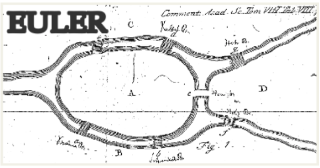

THE EULER NEWSLETTER

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The EULER project

The EULER project is a 3-year STREP targeting Challenge 1 "Technologies and systems architectures for the Future Internet" of the Seventh Framework Programme (FP7). The project scope lies within the Objective ICT-2009.1.6 part b: "Future Internet experimentally-driven research". The main objective of the EULER exploratory research project is to investigate new routing paradigms so as to design, develop, and validate experimentally a distributed and dynamic routing scheme suitable for the future Internet and its evolution. The resulting routing scheme(s) is/are intended to address the fundamental limits of current stretch-1 shortest-path routing in terms of routing table scalability but also topology and policy dynamics (perform efficiently under dynamic network conditions). Therefore, this project will investigate trade-offs between routing table size (to enhance scalability), routing scheme stretch (to ensure routing quality) and communication cost (to efficiently and timely react to various failures). The driving idea of this research project is to make use of the structural and statistical properties of the Internet topology (some of which are hidden) as well as the stability and convergence properties of the Internet policy in order to specialize the design of a distributed routing scheme known to perform efficiently under dynamic network and policy conditions when these properties are met. The project will develop new models and tools to exhaustively analyse the Internet topology, to accurately and reliably measure its properties, and to precisely characterize its evolution. These models, that will better reflect the network and its policy dynamics, will be used to derive useful properties and metrics for the routing schemes and provide relevant experimental scenarios. The project will develop appropriate tools to evaluate the performance of the proposed routing schemes on large-scale topologies (order of 10k nodes). Prototype of the routing protocol components and their functional validation and performance benchmarking on the iLab.t experimental facility (located at IBBT in Ghent, Belgium) and/or virtual experimental facilities such as PlanetLab/OneLab will allow validating under realistic conditions the overall behaviour of the proposed routing schemes.

For more information refer to the EULER website and project leaflet available at **http://www.euler-fire-project.eu**.

Call for Papers

14th IEEE Global Internet Symposium — **20/12/2010**
(with IEEE Infocom 2011), Shanghai, China

30th Annual ACM PODC 2011 — **10/01/2011**
San Jose, California, USA

23rd ACM SPAA 2011 — **12/01/2011**
San Jose, California, USA

10th International SEA 2011 — **21/01/2011**
Chania, Crete Island, Greece

ACM SIGCOMM 2011 — **24/01/2011**
Toronto, Ontario, Canada

13rd AlgoTel '11 — **04/02/2011**
Cap Estérel, France

38th ICALP — **15/02/2011**
Zurich, Switzerland

Computer Networks journal — **18/02/2011**
Complex Dynamic Networks: Tools and Methods

EULER

Experimental UpdateLess Evolutive Routing

http://www.euler-fire-project.eu

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Recent advances in routing algorithmic

The most fundamental issues faced by the Internet architecture are the scalability, convergence, and stability properties of its inter-domain routing system. Solving them requires to address multiple dimensions altogether i) the **routing table size growth** resulting from a larger number of routing entries, and ii) the **routing system dynamics** characterized by the routing information exchanges resulting from topological or policy changes. Prominent research and protocol engineering efforts have been conducted to overcome the current limitations of the Border Gateway Protocol (BGP)-based Internet routing system including 1) Shorten routing update interval, 2) Route flap damping, 3) Inclusion of AS-Path dependency and Root cause/Failure location information, or 4) BGP multi AS-Path. Over time, some these ad-hoc improvements have permitted to limit degradation of the Internet routing system but none of them actually improve the intrinsic scaling properties of the BGP (path-vector) routing algorithm nor eliminate the BGP protocol limitations impacting routing system stability and convergence.

Compact routing[1] was until recently considered as the main alternative to overcome the fundamental limitations of the Internet routing system. But, when adding the associated routing topology/information updates required to handle topology dynamics, one can no longer guarantee the required scaling behaviour. Nonetheless, scaling properties of resulting **updateful compact routing** schemes (also referred to as dynamic compact routing) would still be much better than the exponential communication costs of BGP.

Removing the dependency on linear scaling of the communication cost resulting from routing updates, leads to updateless routing schemes. The idea consists in introducing a scheme for which the geometric properties of the topology facilitate the packet forwarding process and its efficiency remains robust even under dynamic network conditions. Such a version of a dynamic routing scheme (for which an updateful counterpart exists) is known as **greedy routing**.

In the context of **updateful greedy routing**, Kleinberg[2] has recently demonstrated that greedy embedding performs well when the topology (finite) graph is embedded into the hyperbolic plane, i.e., greedy routing is always successful. However besides requiring full view of the topology graph, the problem of finding low stretch greedy path and low congestion path has not been investigated so far. Indeed, a desired property for greedy embeddings is to obtain low-stretch routes, i.e., the routes implied by the greedy paths are always not (much) longer than the original ones. In **updateless greedy algorithm**, Krioukov[3] showed that scale-free networks appear to be congruent with hyperbolic spaces (used as hidden metric spaces underlying the real Internet) and are thus potentially good candidates for embeddings of the real Internet topology. On such setting, greedy routing, which relies on hidden geometry to find the path to the destination, achieves about 100% (for a scale index between 2.0 and 2.2) of reachability and optimal shortest-path length with limited degradation (of one or two percent) under dynamic network conditions.

Over time the research community has also investigated various alternatives to circumvent limitations of path-vector routing protocols. These can be classified into three well-distinct classes. **Hierarchical routing** describes how hierarchical clustering could be used with appropriate node addressing scheme to produce scalable routing tables. This name-dependent routing scheme is the basis of hierarchical routing used today in practice, e.g., Classless Inter-Domain Routing (CIDR) in interdomain routing, or Open Shortest Path First (OSPF) areas in intra-domain routing. Hierarchical routing approaches seem unsuitable for the Internet because the effectiveness of hierarchical network partitioning and aggregation depends either on the abundance of remote nodes or on strong regularity of tree structure whereas none of these properties is present in scale-free graphs like Internet. **Overlay routing** methods rely on the segmentation between the user (identifiers) and network routing space (locators) such as the Locator ID Separation Protocol (LISP) started at the IRTF and now moved to the IETF as an Experimental Working Group. It may not result into a global routing scalability improvement because in addition to maintaining and updating locator tables, the network must maintain and update a (distributed) database of identifier-to-locator mappings to allow for identifier-to-locator resolution that results from the addition of an indirection layer. In **geographical routing on Euclidean-metric space**, each node resides in a coordinate space—a grid embedded in the Euclidean plane. Unfortunately, metric spaces hidden beneath the Internet and other real networks are hyperbolic (and thus not Euclidean planes). Thus, a greedy routing scheme based on Euclidean spaces is not maximally efficient due to the mismatch with hyperbolic metric space underlying the observed Internet topology, unless a Euclidean space with sufficiently many dimensions is used.

EULER project will design new routing schemes based on compact and greedy routing that 1) produce routing paths whose stretch is bound and independent of the network size and 2) store corresponding entries in routing tables whose memory scaling is sub-linear in the number of nodes, based on the exploitation of unique properties of Internet topology that presents some of the properties of scale-free graphs.

1 I. Abraham et al., "Compact name-independent routing with minimum stretch", *ACM Transactions on Algorithms*, vol.4(3), Jun. 2008

2 R. Kleinberg, J. Kleinberg, "Isomorphism and embedding problems for infinite limits of scale-free graphs", *15th ACM-SIAM SODA*, Jan. 2005.

3 D. Krioukov et al., "Efficient navigation in scale-free networks embedded in hyperbolic metric spaces", *CoRR*, May 2008.

EULER positioning in FIRE context

The Future Internet Research & Experimentation (FIRE) Initiative is promoting the concept of experimentally-driven yet long-term research, joining the two ends of academy-driven visionary research and industry-driven testing and experimentation, in a truly multidisciplinary and innovative approach. The scope and approach taken in EULER are in line with these characteristics:

1) Scientific and technical report deliverables will be made publicly available and the experimentation will be repeatable, reproducible, and verifiable;
2) Software deliverables will also be made publicly available under GPL;
3) The research project combines multi-disciplinary research such as structural, stochastic, dynamic modelling, routing algorithms and distributed computing with experimentation to provide sufficient proof of the solutions.

Upcoming EU events

Future Internet Conference Week **13/12 - 17/12/2010**
*** Living Labs Conference** **14/12/2010**
*** FIRE Conference** **15/12/2010**
*** Future Internet Assembly** **16/12 - 17/12/2010**
http://www.fi-week.eu/ Ghent, Belgium

FutureNetworks FP7 Concertation Meeting **10/02 - 11/02/2011**
http://ec.europa.eu/information_society/events/future_networks/concertation
Brussels, Belgium

Future Network & Mobile Summit **15/06 - 17/06/2011**
http://www.futurenetworksummit.eu/2011/ Warsaw, Poland