Towards a Methodology for the Development of Routing Algorithms in Opportunistic Networks

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Overview

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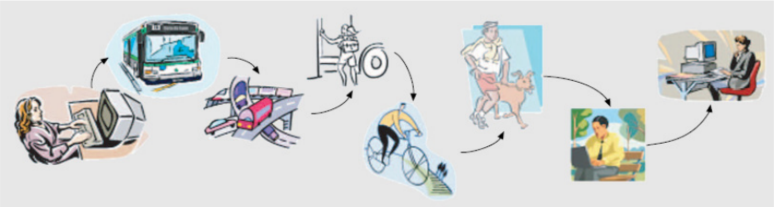
Introduction to Opportunistic Networking (OppNet)



Opportunistic networks highlights:

- set of mobile devices
- exchange information by exploiting direct communication **opportunities**
- an end-to-end route never exist
- nodes does not have any knowledge about the network topology
- Opportunistic networks allow a flexible and highly dynamic connection between the nodes
- Topology network is continuously changing

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State of the Art

OppNets

- cellular network offloading, communication in challenged areas, censorship circumvention and proximity-based applications and Internet of Things (IoT), among others

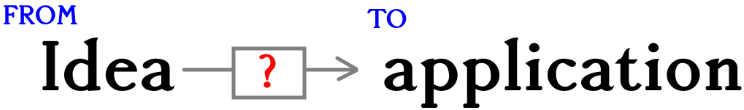
Evaluation strategies

- A standard methodology that allows the evaluation of routing algorithms in the OppNets field does not exist.

Routing algorithms in OppNet

- Routing protocols in OppNets works on the basis to send a message from a source to a destination even if an end-to-end route never exist.
- Information is sent "opportunistically" hop by hop between source to destination using the" Store-Carry-and-Forward" approach.
- Routing protocols in OppNets can be classified into three broad families: replication, forwarding, and hybrid family.
- Finding the optimum path is a challenge regarding the constant change in the network's topology.

Methodology for developing routing algorithms



This paper introduces a methodology for the development of routing algorithms that takes into consideration opportunistic networking. The proposal focus on the rationale behind the methodology, and highlights its most important stages and components. It also discusses the importance of two core elements in the process of protocol designing: the scenario selection, based on essential characteristics, and the choice of standard evaluation metrics. As of now, there has been no common methodology for developing new routing algorithms, and this has led to proposals difficult to compare, to evaluate, and lacking a rigorous objectivity ensuring fairness. Thus, there is the urgent need to propose, agree, and use a common methodology for the development of routing algorithms.

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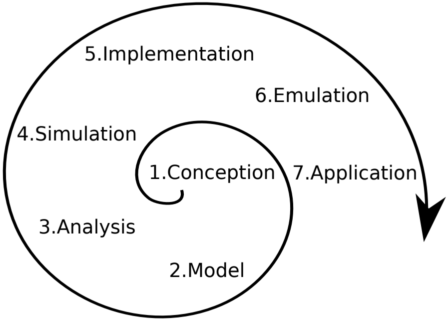
Methodology stages



The methodology has seven well differentiated stages, the rationale behind the methodology, and highlights its most important stages and components.

Methodology stages

- **Conception:** the initial idea behind the algorithm, the conception of the mechanisms.
- **Model** After the initial stage of conception, the idea must be reified into a particular mathematical model, which can then be analyzed formally.
- **Analysis** During this analysis, the mechanisms and procedures can be checked, some theoretical results can be obtained, and basic limitations can be identified.

Methodology stages

- **Simulation** In a simulator, the model can be tested in a given set of scenarios. Eventhough these scenarios involve datasets that come from the real world (e.g., real traces from vehicles or people), or even if the simulator simulates very accurately all network protocols involved, the model under evaluation is usually executed based on pseudo-code. *This does not prove that the system being designed can eventually be deployed and used for real.
- **Implementation** In this stage, a code is produced so that the algorithm can be used on a real scenario. The implementation itself shows the feasibility of the algorithm.

Methodology stages

- **Emulation:** Emulation allows to run real code in tightly controlled (and repeatable) conditions. This stage is the link between a proof-of-concept implementation and the deployment of a software that is useful in the real world and behaves as predicted.
- **Application** The last stage of this methodology is testing the routing algorithm in a real environment, with real devices and users. This is the ultimate test that shows how the designed algorithm behaves in the real world and allows to evaluate.

Methodology stages

The application of the methodology should not be strictly sequential. Some of the work in one stage can help to improve some of the previous stages.
Applying a methodology like the one described is necessary, but not enough to produce good quality routing algorithms.

There are two elements that have also to be considered:

- **Scenarios**
- **Performance metrics**

Simulation and **Emulation** stages need some scenarios

Scenarios and metrics in opportunistic networks

Different scenarios and metrics are generally used in articles to measure the performance of Routing Algorithms.

As it is difficult to reproduce real-world conditions, the use of scenarios tries to create a model of them, assuming performance will be similar.

Many papers use several scenarios to show the algorithm has a large scope of applicability.

However, articles use to pay little or no attention to the selection and definition of these scenarios, neglecting the importance they deserve in the significance of the results.

Scenario's components

Scenarios of OppNet consist of a set of nodes and their positions during a time frame. When analysing the behaviour of a routing algorithm on a scenario, more details have to be provided, such as a set of messages (with recipients and size), and the communication range of the nodes.

$$S = (Nodes, Messages, NodeContacts) \tag{1}$$

Selection of scenarios

Because it is impossible to test the routing algorithms in all possible scenarios, making a selection of scenarios is required. This process have to be scientifically justified, to be representative enough and avoid any possible bias.

Just having different traces that generate different results without analyzing the entire spectrum of action of the OppNet comprehensively would **result insufficient.**

A fine selection of scenarios will act as a representation of the whole scope of opportunistic networks.

All-in-One scenario trap

A valuable scenario aims to be a good representation of reality. This representation must introduce as many elements as the real event contains, but this could end up into an unrealistic task due to the number of characteristics involved.

Therefore, modelling a scenario requires a balance between simplification and real-world accuracy has a direct implication of usability.

Not every characteristic must be taken into account.

Instead of build an "All-in-One" scenario, the development of a set of different scenarios,

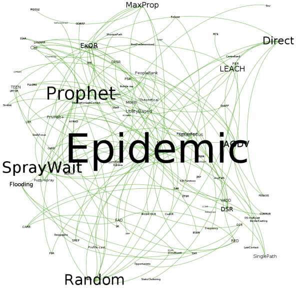
Performance metrics

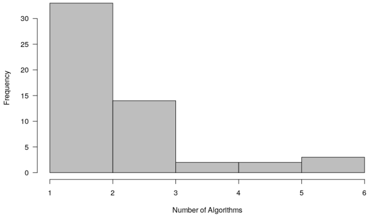
Metrics help to answer the question: **how well is a scenario working?** The evaluation function can be represented as:

$$M = M_1, M_2, ..., M_n$$
$$Eval(A, S, M) = (M_1(A, S), M_2(A, S), ..., M_n(A, S)) \quad (2)$$

Metrics should **always** refer to the same measurable properties, thus all proposals have to use exactly the same names for the metrics to avoid confusion.

Routing comparison





- We studied more than 50 opportunistic routing algorithms.
- Approximately a 62% of the algorithms tests their performance with one or two algorithms when they are presented
- Less than 5% of the reviewed algorithms present a comparison with 6 algorithm

Comparison with Epidemic

Epidemic routing in a simplistic view:

algorithm sends the message to all of their reachable neighbours

Why this is a concern in a comparison?:
The algorithm does not have to make any decision whether to send a message or not.

Epidemic routing is the most compared-to algorithm.

Fairness in the comparison

- Own evaluation metrics and scenarios
- Proposals normally compare their protocol to others
  - Testing environment
  - Chosen scenarios
  - Metrics and conditions
- Bias can be introduced unintentionally
- **Reproducibility??**

A way of alleviating these effects and giving better prospects to the (useful) development of new routing algorithms in ooportunistic networking is by using a methodology like the one presented in this paper.

This can decisively help on the difficult task of starting a cultural change on routing algorithm development, proposal evaluation, and algorithm selection.

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Thanks