EXPERIMENTAL COGNITIVE DISTRIBUTED ENGINE

ECODE

Project overview

The goal of the ECODE experimental project is to develop, validate, and implement a cognitive routing system, which uses machine learning techniques that can meet Future Internet challenges, in respect to manageability, security, availability, and accountability. This project combines networking with machine learning expertise in order to address these challenges in the most efficient way possible.

During the building phase, the cognitive routing system is both designed and prototyped. Then in the second phase the project evaluates the benefits of applying new online distributed machine learning techniques on three sets of use cases.

- Manageability and Security of the Internet: efficiently monitor the path performance by combining passive and active measurements, and cooperatively detect traffic anomalies (leading to performance or QoS decrease) so as to detect intrusions and attacks.
- Availability and Accountability of Internet paths: efficient path ranking based on QoS and availability metrics, efficient path re-routing to other links in cases of failure, and traffic flow correlation by routers in order to diagnose and predict their deviation over time (with respect to profile-based resource allocation), then adapting these profiles so as to maintain an acceptable resource usage.
- Scalability and Quality of the Internet routing system: by detecting events that are detrimental to the routing system dynamics and to efficiently react to such events.

The experimentation of these techniques is carried out on physical experimental facilities such as the iLab-T virtual wall.

Type of project
Small/medium-scale focused research project (STREP)

Contract number
FP7 - 223936

Project coordinator
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Project website
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Community contribution to the project
EUR 3 070 000

Project start date
1 September 2008

Duration
36 months

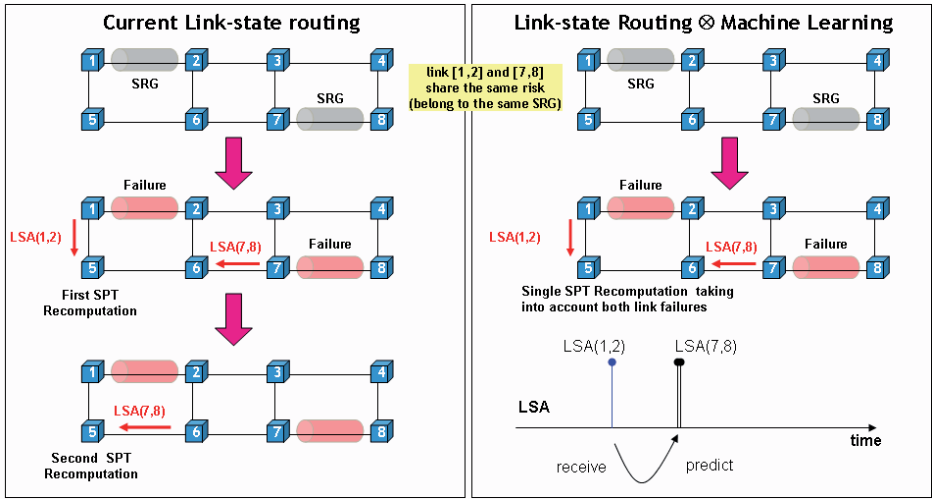
Research description

Machine learning has recently attracted the attention of the communication networks community. Indeed, problems observed in communication networks are similar in nature to the conditions traditionally encountered in classical machine learning applications. From this analogy, the driving idea of the ECODE project is to augment the communication network control paradigm (that is based on low-level data collection and its associated decision process) with a machine learning component using online, and distributed machine learning techniques (see Fig. 1). This architectural component aims to enable networked systems to learn about their own behaviour and environment over time, so as to better analyse any problems, and to tune their operation to better satisfy end-users and increase the overall utility of the Internet. Augmenting an Internet control system with a distributed machine learning component revisits the capabilities of the IP/networking layer as it is expected to:

- enhance Internet functionality to cope with known operational challenges (such as manageability, diagnosability, and availability) but also to address new challenges (such as security and accountability) without impacting its evolvability;
- limit the network equipment and its operational complexity resulting from Internet growth (compared to continuously patching existing routing equipment);
- reduce/improve degradation/gain as regards performance by adapting forwarding and routing system decisions.

A cognitive routing system using online, and distributed machine learning techniques would address these challenges altogether. This system, realised by means of a distributed and loosely coupled machine learning component, will coexist with and augment the existing routing engine of current IP networking equipment.

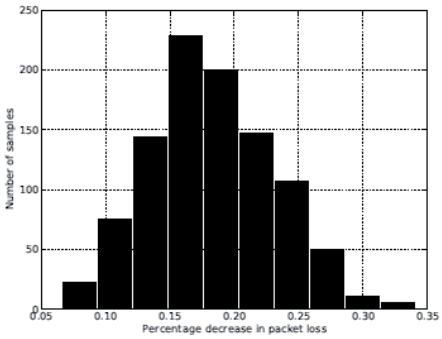
The ECODE project aims at the creation, the development and the experimentation of a distributed machine learning engine that coexists and sits next to the existing routing engine of current IP networking equipment. This project experiments on the capability of this machine learning component to solve the new and operational Internet challenges. Like the application of graph theory in the networking domain has allowed for the emergence of the well-known routing discipline, the introduction of a distributed machine learning component cooperating with the routing and forwarding engines allows them to evolve beyond their current capabilities and give rise to a new paradigm for the Internet.



Example of application

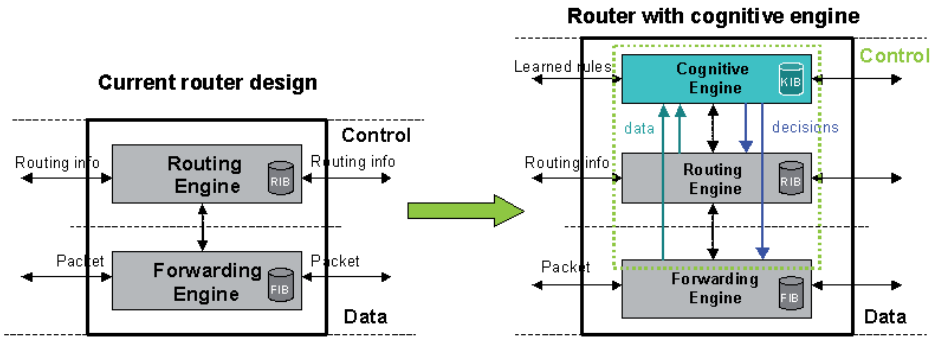
Among the various experiments conducted in the project, inference of Shared Risk Group (SRG) is a notable application of machine learning to enhance capabilities of Link State routing protocols such as Open-Shortest Path First (OSPF). As depicted in Fig. 2, time correlation between successive Link State Advertisement (LSA) arrival patterns is used to statistically learn about the possible existence of SRGs and subsequently predict their occurrence so as to prevent successive shortest path tree re-computation upon shared-risk failure (that affects multiple links simultaneously).

With current link state protocols, simultaneous link failures resulting from an SRG failure can trigger multiple successive routing table entries' re-computation, one to address each of the link failures. Failing to prune the set of links involved by the SRG failure during routing table entries re-computation leads to longer recovery time and thus a higher magnitude of packet losses compared to the situation where the set of links (associated to the SRG failure) results in a single step for the re-computation of all routing tables entries affected by the failure. Indeed, failing to take into account the set of links affected by the SRG failure leads to traffic losses until all failed links have been accounted in the re-computation of the routing table entries. Instead, if the router learns about the existence of SRGs from the arriving LSAs, then decisions regarding SRG failure can be taken promptly to avoid successive re-computations of alternate shortest paths across the updated topology. For this purpose, the outcome of the SRG detection and identification phase is used to reduce the recovery time upon failure occurrence by triggering simultaneous routing table updates from the arrival of a single LSA.



Distribution of the percentage of packet loss decrease

Other experiments have shown that ordering the update of the routing table- entries-based online traffic statistics allows additional reduction of traffic losses upon failure occurrence. Depending on the traffic model fit and prediction technique, reduction of traffic loss shows a distribution whose average approaches 20% (see Fig. 3) compared to the traffic losses observed when using the default unordered update of routing table entries. When applied altogether, these techniques enable significant



improvement of both link-state routing protocol scaling (in terms of number of links and nodes) but also network connectivity availability and reliability.

Target users and benefits

By introducing a new architectural cognitive component, the ECODE project targets to (1) improve and extend Internet functionality by providing adequate solutions to existing and foreseeable Internet challenges, (2) limit the cost of the Internet infrastructure growth, and (3) reduce the operational complexity of the Internet compared to the approach that would consist in continuously patching existing routing equipment. The results of this experimental multidisciplinary research project are also drivers for standardisation actions at the Internet Research Task Force (IRTF) and the European Telecommunications Standards Institute (ETSI), including the architecture of the cognitive routing system and the communication protocols between IP routers (augmented with a machine learning component). The ECODE project results can be exploited by IP routing equipment that would be able to sustain the Internet evolution in terms of growth, demands and loads. The project should also result in a 'revisited loosely coupled control infrastructure' of the Internet that would be easier to manage and operate under increasingly challenging conditions as well as offer a higher level of availability.

Project partners	Country
Alcatel-Lucent Bell	BE
Universite Catholique de Louvain (UCL)	BE
Universite de Liège	BE
Interdisciplinair Instituut voor Breedbandtechnologie (IBBT)	BE
Institut national de recherche en informatique et automatique (INRIA)	FR
Lancaster University	UK
Centre national de la recherche scientifique (CNRS)	FR