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Description of the funded research project

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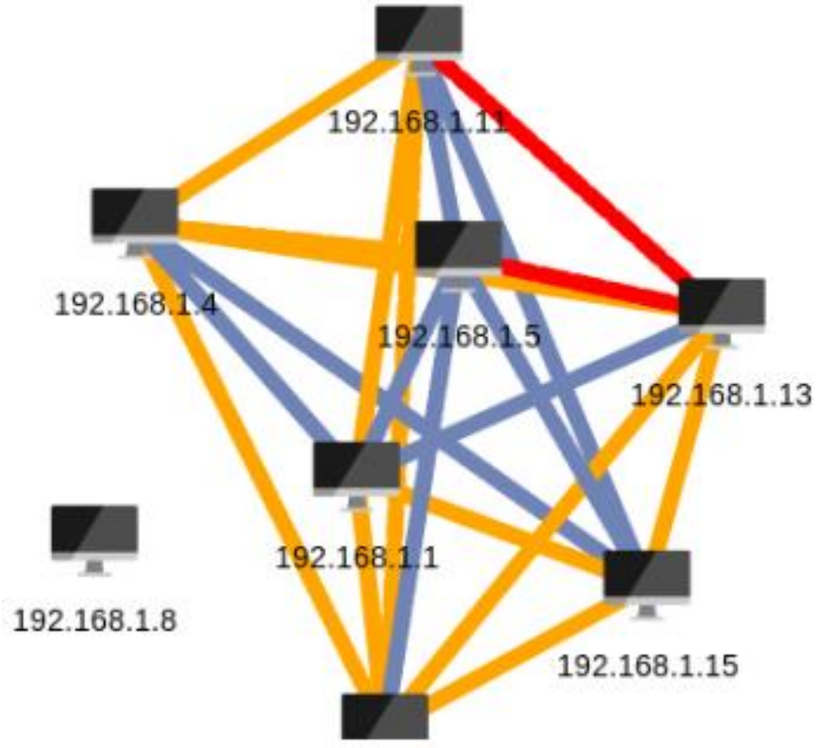

Title of the research project: Wireless Mobile Delay-Tolerant Network Analysis and Experimentation

Principal Investigator: Stavros Toumpis

Reader-friendly title: Wireless Network Analysis and Experimentation

Scientific Area: Wireless Networking

Institution and Country: AUEB, Greece

Host Institution: AUEB

Collaborating Institution(s): ---

Project webpage (if applicable): https://mm.aueb.gr/projects/lemonade

Budget: €171200

Duration: 36 months

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Research Project Synopsis

The aim of project LEMONADE is the analysis of and experimentation with wireless mobile Delay-Tolerant Networks (DTNs).

In DTNs data delivery delays are very large, often comparable to the time it takes for the topology of the network or its other important features to change significantly. The subject of this project, wireless mobile DTNs, is an important class of DTNs wherein nodes store data, carry them in their buffers as they move in space, and transmit them wirelessly to other nodes they encounter.

The scientific results of this project can be applied to important types of networks of emerging importance that can be viewed as wireless mobile DTNs, in particular:

- Networks of satellites orbiting the Earth that transport to/from ground stations data related to terrain monitoring, deep-space missions, etc.
- Networks of Unmanned Airborne/Surface/Ground Vehicles (UxVs).
- Pocket-switched networks (PSNs), made up of smartphones.
- Vehicular networks.

The last two examples are also representative of the Internet of Things (IoT) paradigm (under which everyday objects form networks and exchange data without direct control by humans) in the important case where large data delivery delays are either unavoidable or acceptable.

Project LEMONADE has three main scientific goals:

- Advance the state of the art in our fundamental knowledge on the traffic-carrying capabilities of DTNs, specifically in the directions of optimizing the forwarding rules with which data packets are forwarded and, on a broader level, optimizing the complete traffic flow.
- Advocate, enable, and demonstrate the use of DTN principles in two emerging networking paradigms, i.e., the IoT and UxV networks.
- Build a wireless mobile DTN testbed that will be used for experimentation, through which results can be verified, challenges will be revealed, and intuition and knowhow can be accumulated.

Project originality

Research on DTNs thus far has been mostly by analysis, adopting relatively simple assumptions on the properties of the wireless channel and straightforward traffic optimization methods. Part of the reason for the dearth of results is the focus of the scientific community on the cellular topology, which indeed has been proven very successful in satisfying the needs of the users for connectivity in urban settings, but does have its limitations in scenarios such as those described above.

Considering the current state of the art, the project will provide crucial original work in three main directions:

1. We will build a wireless mobile DTN testbed and perform experiments, through which results can be verified, challenges can be revealed, and intuition can be accumulated. The goal will be to improve our understanding of how the wireless channel and physical layer should be used in a delay-tolerant setting.
2. Building on the previous research thrust, we will advance the state of the art in our fundamental knowledge of how to perform traffic optimization in wireless mobile DTNs, specifically in the directions of optimizing the forwarding rules with which data packets are forwarded under incomplete knowledge of the evolution of the network topology (as is the case, for example, in PSNs) and of optimizing the complete traffic flow under complete such knowledge (as is the case, for example, in satellite networks).
3. Building on the first two research thrusts, we will advocate, enable, and demonstrate the use of wireless mobile DTN principles in the context of IoT-enabled and UxV networks. In the IoT paradigm, the problems of performing optimal sensing and offering delay-tolerant personalized services will be studied. In the UxV networking paradigm, the problem of selecting the trajectory of UxVs and evaluating the resulting network performance will be studied. Since an important inherent challenge for these classes of mobile DTN networks is that of *learning by experience*, we will develop algorithms and techniques grounded on reinforcement learning to solve concrete learning problems for different use cases.

Expected results & Research Project Impact

LEMONADE will bring wireless mobile DTNs a step closer to their wide adoption, by removing key scientific hurdles. In particular, the scientific results of LEMONADE include the following:

1. The experimentation activities of the first workpackage will raise awareness on practical issues and point to new problems that must be addressed before DTNs realize their full potential.
2. The traffic and flow optimization activities of the second workpackage will significantly advance the research community's basic understanding of the fundamental capabilities of wireless mobile DTNs to carry traffic and, in particular, trade off delay with other performance metrics.
3. The activities of the final workpackage will address open research questions regarding the possible role that the DTN approach of storing and transmitting information can play in scaling up sustainably two networking paradigms (i.e., the IoT and UxV networks) that are expected to have a huge impact on society in the coming years, due to their numerous and disparate applications. The activities of WP3 related to ML will provide a new framework for solving efficiently tough delay-tolerant networking problems with cutting-edge tools.

Regarding the economic impact of the project, the LEMONADE team aims to empower those entities in the business value chain (technology/service/equipment providers) that have the mission and the capacity to develop DTN technology by responding to some fundamental questions about its performance and robustness that prohibit the widespread use of its use in a number of technological sectors, where it can be a game changer.

Regarding the social impact of the project, we note that wireless mobile DTNs are typically infrastructure-less, therefore they can be deployed rapidly, and with little expenditure. This is an important advantage for the whole society, but especially for underdeveloped regions.

The importance of this funding

This funding allows the PI and his team to work on a key research area and maintain a high profile in the wider field of wireless networking. The results of this project will have a lasting effect and will thus help the team be part of the community that shapes the future of technology in this field.

Also, the experimental network that will be installed will be used for training and experimentation even after the end of the project.

Furthermore, the project enables the PI to support a small team of young researchers and train graduate students, thus also fulfilling his role as a mentor of young researchers and doing his part in stemming the dramatic scientific brain drain that Greece has been experiencing in the last several decades.

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