrid routing solution.

It can be envisaged that there will be a migration path from current control/management systems towards self-adaptive networks. While some parts of the functions could be implemented soon in an automatic ways (e.g. the algorithms for the route calculations utilized in the path-provisioning function), some others will still be made by manual intervention (e.g. the decisions when triggering the path-provisioning, and the decision to dynamically route paths). Eventually, the network as a whole could be schematized as the closed loop control system described above.

References

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