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DISTRIBUTED CORRELATORS FOR SATELLITE SWARMS

Abstract

Low-frequency radio astronomy enables a plethora of fundamental sciences including the study of dark ages, detecting transient radio sources and, investigating solar science and space-weather. However, at frequencies below 30MHz, terrestrial radio astronomy instruments are severely hampered by ionospheric distortion, man-made interference, and almost complete non-transparency below 10 Mhz. To overcome this impediment, various space-based satellite solutions have been investigated in the past decade, e.g. OLFAR (Orbiting Low Frequency Antennas for Radio Astronomy). OLFAR is a cooperative satellite swarm of more than 10 cube/nano satellites, and will achieve interferometry to make radio-maps of the sky at 0.3-30 Mhz. One of the key technological challenges of OLFAR is distributed processing, and in particular distributed correlation, which is the topic addressed in this paper.

In radio astronomy, sky maps are made by measuring the Fourier transform of the measured coherence function, where the coherence function is the correlation product between spatially separate antenna signals which are averaged over an integration period. Such a system is conventionally implemented by terrestrial correlators using a centralized FX architecture, which populates signals from various antennas using fiber-optical cables. The FX architecture employs a Fourier transform followed by a correlation for the chosen instantaneous bandwidth.

However, in contrast to terrestrial arrays, OLFAR satellites will communicate the measured signals wirelessly to each other, and estimate the coherence function in a distributed fashion to ensure single-point of failure (SPOF). Previously, a frequency-distributed FX (FDFX) architecture was proposed, where each satellite was assigned a frequency sub-band for correlation, and thereby mitigating SPOF. Nonetheless, FDFX architecture would still require a full-mesh inter-satellite network, which is extremely demanding for the OLFAR inter-satellite communication. For example, each OLFAR satellite is estimated to generate 6Mbps of data for a modest observation bandwidth of 1MHz, and this observed data must be correlated with every other satellite which could be as far as 100km from one another.

In this paper, we present distributed correlator architectures for space-based satellite swarms. The goal of such architectures is to remove SPOF, and to minimize both processing and communication energy of the resource constrained satellites. These architectures would exploit various state-of-the-art algorithms e.g., asynchronous variants of distributed optimization tools (e.g., ADMM), distributed consensus-based algorithms (e.g., gossip), and graphical model-based algorithms. In conclusion, we compare the advantages and disadvantages of the proposed architectures against existing methodologies, using OLFAR as a benchmark application.