CONTRIBUTIONS TO THE DEVELOPMENT OF CHALLENGED NETWORK COMMUNICATIONS SYSTEMS

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Work motivations

The concept of challenged communications applies to those scenarios where traditional protocol architectures may be hindered by external conditions, thus new approaches have to be taken in order to perform an effective information exchange.
The origins of this concept were initially linked to the needs of an IP-based communications system that could connect endpoints across interplanetary distances in support of deep space exploration, also known as the interplanetary Internet [1].

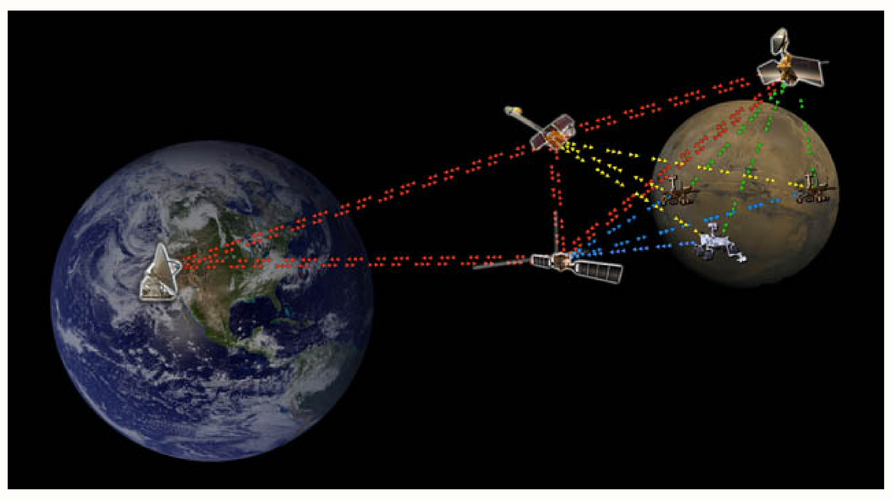

Figure 1: Interplanetary network. Image from the InterPlanetary Networking Special Interest Group (IPNSIG) home page [2].

The challenges of this communications scenario include, but are not limited to, coping with high latency, low data rate, frequent network disconnections, and the combination of many heterogeneous network types and capabilities (fig. 1).
These constraints prevent classic Internet protocols such as TCP from operating correctly, which led to the definition of new communications architectures such as Delay- and Disruption-Tolerant Networking (DTN) [3] and the *Bundle Protocol* [4]. This architecture defines an end-to-end message-oriented overlay above the transport OSI layer that applications can access directly. This overlay uses persisten storage mechanisms to counter the challenges suffered by the network, effectively implementing a store-and-forward channel that is complemented with hop-by-hop delivery responsibility transfer and optional end-to-end acknowledgements to provide reliable data exchanges.
However, the benefits derived from the usage of DTN network architectures are not only applicable to interplanetary communications, but also to networks that share some of their special characteristics. For example: vehicular networks (C2C and C2I) suffer frequent interruptions due to the high relative velocity of communicating nodes (fig. 2); wireless sensor networks usually present important energy constraints that lead to nodes turning off their communications hardware for most of the time, thus increasing communications latency or creating temporary network partitions; emergency and military communications can't always rely on a previously deployed infrastructure, so they must be supported by a combination of heterogeneous underlying networks that are not always reliable.

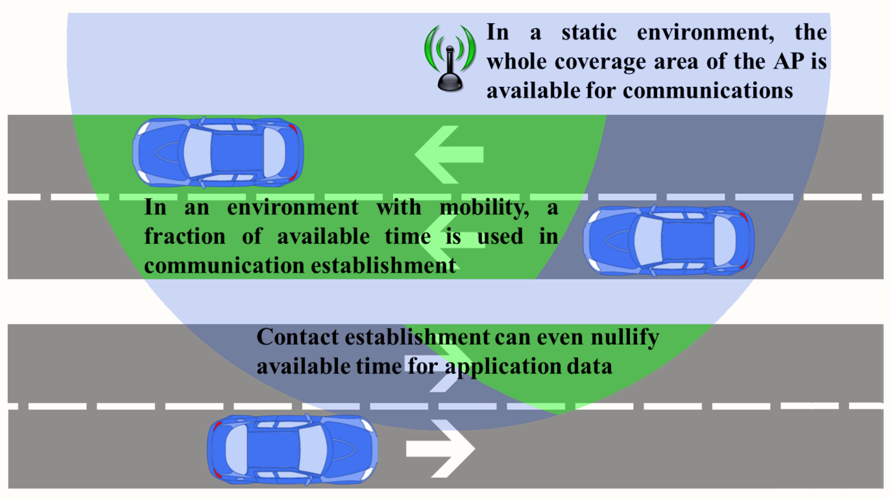

Figure 2: Example of challenges in a vehicular communications scenario.

Although DTN architecture is one of the research topics with wider application coverage in the field of challenged communications, there are many other aspects of interest that can lead to potential improvements. For example, the use of devices with limited communication capabilities in environmental monitoring or personal healthcare applications has drawn attention to the equilibrium that has to exist between application requirements and low communication performance, which in many cases affect the design of applications themselves.

Thesis objectives

The main objective of the presented thesis is to improve communications in some of the previously mentioned challenged scenarios. This improvement can be measured in terms of bandwidth, effective contact time, network stability, scalability, battery life of communicating nodes or many other target parameters. Also, cooperating in the evolution of applications that can make use of network architectures defined for those scenarios will be part of the work planned for this thesis.

This research effort will continue the line opened by previous publications by the author, covering topics like the integration of store-and-forward protocols to increase the functionality of automotive HMI [5, 6]; the application of DTN protocols in the development of a mobile WSN for environmental monitoring [7]; raising the scalability and integration possibilities of Smart Grid communications by including them in the IMS architecture via the use of SIP signaling [8]; or evaluating the possibilities of increasing the time available for application data exchanges in IEEE802.11 C2C and C2I links and proposing methods to effectively increase this time in DTN applications (fig. 3) [9].

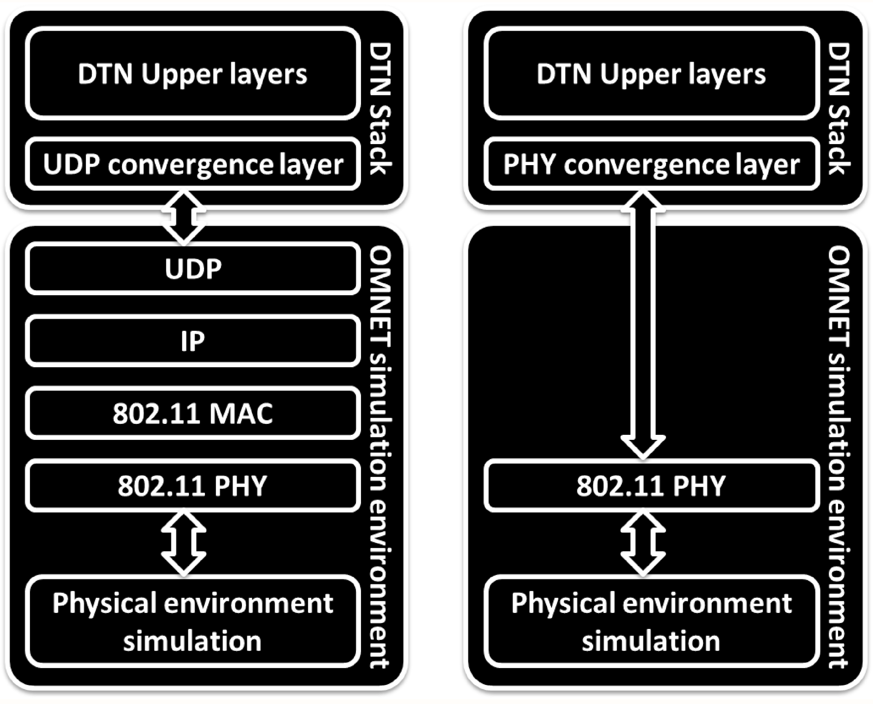

Figure 3: Proposed modification of the DTN over IEEE802.11 stack in order to increase available time for application data exchange. Image from [9].

Research plan

During the first stage of the development of this thesis, previous contributions by the author were analysed to define a common baseline that would focus future research efforts. This baseline was identified as the challenged network communications systems, and the research plan was defined accordingly and presented for evaluation.
At the same time, the author participated in a research publication in the line of work of this thesis, in cooperation with the Group of Information Technologies of the University of Vigo.

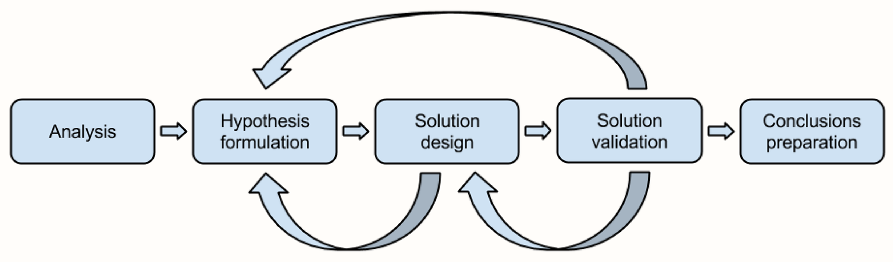

Figure 4: Proposed research plan stages.

From a general point of view, the research plan should cover the stages shown in figure 4, namely:

- Analysis: This stage includes reviewing the current state of the art in some of the topics addressed by this thesis, and identifying some possible improvement over this current state.
- Hypothesis formulation: Taking the results of the previous stage as input, a work hypothesis will be posed.
- Solution design: This stage includes designing a solution that, based on the hypothesis taken from the state of the art, will improve some aspect of the analysed system.
- Solution validation: The solutions designed in the previous stage should be tested and validated in this stage, possibly needing the review of the proposed solution and even the working hypotheses.
- Conclusions preparation: Finally, the results of every preceding stage should be taken into account to evaluate the possibility of presenting them to a scientific congress or academic publication.

Results and discussion

The main results produced during this first period of thesis are collected in a scientific publication [10] in which the author has cooperated with the Group of Information Technologies of the University of Vigo. This publication was published in the open access journal *Sensors*.
The topic of challenged network communications was applied in this work to a vessel under construction, where a wireless sensor network to monitor hazardous gases produced by shipyard tasks (for example, wielding) in confined spaces was proposed and evaluated with real field tests.
The proposed sensor network was intended to improve worker safety in an environment that is extremely complex for wireless communications, due to the vast amount of metal and enclosed zones present in a ship, and the added dificulty of the dynamic nature of a shipyard, where both workers and metallic equipment move frequently.

The conclusions of this work state that it is possible to deploy such a network in this scenario, taking advantage of the openings in metallic surfaces (such as doors, ventilation pipes, corridors, etc.) and the routing capabilities of Zigbee nodes to provide paths for data propagation (figures 5 and 6).

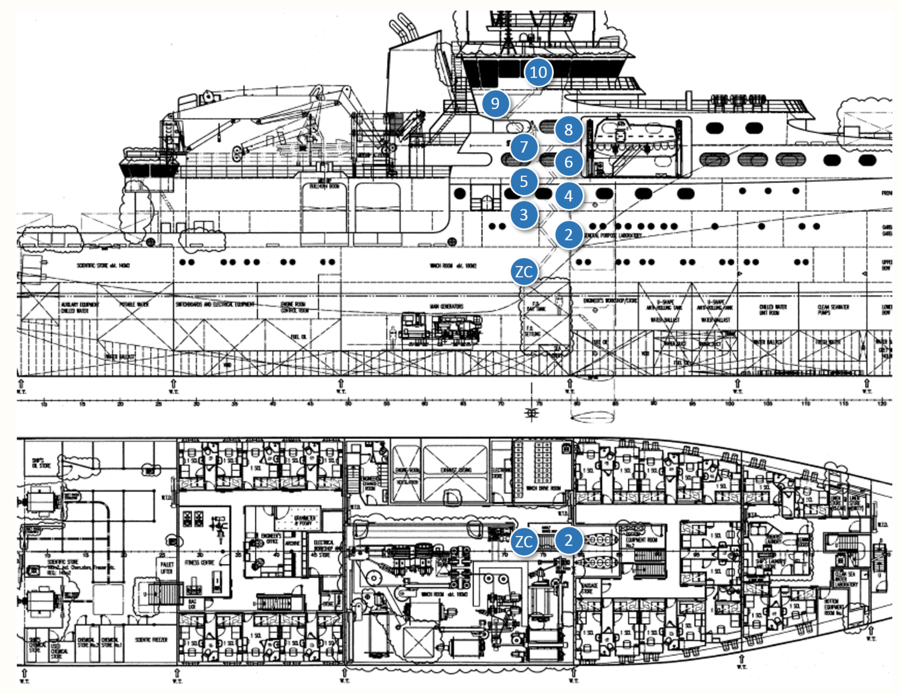

Figure 5: Positioning of measurement points for in-ship test scenario: Staircase connecting inner decks with bridge. Image from [10].

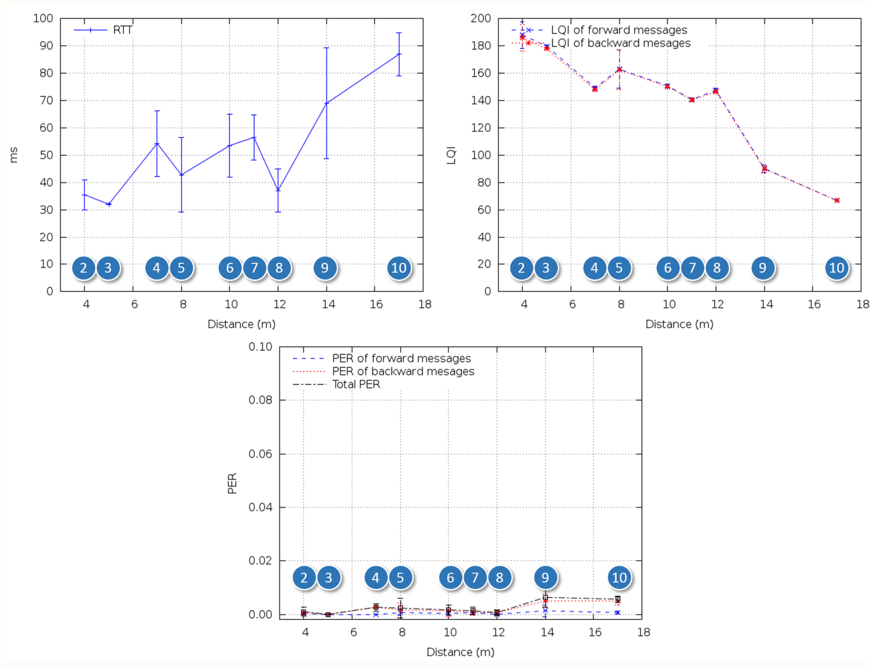

Figure 6: RTT, LQI and PER for in-ship test scenario: Staircase connecting inner decks with bridge. Images from [10].

Next steps

The following steps devised for the development of this thesis include the contribution to new works covering the deployment of WSNs to help sport training activities.
Also, the paradigm of the Internet of Things will be analysed in order to evaluate the possibilities of the techniques described in this presentation to improve IoT communications in some application environment.

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