



# Optimal Route Synthesis in Space DTN Using Markov Decision Processes

Pedro R. D'Argenio<sup>(✉)</sup> 

Universidad Nacional de Córdoba & CONICET, Córdoba, Argentina  
`pedro.dargenio@unc.edu.ar`

Delay-tolerant networks (DTN) are time evolving networks which do not provide continuous and instantaneous end-to-end communication [5, 9]. Instead, the topological configuration of DTN changes continuously: connections are available only during some time intervals and thus the network may suffer from frequent partitions and high delay. In this sense, the DTN paradigm is fundamental to understand deep-space [3] and near-Earth communications [4]. A particular characteristic of space networks is that, due to the orbital and periodic behavior of the different agents (e.g. satellites and terrestrial or lunar stations), contact times and durations between nodes can be accurately predicted. This type of DTNs are called *scheduled* and expected contacts can be imprinted in a *contact plan* that exhaustively describes the future network connectivity [10].

Scheduled routing algorithms such as the Contract Graph Routing (CGR) assumes that the future topologies of the network are highly accurate and that communication between nodes are perfect [1]. That is, it disregards transient or permanent faults of nodes, antenna pointing inaccuracies or unexpected interferences. The likelihood of these communication failures can normally be quantified *a priori* and hence included in the contact plan. Thus, the addition of this new information gives rise to a new type of DTN called *uncertain* DTN [12, 13].

The behavior of the contact plan with probability failures on contacts yields a Markov decision process (MDP) where the non-determinism corresponds precisely to the routing decisions. With this model at hand, we have developed and studied several off-line techniques for deriving optimal and near-optimal routing solutions that ensure maximum likelihood of end-to-end message delivery. In particular, we have devised an analytical solution that exhaustively explores the MDP very much like probabilistic model checking does. This technique, which we called *routing under uncertain contact plans* (RUCoP), was reported in [13]. As the exhaustive solution is memory and time demanding, we have also explored in [6] simulation based techniques using *lightweight scheduler sampling* (LSS) [8] which has been implemented in the MODES statistical model checker [2] within the Modest toolset [11]. We have also studied variations of these approaches with communication redundancy in order to increase reliability by allowing a network-wide bounded number of message copies. In addition, an exhaustive comparison of these and existing techniques were reported in [7].

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The objective of this presentation is to report this research as well as current ongoing developments for multi-objective routing optimization on space DTN.

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