Cognitive augmented routing system and its standardisation path

ETSI Future Network Technologies Workshop

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Self-Adaptive (top-down) vs Self-Organizing (bottom-up)

**Current Internet model -> top-down approach**
- Evaluate global behavior and change it when the evaluation indicates that networking systems are not accomplishing what they were intended to do, or when better functionality or performance is possible
- Typically operate with an explicit internal representation of themselves and their global goals

**Patching is reaching its limits**
- Improvement of the routing system to accommodate various scales of challenges in network efficiency further complicates its operations
  -> Further patching of the routing system and equipment will create more operational complexity

**Alternative: learning and reasoning**
- Systems dynamically adapt their behaviour to varying network conditions in order to monitor the operation, optimize overall performance and even add functionalities
  -> Bottom-up approach (with rules translating high-level to low-level objectives)
Why Learning Paradigm for the routing system

**Machine learning**

- Class of algorithms that discover the relationship between the variables of a system (i.e. the input, output and hidden variables) from direct samples of the system
- Example of field of applications
  - Natural language processing, speech and handwriting recognition
  - Object recognition in computer vision, pattern recognition
  - Bioinformatics (classifying DNA sequences)

**Events characterising networking problems are similar to the ones classically addressed by machine learning**

- **Nature**: events cannot be well characterized even when examples are available (inherent complexity in characterizing an event)
- **Relationship**: hidden correlations and trends between events within large amounts of associated data
- **Environment**: changing conditions over time (in particular, for routing system but also variability of traffic, user expectations & behaviors)
- **Quantity**: amount of available data is too large for handling by manual intervention
- **Evolutivity**: new events are constantly detected/discovered
Architectural Principles

- **Adaptability**: modular instead of relying on unified and ubiquitous approach to ensure gradual development (e.g. access vs core router)
- **Segmentation**: rely on relative local view rather than a network global view to ensure scalability, robustness, and resiliency
- **Sizeability**: inherits distributed properties and capabilities of routing system (e.g. intra- vs inter-domain) instead of a uniform and ubiquitous plane construction to ensure organic deployability
Driving Concept

Augment control paradigm of lower-level data collection and decision making process, with **machine learning component** enabling system and network to

- Learn about its own behavior and environment over time
- **Detect** and **analyze problems**, tune its operation and increase its functionality and performance

Cognitive engine using semi-supervised, online, distributed machine learning
Step 0: Choose training experience $E$ as well as training and test data sets for experience $E$

Step 1: Training (learner): learn an hypothesis $h$ (model), function of the input (training data set) that approximates at best output $y$ (symbolic = classification, numeric = regression)

Knowledge -> use prior “knowledge” stored in KIB to learn $h$

Step 2: Testing (performer): evaluate learned model using test data set
Example: SRG Inference

Infer Shared Risk Group (SRG) from LSA arrival pattern to prevent successive SPT recomputation upon shared-risk failure (affects multiple links simultaneously).

Current Link-state routing

Link-state Routing ⊗ Machine Learning

link [1,2] and [7,8] share the same risk (belong to the same SRG)

First SPT Recomputation

Second SPT Recomputation

Single SPT Recomputation taking into account both link failures

LSA(1,2) LSA(7,8)

receive predict time

LSA(1,2) LSA(7,8)
“The overall objective of the ECODE project is to investigate a new architectural component to sustain growth of an Internet that performs in accordance to what it is expected to deliver to end-users. With this improvement that preserves its original design principles, the Internet is also expected to perform according to the end-user expectations while coping with a growing number of users with increasing heterogeneity in applicative communication needs.

This experimentally driven research project will determine whether composing the Internet high-level goal - societal, economical, etc. - can be translated into lower-level objectives (in terms of functionality and performance) and constraints (both technical and non-technical) and enforced via this novel cognitive component.”
Cognitive augmented routing system -- standardisation approach

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Traditional standardisation process not necessarily well adapted for research

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<thead>
<tr>
<th>Traditional standardisation process</th>
<th>Requirements from research on standardisation models</th>
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<tr>
<td>- Short term agenda</td>
<td>- Pre-standardisation work</td>
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<tr>
<td>- Focus on current work items/roadmap</td>
<td>- More lightweight</td>
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<td>- Generally solution oriented</td>
<td>- Open to academic participants</td>
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<td>- Tactics</td>
<td>- Should allow a design based on the iterative/“spiral” model</td>
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<td>- Regulation</td>
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Standardisation bodies adapting their processes to capture these requirements

- IRTF/ISOC, ETSI ISG, ITU-T Focus Group, IEEE-SA Industry Connections Program
- It is also possible to incubate research ideas with the traditional standardisation process
  - Generally leads to the creation of dedicated Working Group with requirements/use cases and architecture definition in scope
Set the standardisation approach for research projects

Needs a well-defined methodology

1. What do we need to standardise to allow the technology proposed by the project to be interoperable / deployable at a large scale
2. Role and impacts of standardisation bodies on the segment targeted by the research project
   - Standardisation activities is a food chain model
3. Do we need to improve the standardisation eco-system to maximise the chance of success
   - Create new Technical Committee, working groups and/or
   - Attract major actors
4. Identify the “structuring” aspects when choosing standardisation bodies

Derive a coherent standardisation approach
Systematic approach for standards - Cognitive augmented routing as a use case

1. What do we need to standardise?
   - The functional and network architecture components of the proposed solution.
   - The communication protocols between different cognition augmented IP routers (i.e. between two cognitive engines)
   - The additional interfaces between the cognitive engine and the (existing) components of the control engine and the forwarding engine of IP routers

2. Role/impacts of standardisation bodies and forum

3. Do we need to improve the standardisation eco-system?
Structuring aspects of the research approach and target to standardisation

Introduction of **machine learning component** to address

- **Current** operational challenges
  - Limit infrastructure and operational complexity resulting from Internet growth (compared to continuous patching existing routing equipment) → Ensure Internet durability
  - Reduce/Improve performance degradation/gain by adapting forwarding and routing decisions

- **New** challenges to meet Future Internet requirements
  - Extend Internet functionality (diagnosability, security, etc.) to cope with known Internet challenges without impacting its genericity and evolvability

**Iterative cycles of experimental research** for progressive validation and adaptation (to cope with discovered limitations)
Proposed standardisation approach for the Cognitive augmented routing

1) Define problem statement
2) Translate/use initial results into specific research goals and delimit the topic and scope of research
3) Build-up the community of interests
4) Define/refine architecture framework, design goal and protocol framework
5) Experiment distribution of information between Machine Learning Engines
6) Formulate recommendations
7) Start base protocol engineering work
7') Start advanced architecture work

First, iterate in IRTF

Socialise
De-risk
Validate
Specify
Specify next