SKA MONITORING AND CONTROL PROGRESS STATUS

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Abstract

The Monitoring and Control system for the Square Kilometer Array (SKA) radio telescope is now moving from the conceptual design to the system requirements and design phase, with the formation of a consortium geared towards delivering the Telescope Manager (TM) work package. Recent program decisions regarding hosting of the telescope across two sites, Australia and South Africa, have brought in new challenges from the TM design perspective. These include strategy to leverage the individual capabilities of autonomous telescopes, and also integrating the existing precursor telescopes Australian Square Kilometre Array Pathfinder (ASKAP) and MeerKat with heterogeneous technologies and approaches into the SKA. A key design goal from the viewpoint of minimizing development and lifecycle costs is to have a uniform architectural approach across the telescopes, and to maximize standardization of software and instrumentation across the systems, despite potential variations in system hardware and procurement arrangements among the participating countries. This paper discusses some of these challenges, and their mitigation approaches that the consortium intends to work upon, along with an update on the current status and progress on the overall TM work.

INTRODUCTION

As per the latest baseline design [1] published by the SKA Office, the phase one or the pre-construction phase of the SKA telescopes will comprise of three telescopes SKA1-mid, SKA1-Survey and SKA1-Low in addition to the already built precursor telescopes for SKA which are ASKAP and MeerKat hosted in Australia and South Africa respectively. The new telescopes will be built across Australia and South Africa. For the construction of SKA phase 1 the different building blocks of the telescopes have been identified and structured in the form of a Work Breakdown Structure (WBS). Telescope Manager (TM) has been identified as one of the level three elements of the SKA WBS. For the design and construction of the various level three elements the SKA organization published an RfP to all the interested countries and research organizations to own the responsibility for the development. In that respect the SKA TM consortium has been formed with various participating countries. The first section of the paper provides a brief background on the consortium. Section two talks about the main challenges behind the TM work. Section three talks about design mitigation approaches based on some of the thinking that has already gone into it, following which we conclude with the summary section.

TM CONSORTIUM BACKGROUND

The participating countries in TM consortium are India, South Africa, United Kingdom, Italy, Portugal, Australia and Canada. The consortium is being led by National Centre for Radio Astrophysics (NCRA) from India which has significant background in the area of radio Astronomy and astrophysics. NCRA build the Giant Meter-wave radio Telescope (GMRT) which has been operational since the 2002. Out of the participating countries, the team from Australia and South Africa were already involved in the development of the SKA precursor telescopes ASKAP and MeerKat and hence possess significant background on the TM problem for SKA. The research organizations UK Astronomy And Technology Centre, Istituto Nazionale di Astrofisica (INAF) and National Research Council – Herzberg (NRC-HIA) from UK, Italy and Canada respectively are world leading organization on astronomy, whereas the organization Instituto de Telecomunicações (GRIT) from Portugal brings its strong expertise in the field of Telecommunication. The TM consortium also has members from Industries with strong background on the execution of similar scientific projects Tata Research Development and Design Center (TRDDC), a research organization within TCS and GTD GmbH, with the possibility of other industries joining.

A year before the consortium was formed SKA office invited NCRA to create a concept design of the TM problem. NCRA in turn collaborated with various organizations from within India including private companies such as TCS (TRDDC), Persistent Systems Ltd (PSL) and Embedded Computing Machines (ECM) to come with a concept design for the SKA TM problem. Subsequently a CoDR was held in India with invited

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reviewers from various research organizations provided their review comments which were closed subsequently.

Subsequent to the TM CoDR, the decision on splitting sites to host multiple telescopes was taken by the SKA organization which added some new challenges to the design concept [2] created for the CoDR phase. The TM consortium plans to take the existing work done for the TM CoDR and the new baseline design published by the SKA office to create detailed design and prototype implementation of TM which will eventually be translated into the actual SKA TM element in the construction phase.

SKA PRE-CONSTRUCTION PHASE

It has been decided that for the construction of SKA phase one, the telescopesSKA1-mid would be built in South Africa, whereas SKA1-Survey and SKA1-Low would be built in Australia respectively. This decision added further challenges to the overall design suggested in the baseline design.

The pre-construction phase is divided into the two stages: stage1 dedicated for requirement analysis and preliminary design and stage2 for creating the detailed design. Timeline to complete the pre-construction phase is three years from its start.

TM RESPONSIBILITIES

As per the baseline design, each of the three telescopes SKA1-mid, SKA1-Survey and SKA1-Lowto be designed in the pre-construction phase will incorporate a Telescope Manager responsible for the following functionalities:

- Management of all astronomical observations.
- Management of all the telescope hardware and software systems that facilitate performing the observations.
- Facilitating communication across the primary stakeholders, including operators and maintainers as well as systems and subsystems.

TM is also responsible for ensuring safety round the clock. Each of the functionalities is briefly described in the following subsections.

Observation Management

This piece enables specification and execution of the astronomical observation procedures. Some of the main functionalities that it performs are selection, acquisition and configuration of the required receptors needed to carry out the observations, coordinating the instrument subsystems and performing the sequence of activities necessary to execute observations, dynamically monitoring and responding to changes in instrument capability and performance, any reconfiguration of the instrument or aborting the observation as needed, defining the metadata to be captured to facilitate interpretation of observation data, scheduling the sequence of observations with optimized telescope utilization.

Telescope Management

This piece is responsible for performing engineering functionalities with the main ones including startup and shutdown of the telescopes and each of their components, configuration and setup, coordinated system functioning, monitoring the behaviour and operational parameters of the system as a whole and all its components, detecting and responding to adverse situations, providing status monitoring dashboards and control interfaces to operators, and supporting commissioning, troubleshooting, upgrades and other engineering operations. Its responsibilities include system security, safety, reliability and availability of the systems and subsystems, managing system performance and monitoring the environment.

Other Responsibilities

In addition to providing monitoring and control interfaces for operators, scientists and engineers, TM also provides general-purpose communication capabilities enabling interaction and co-operation between operators, engineers and scientists. It supports remote troubleshooting, enabling engineers to access and manage devices from remote locations. It includes operations support databases to maintain engineering information (e.g. system status, capabilities, change history, engineering contacts) and makes them available to users

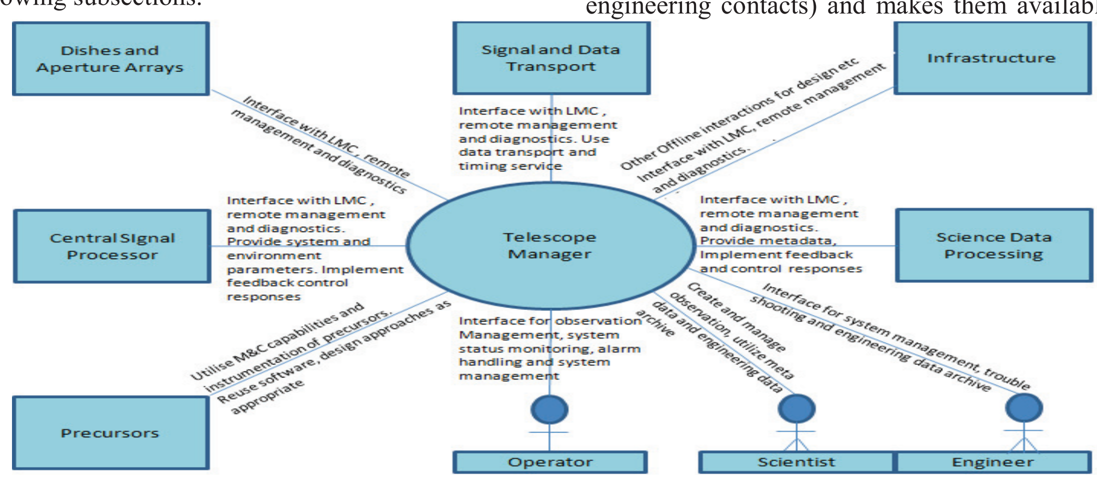

Figure 1: Context diagram explaining how interaction between TM and other SKA elements.

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of the instrument. The context diagram below indicates. the mutual responsibilities and interactions between TM and other SKA Elements The context diagram in Figure1 indicates the mutual responsibilities and interactions between TM and other SKA Elements. The Telescope Manager interfaces with every other part of the system to collect monitoring data, issue high-level control commands, and provide system level handling of alarms, either through automated response and/or through operator intervention. In addition, it has specific responsibilities towards other elements, including supply of metadata to the other SKA elements requiring the same.

CHALLENGES

TM is faced with various types of challenges right from its design to realization to all the way unto its operation. Some of the main types of challenges and their mitigation approaches are discussed in the subsections below.

Realization Challenges

Each telescope may be realized independently with the possibility of each having its own independent implementation strategy. This gives rise to the following concerns:

- Usage of a vast variety of technologies to achieve the same M&C functionality implemented by individual telescopes.
- Development of M&C will happen across geographically distributed teams, given the structure of the SKA organization. Keeping all the teams on the same page with respect to realization choices and process will be a challenge.
- Creation and maintenance of isolated science and engineering data archives, since the telescopes will operate independently. Ensuring compatibility in data formats as well as processing algorithms such that multiple telescopes can participate in the same observation is a challenge.
- Integration of precursor telescopes since they have been already developed using independent design [3] and implementation technologies.
- Enabling continuous evolution over long project lifetime and dealing with newer requirements, technologies, operation models and so on.

It is believed that most of these challenges will be mitigated through incorporating principles that will help identify commonalities across all phases from requirement, design into the operation of the telescopes so that there can be reusable solutions developed which could be used across telescopes to reduce cost and effort. Examples of a few areas of commonalities are:

Common architecture: Although the control responsibility for the instrumentation hosted in the two sites may be independent, all the systems can still implement the same M&C architecture as both will need to address similar concerns such as control of a hierarchical system, distribute, aggregate and propagate commands, responses and events, allocate resources, create worldviews as so on. A common architecture will allow for identical componentization and reuse of components across the telescopes. Architecture with support for adding plugins will provide the ability to seamless integrate newer technologies to support evolution of the SKA system. Common architectural pattern such REST, hierarchical semi-autonomy, service capability matching should be looked at.

Common realization approach: The decision to select technologies (both hardware and software) for realization of the M&C may not be strictly standardized so that individual sites can select a particular technology for implementing the required component functionality. This will enable integrating precursor subsystems with their own controllers that use their own logic to achieve science goals by building interface adapters to their control software. However, variation of technology choice based on preference should be minimized to reduce future maintenance cost and allow reuse. Identification of capabilities that are common to both the telescopes could be separated as common libraries reusable across the telescopes. e.g. IDE's, libraries for various functionalities such as logging, reporting, visualization and so on. Effort to standardize on hardware and software technologies for similar problem areas can also eliminate unnecessary effort to choose an implementation technology. The problem of handling the necessary variation also gives opportunity to build specification or model driven approaches that handle the variability in the underlying platform by defining a standard M&C specification model and implementing translators that translates the spec into individual platform specific format automatically in a transparent manner.

Common strategy for safety, security and reliability: Uniform approaches to safety, security and reliability functions in the telescopes will make it easier for all stakeholders to predict the behaviour and switch between facilities. For example the mechanism to authenticate users or setting security policies can be made uniform across the telescopes. Similar test cases could be developed for testing both the telescope for safety and reliability. Commonality of approaches makes it easier for procurement and also translation of learning between the facilities. However, specific handling mechanisms are a matter of configuration and can easily vary depending on local factors.

Operation Challenges

Operational challenges arise because of widely distributed telescopes with independent control infrastructure needing to be coordinated for various purposes. Following are the few areas of operations that TM will need to deal with:

- Supporting System Operation catering to the needs of operators and engineers, will require handling

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challenges such as avoidance of information overload such as flooding of alarms, automated real-time information exchange with external entities such as weather stations and resource providers, and handling of command and control latencies given the wide geographic distribution of the telescope.
- Support for continuous system deployment and evolution over a long lifetime, leading to requirements for continuous integration and commissioning of entities while the system is operational.
- Since individual telescopes will serve complementary science objectives, they are likely to have independent control rooms. But this doesn't rule out the possibility of their coordinating loosely to carry out certain observations which can be challenging.

Most of the above challenges will be mitigated by employing a uniform strategy for common problems leveraging existing design principles and architecture choices. Some of these strategies are as follows:

Common strategy for user interface and visualization: For the ease of usage, it is important for the telescopes to provide uniform interfaces to all stakeholders. Uniformity in UI's, API's and scripts will make it easier for users to use all the telescopes. This would also enable the implementation of the interfaces to easily adhere to common standards for usability, re-using strategies for handling information overload, building engineering interfaces, creation of user assistance and so on. Having the same concepts will minimize the cognitive load on both users and operators, and is essential for SKA to be viewed as a unified project.

Common protocol: Protocols conforming to a common abstraction layer can ease communication across the telescopes and help in resolving dependencies. Common abstractions such as Common Operating State, Operating Mode etc. will not only help both the telescopes in their internal operations but will also facilitate better coordination between them due to their knowledge about each other. Information models, including the science metadata model, engineering metadata model, observation schedule representation etc should be maintained in common, so that algorithmic modules could be reused at both ends. Protocol commonality enables common hardware, simplifying procurement and reducing cost.

Variation points: Reducing the need for millions of monitoring data from each region to move to Central M&C through alternative strategies such as implementing local data archives at individual stations, and sending only high-level abstractions and summaries of the monitoring data to Central M&C also eliminating the need for duplicated data handling as a prelude to archival.

Coordination analysis: The extent of coordinated functioning that needs to exist across telescopes will need to be analyzed thoroughly and an early decision taken. If purely manual offline coordination is sufficient, then there can effectively be multiple instances of Telescope Manager running, one for each telescope, with a minimal overall coordination and information exchange capability that can provide, for example, integrated reporting and engineering status display, and perhaps exchange of science data for archiving & delivery. But it is possible to imagine scenarios that need more coordination:
- Application of engineering patches / upgrades to all devices at both sites.
- Engineering diagnostic routines that collect and correlate data from both sites.
- Backup control e.g. use the control room at the other site if there is an outage at one site.
- Unified control e.g. to investigate a target of opportunity.
- Exchange of parameters for signal processing or science data processing, especially if simultaneous observations are being carried out.
- The ability to carry out strongly coordinated observations.

SUMMARY

The individual SKA telescopes can be thought of as independent autonomous facilities. While there may be autonomy in the dynamic functioning, it is strongly desirable to have common engineering. Several dimensions of commonality that need to be maintained are being discussed, relating to architecture, operation and realization. If the telescopes follow similar architectural patterns and implement similar set of components using similar realization technologies, it would be much easier for all stakeholders participating in the program to develop and effectively use the system. A uniform approach towards realization and operation would also reduce the effort to build and maintain the individual telescopes.

The coordination problem between telescopes should be carefully analysed, including expected evolution in the requirements over the lifetime of the telescope, since it will have significant architectural impact on TM.

ACKNOWLEDGMENT

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