Modeling and Analysis of Space Based Transceivers

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NASA GRC and GD logos can be put here also

1. Abstract

This paper presents the tool chain, methodology, and results of an on-going study being performed jointly by Space Communication Experts at NASA Glenn Research Center (GRC), General Dynamics C4 Systems (GD), and Southwest Research Institute (SwRI). The team is evaluating the applicability and tradeoffs concerning the use of Software Defined Radio (SDR) technologies for Space missions. The Space Telecommunications Radio Systems (STRS) project is developing an approach toward building SDR-based transceivers for space communications applications based on an accompanying software architecture that can be used to implement transceivers for NASA space missions. The study is assessing the overall cost and benefit of employing SDR technologies in general, and of developing a software architecture standard for its space SDR transceivers. The study is considering the cost and benefit of existing architectures, such as the Joint Tactical Radio Systems (JTRS) Software Communications Architecture (SCA), as well as potential new space-specific architectures.

While it is possible to compare the cost of two particular implementations by manually tabulating anticipated performance and expense of each design choice made along the way to describing the particular instances, this type of comparison only shows the two choices made. Quickly the "what-if" questions arise concerning alternate methods for achieving comparable approaches. As such, manual tabulation for evaluating the efficacy of regions of the design space was rejected by the study team. Rather, the approach of the study has been to develop a set of models that describe the communications requirements, the processing requirements, the available hardware, and the relevant properties of the alternative software architectures, then to analyze the design space using objective cost and capability metrics. A tool implemented for this study, called the SDR Transceiver Analysis Tool (STAT), aids the modeling and analysis process. STAT aids the user in identifying and selecting representative designs, calculating the cost and benefit metrics, and to perform a comparative analysis of the representative designs. The study is applying STAT to examine the impact of design choices such as software architecture, middleware, number and type of hardware components, and channel parameters (e.g. modulation scheme, channel data rate) on costs (e.g. size, weight, power, engineering costs, purchase costs) and transceiver capabilities (e.g. in-flight reconfigurability and reprogrammability). This tool allows the design space to be searched quickly while being incrementally refined in regions of higher payoff.

An important observation of this study is that the STAT supports a thorough, objective, and quantitative analysis of the design alternatives for space transceivers. Often, when critical decisions are made about future design strategies (e.g. software versus hardware, middleware versus traditional software approaches, open standards versus vendor-centric designs, one language or software architecture versus another), both the lack of objectivity of vendors and the size and complexity of the design space can result in these

decisions being made without quantitative comparisons of the costs and benefits of the alternatives. The STAT has enabled the STRS project to conduct a structured, objective analysis of the design alternatives, considering the metrics that are most important to space applications, such as size, weight, and power. This will result in a high degree of confidence in the selection of an implementation strategy for transceivers to support future NASA space missions. As real transceivers are implemented, the models that were used to predict the size, weight, power, and resource utilization of the design can be updated to reflect the measurements of the actual as-built system, thereby improving the fidelity of future analyses. As the STAT is used over time, the model database will grow and become more accurate, and will become a key part of the transceiver design process.

A significant benefit of the analysis approach adopted for this study is that the transceiver modeling and analysis capability provided by STAT can be applied during the life-cycle of the space transceivers, long after they have been designed, implemented, and deployed in their planned missions. One of the reasons that NASA is considering application of SDR technology to space communications systems is to provide the possibility for transceivers to be reconfigured and retargeted during their life cycle as mission requirements change. Many space communications systems are designed for missions lasting 10 or more years (e.g. TDRSS), and during these long life cycles, there is a constant push toward higher data rates and more capable space-based communications networks. The modeling and analysis approach that NASA has taken will provide models that can be used during the design phase to analyze the implementation, and later in the system life cycle to trade the cost, benefit, and feasibility of potential design changes before implementation.

The following provides details about the STAT modeling and analysis tool (the contents of the models, how to examine the design space, and the metrics that are calculated), as well as an example of the analysis that are being performed by the STRS team. Although the analysis project is still under way, and as such the analysis are not yet complete (expected completion in March of 2005), the analysis will be available well before the conference and publication dates, in time for a complete example to be provided at the conference.

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    b) Hardware Models
    c) Infrastructure Models
    d) Transceiver Models
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        ii) Mapping waveforms to hardware
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3) Transceiver Analysis
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4) Example Transceiver Analysis
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