SKA CSP Controls: Technological Challenges

C.Baffa[a], E.Giani[a], S.Vrcic[b], M. Vela Nuñez[a]
[a]INAF Osservatorio di Arcetri, Largo E.Fermi 5, Firenze, Italy;
[b]NRC Dominion Radio Astrophysical Observatory, Penticton, British Columbia, Canada

The Square Kilometre Array (SKA) project is an international effort to build the world's largest radio telescope, with eventually over a square kilometer of collecting area. For SKA Phase 1, Australia will host the low-frequency instrument with more than 500 stations, each containing around 250 individual antennas, whilst South Africa will host an array of close to 200 dishes. The scale of the SKA represents a huge leap forward in both engineering and research & development towards building and delivering a unique instrument, with the detailed design and preparation now well under way. As one of the largest scientific endeavours in history, the SKA will brings together close to 100 organizations from 20 countries.
Every aspect of the design and development of such a large and complex instrument requires state-of-the-art technology and innovative approach. This poster addresses some aspects of the SKA monitor and control system, and in particular describes the development and test results of the CSP Local Monitoring and Control prototype.
At the SKA workshop held in April 2015, the SKA monitor and control community has chosen TANGO Control System as a framework, for the implementation of the SKA monitor and control. This decision will have a large impact on Monitor an Control development of SKA. As work is on the way to incorporate TANGO Control System in SKA is in progress, we started to development a prototype for the SKA Central Signal Processor to mitigate the associated risks. In particular we now have developed a uniform class schema proposal for the sub-Element systems of the SKA-CSP.

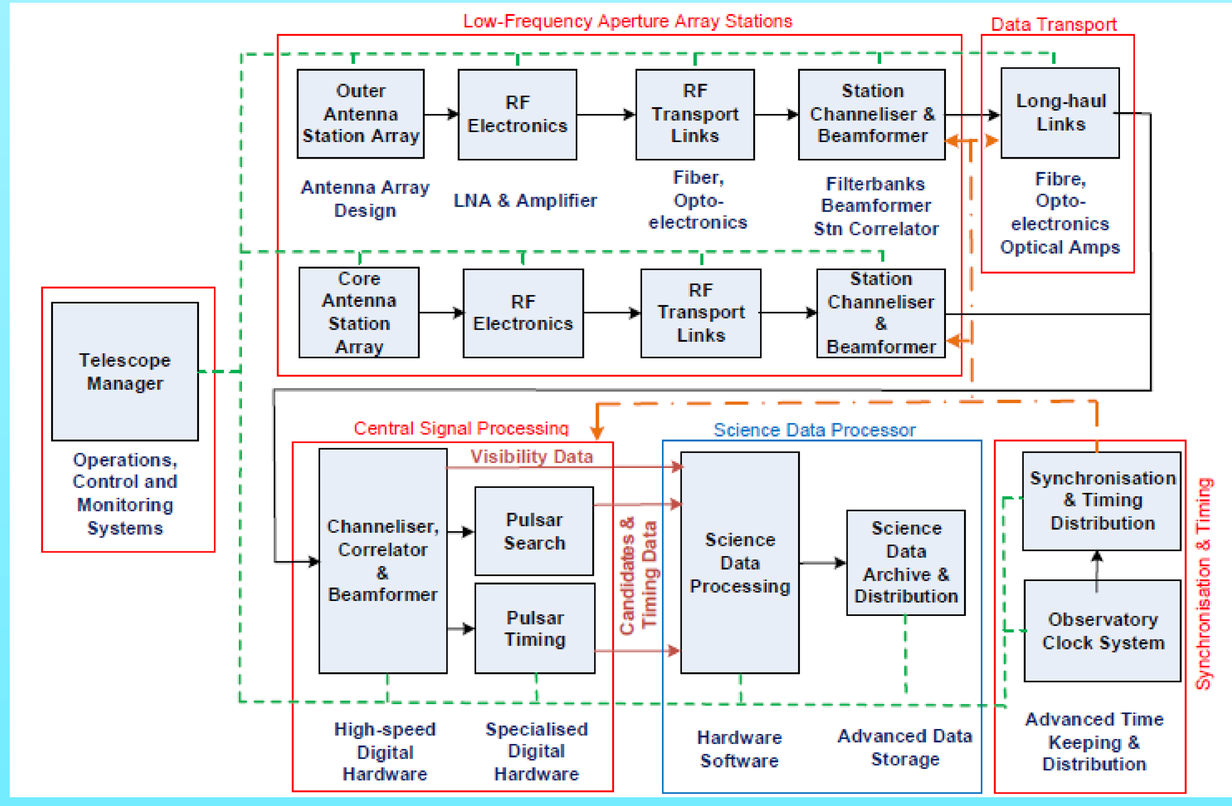
SKA Overview

The Square Kilometer Array (SKA) is a giant radio telescope project and will be the largest Radio Telescope ever built.
It will have two phases: a smaller one, SKA1 and the final SKA. It will be divided in two locations, South Africa (Mid) and Australia (Low).
SKA1 will consist of two networks of antennas:
●Low array, 1024 groups of 256 small antennas in phase 1
●Mid array, 256 large dish telescopes in phase 1

Phase 2 will make SKA 10 times larger!

4 main instruments:
●Low frequency array correlator and pulsar beam-former
●Mid frequency array correlator and pulsar beam-former
●Pulsar search machine
●Pulsar timing machine

SKA1 MID Schematic Structure



1 – SKA Structure

The telescope facilities for SKA1 have been defined as:
- SKA1_Low, a low-frequency aperture array to be built in Australia; and
- SKA1_Mid, a mid-frequency array of parabolic reflectors (dishes) to be built in South Africa.

In Illustration on the left there is a schematic representation of the SKA1_Mid Telescope. From the Monitor and control prospective the two facilities will be handled in a similar manner, with differences only in minor details. In the following we will refer to SKA1_Mid. Data coming from Antennas are fed to the Central Signal Processor (CSP). CSP is in charge to collect, correlate, filter and analyse the observational data, according to the astronomical prescriptions for the current observation(s) coming from the Telescope Manager (TM). Processed data is then forwarded to the Science Data Processor for the final reduction and post-processing in order to obtain scientifically meaningful results.

For the "imaging mode" each pair of antennas in a sub-array is cross-correlated to produce full-polarization visibility spectra across the required bandwidth and number of channels. The visibilities are packaged and transmitted to the Science Data Processor (SDP) which produces high-quality continuum and/or spectral-line images.

In the "non-imaging mode" a sub-array can form a number of tied-array beams and process data for each beam independently:
1) SKA1_MID is able to form up to 1500 Pulsar Search beams based on the sum of selected antennas which are used to search for pulsars and fast transient sources. Similar functionality is supported by SKA1_Low for up to 500 beams.
2) Both SKA1_Mid and SKA1_Low can form up to 16 Pulsar Timing beams, each covering up full input bandwidth for the observing band, based on the sum of selected antennas which are used to very accurately measure deviations between observations of known pulsars and existing ephemeris.

2 – SKA Central Signal Processor (CSP) Structure

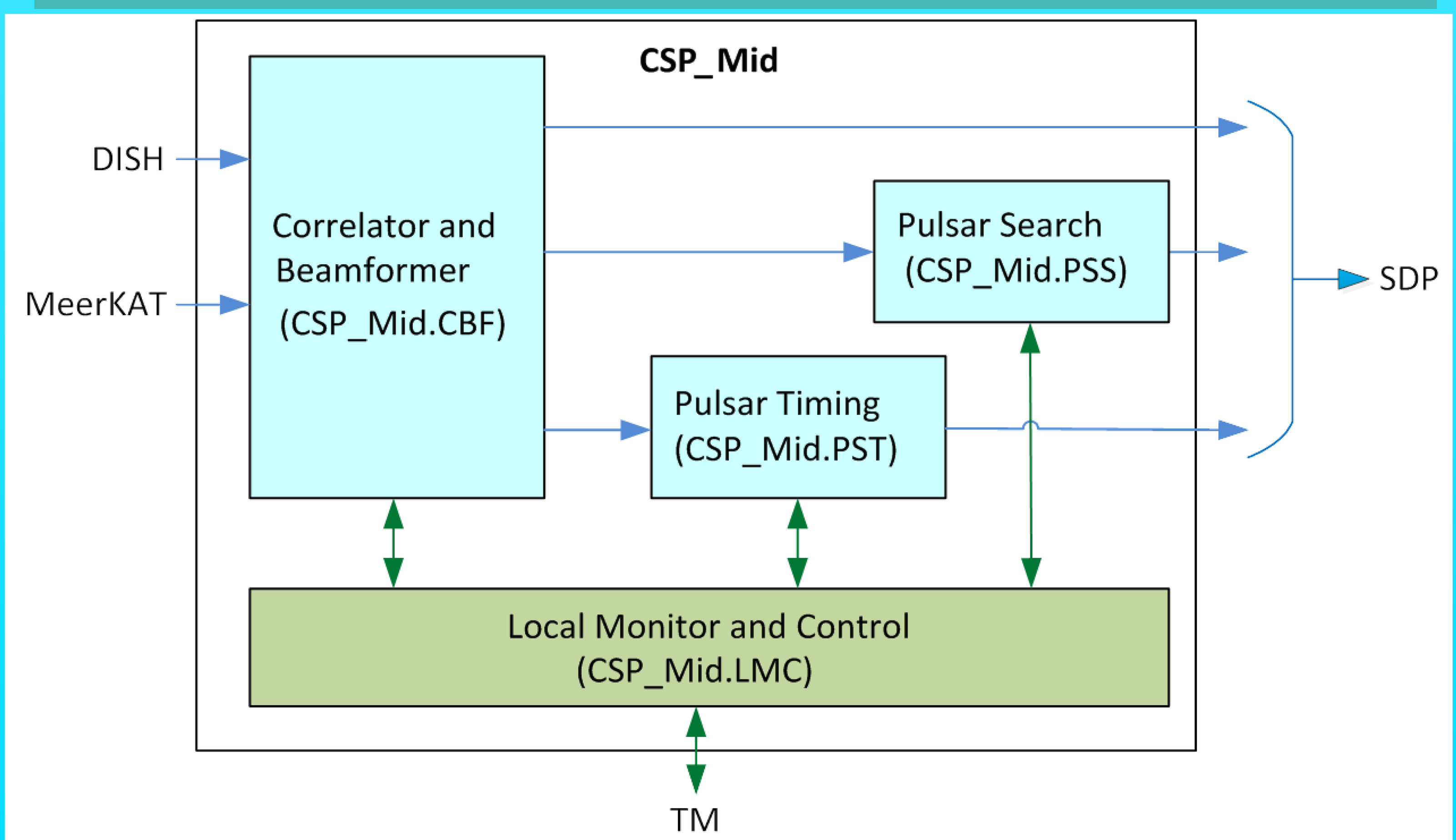
The CSP_Mid comprises four design sub-elements (see Illustration below):
1. Correlator and Beamformer (CSP_Mid.CBF)
2. Pulsar Search (CSP_Mid.PSS)
3. Pulsar Timing (CSP_Mid.PST)
4. Local Monitor and Control (CSP_Mid.LMC).

CSP_Mid.CBF performs two basic functions, correlation and beam-forming. It calculates full-polarization cross-correlation spectra with ~64,000 channels for every pair of antennas. The maximum data rate to the SDP arises when all 197 antennas are used together In this case is ~2.85 TBps.

The Pulsar Search Engine accepts up to 1500 different beams. The engine searches each beam for pulsars and transient sources over a range of dispersion measures (DM), accelerations, and periods. The resulting source candidates are sorted and transmitted to the SDP. Maximum data rate is of the order of 0.6TBps

The Pulsar Timing Engine is able to time concurrently up to 16 known pulsars, each in a different Pulsar Timing beam produced by CSP_Mid.CBF.

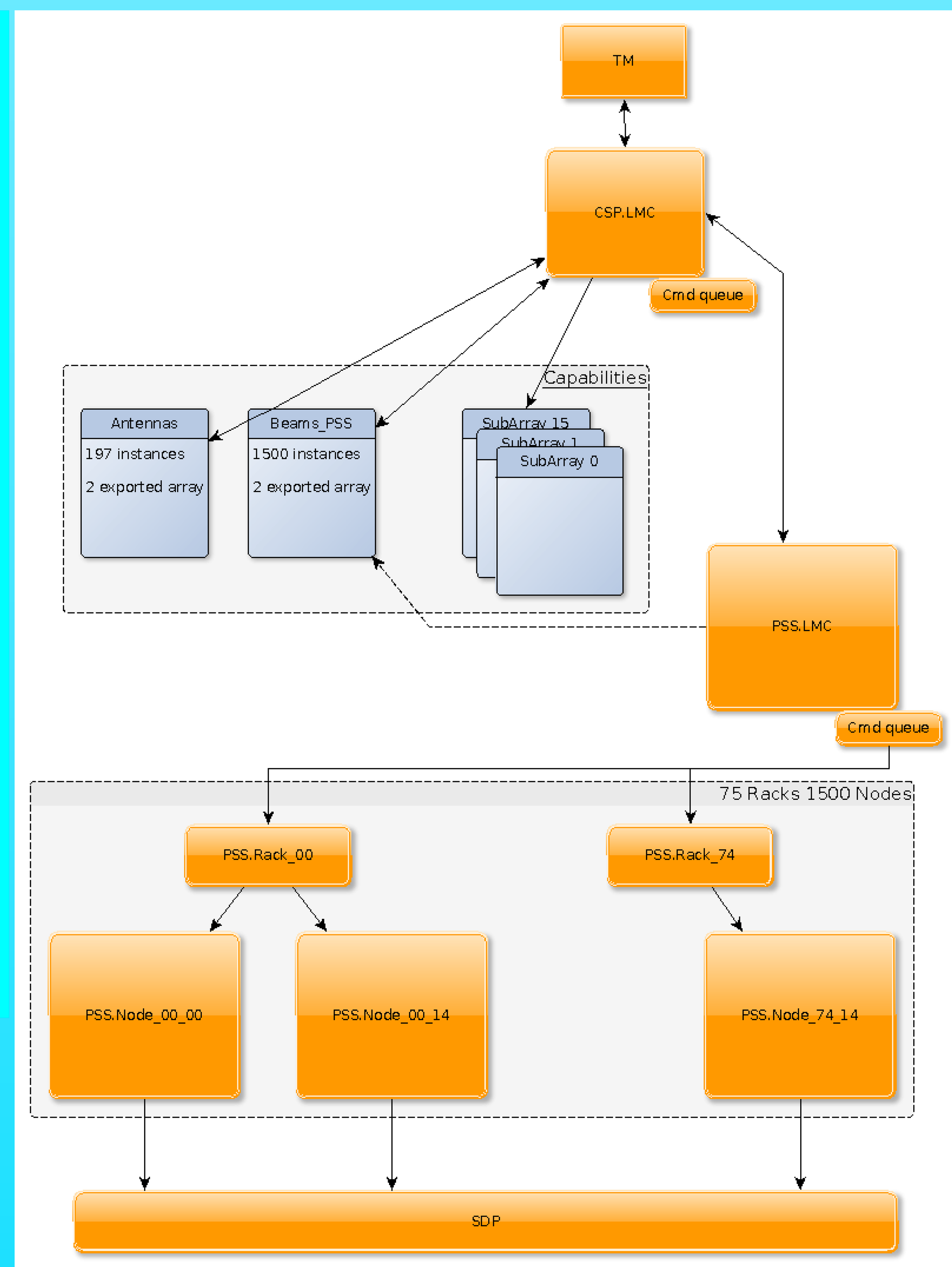
The CSP_Mid Local Monitor and Control provides the gateway to the Telescope Manager (TM) to all CSP_Mid sub-elements. All configuration, control, and monitor messages for CSP_Mid flow through CSP_Mid.LMC.
CSP.LMC implements an abstract access mode called Capabilities, that represent CSP functionality. This allows CSP.LMC to enable TM and the engineering staff to access the instrument in a less hardware related way easing the translation of astronomical directives to hardware-related commands.



3- Local Monitor and Control (LMC) Implementation

The main role of CSP.LMC is to provide a gateway to Telescope Manager, to make provision for TM to monitor and control CSP as a single entity, without being aware of the details of CSP implementation.
CSP.LMC consists of software running on COTS computers. A meeting of representatives of all LMC actors choose in 2015 to have a single software for the global Monitor and Control infrastructure and, as far it will be convenient, also for the lower levels. In the same meeting the Open Source TANGO Controls framework was indicated as the most promising candidate. For the development of CSP.LMC software Tango Controls is now used as infrastructure up to the possible lower level.
About one year later, a three days workshop aimed to address key areas: provide advanced TANGO best practices and draft a strategy for proficient use of TANGO for SKA. The outcome of this workshop will play a major role on the harmonization process of SKA LMC development.

Following TANGO approach, the CSP element, CSP sub-elements and major components are defined as TANGO devices (see figure on the right). CSP.LMC implements at least two TANGO devices:
1. CSP - this TANGO device implements interface with TM, reports on behalf of the CSP Element as a whole and handles commands issued at CSP level (for example to power- down entire CSP, including all sub-elements).
2. CSP.LMC – this TANGO device implements CSP.LMC monitor and control and reports on behalf of the CSP.LMC sub-element.
Also sub-arrays and even individual Capabilities will be implemented as TANGO devices.
In addition, a top level component CSP_Common.LMC has been defined as a prototype for the components common to all CSP.LMC instances. CSP_Common.LMC comprises the software packages developed by CSP.LMC team that implement functionalities common to all CSP.LMC instances, which are used as a base for the development of telescope specific software components.



4- Future Development

The development of a common approach for the design of SKA LMC has been, and will be in the future, long and difficult, due the complexity and size of SKA and the required flexibility of operations. The harmonization process of SKA LMC development is still in progress. We believe that this effort will have a major positive impact on the global project.

Under the perspective to participate in TANGO community, the whole SKA project could contribute to expand the native TANGO features, in a win-win situation.

Address of this poster and SKA related documentation :