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MULTI ASPECT SIMULATION FRAMEWORK FOR DISTRIBUTED CONTROL OF NETWORKED SATELLITE FORMATIONS

Abstract

In the current "New-Space" and "Agile Space" development we see a growing number of companies and universities turning to use many cooperating smaller satellites instead of single monolithic ones to realize their space missions. Examples for this are the currently developing and planned mega constellations and satellite formation missions, which see an ever increasing number of satellites and higher level of satellite autonomy. As a result we see a high demand for scalable modern distributed control algorithms and measures to efficiently coordinate the resulting high amount of exchanged information between the satellites.

While the performance of single satellite transceiver hardware can be tested pre-flight in respective testing facilities, the validation of network flow and routing algorithms for big satellite formations or constellations are difficult to test in hardware and are therefore often tested in detailed network simulation frameworks like Omnet++ or NS3.

Similarly tests of the control approach are hard to do with real satellite hardware in the full six degrees of freedom and therefore performance, scalability and stability are often tested preflight using a highly precise orbit/attitude dynamic simulator like Stk or Orekit with the control algorithm running in the loop, e.g. in Matlab/Simulink.

In both cases simulations focus on a specific aspect, simplifying or neglecting the other. But in general even slight changes in relative satellite position and attitude, e.g. by neglecting perturbations, can have a significant impact on the reachability of a satellite in the network. On the other hand changes in the information flow induced by complex routing or network control processes can also have a big impact on the resulting formation control performance, as the available information at a satellite about the global state of the multi satellite system can vary over time. In this work we combine multiple established simulation frameworks, each specializing on a different simulation aspect of networked satellite formations, into one single combined simulation to take the interdependecies into account. The challenges for meta data and time-event/time-step synchronization between the frameworks are discussed and appropriate solutions are proposed. To demonstrate the benefits of such a multi aspect combined simulation we provide numerical results of a multi CubeSat formation earth observation scenario which utilizes a distributed

control approach to reconfigure the formation. An important aspect is that the control dynamic is directly influenced by the changing dynamic of the inter-satellite links and vice versa.