The “Smart Observatory” for Autonomous and Remote Observations

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Abstract “Internet-of-things”, “Industry 4.0”, and “Smart Factory” are key words of new, technical revolutions in industry. Over the past years, similar techniques were also developed for geodetic observatories at different places, using available micro-controller boards and software solutions for monitoring and control of telescopes. Transferring these techniques into a concept of a “Smart Observatory”, autonomous and self-organizing operations become possible. Therefore, engineers at the Wettzell observatory started to implement and integrate such techniques into their systems. A key feature is the autonomous, state-driven processing of schedules from autonomous fetching and preparation of schedules, the operation of observations, and the finalization and transfer of the data. Another key technology is the Central Site Monitoring to fulfill aspects of safety and security to protect humans and the technique itself from harmful situations. A third essential part for whole networks is a Central Coordination (& Control). Developments for this globally available state information are funded within the project “JUMPING JIVE” from the European Union’s Horizon 2020 research and innovation program. This paper describes the current state of the developments at Wettzell.

Keywords automation, smart observatory, central monitoring

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1 Introduction

The consequence of an increasing number of antennas in the global VLBI network is increasing costs for operation and maintenance. A local estimation of workload at the Wettzell observatory — planning observations which run 24 hours, 7 days per week — showed that the available staff is not enough. The key feature to solve this dilemma is automation ([Neidhardt(2017)] page 505 f.). While the estimation discussed the principle of shared observations where the responsibility for a session is handed from observatory to observatory to always keep one responsible human operator, administrative regulations, and restrictions, reduce the realization of such a plan to a minimum. But mechatronics and computer techniques are meanwhile sophisticated enough to run sessions completely autonomously.

2 Autonomous Observations

The staff at the Wettzell observatory continuously improves existing scripts to extend automated support of routine tasks. Currently, a script “autodrudg.pl” is used to fetch schedule files from the central data servers, to prepare them for the local session, and to adapt specific parameters to local implementations. Further scripts are tested to support other tasks of an operator during a session. The goal is to prepare everything for an automated and at least autonomous operation of radio telescopes including:

1. Checking for sessions
2. Local prioritization and planning
3. Fetching of session schedules

4. Local preparation (drudg)
5. Local adaption and recorder selection
6. Automatic startup
7. Observation status notification
8. Quality and alarm management
9. Post-processing and archiving

A test version of the script “autodrudg.pl” mentioned above is able to search for new schedule files in IVS, European VLBI Network (EVN), and domestic schedule archives via File Transfer Protocol (FTP). There are additional plans to include combined master plans with session details and prioritization to optimize the search. The script downloads the files, runs the program “drudg” of the NASA Field System with predefined settings, and, for example, adapts recorder settings to select a specific server location for the recording on Flexbuff systems. This optional location reduces manual copying from Mark 5 modules to e-VLBI servers. The results of this first step are antenna-specific “SNAP” and “PROC” files for the NASA Field System, which can be used to run the observations.

Using these SNAP files, a list of startup commands can be created which are time-tagged so that the NASA Field System calls them at the predefined time. This means, that the session automatically starts at an individual antenna at the right time. The rest of the observation is already automated by the Field System.

While information like dewar, cable, and meteorology monitoring are already integrated into the Field System, additional, centralized site monitoring also collects these data in parallel. Trigger levels are used to identify the health state of the system (see next section). Additionally, available sensors at the Wettzell observatory also support automatic status notifications. Cloud coverage can be derived from Nubiscope data. Different rain sensors offer status information about rain situations. Several wind sensors support the detection of necessary wind stow scenarios. Derived offsets between the clocks compared to one observatory-wide master clock allow automatic identification of clock jumps. All data can be combined to create regular status entries in the log file or to produce start, emergency, and stop e-mails sent to the Data Centers.

After finishing an observation, an additional script does the post-processing, including the sending of log files to central services, to bring the antenna into stow position, or to archive local, session-specific files.

Currently, several tasks are still in the hands of the operators, because the scripts are not yet combined into one system. Nevertheless, several tests showed good performance, so that the implementation is promising. To reach the goal of complete autonomy, most of the safety and security relevant tasks were implemented in the antenna control unit and therefore certified by an external company. It is quite important to keep the overview about the health state of each radio telescope and connected equipment.

3 Central Site Monitoring

While automatic observations are already more or less possible, a very important aspect is the collection and interpretation of system data to permanently derive the health status. The current risk planning and management knows four priorities of hazards:

1. hazards to humans: humans can be hurt or killed
2. hazards to systems: system can be damaged or destroyed
3. hazards to products: sessions/data can be corrupted or completely lost
4. hazards to product quality: data sets can be bad or unusable

While the systems must always keep a safe and secure situation without interaction, sensor and system parameters are permanently collected, explored, and logged (see Figure 1). For example, when rack temperatures reach a maximum limit, the automatic emergency system of the racks opens the doors while the parameters are independently collected and interpreted to notify staff or the security guard at the entrance gate. To do this, the monitoring enterprise software “ZABBIX” is used ([Zabbix(2018)]).

All collected data sets are logically grouped and hierarchically combined, so that triggers which identify critical severity states can directly be assigned to locations (see Figure 2). The current monitoring system just uses three severity states: “not classified” (system is ok), “warning” (system is stable but a parameter reached a limit), and “high” (system reached a critical state and requires human interaction). Some of the triggers are also a combination of conditions with different values, so that consecutive errors can be defined.

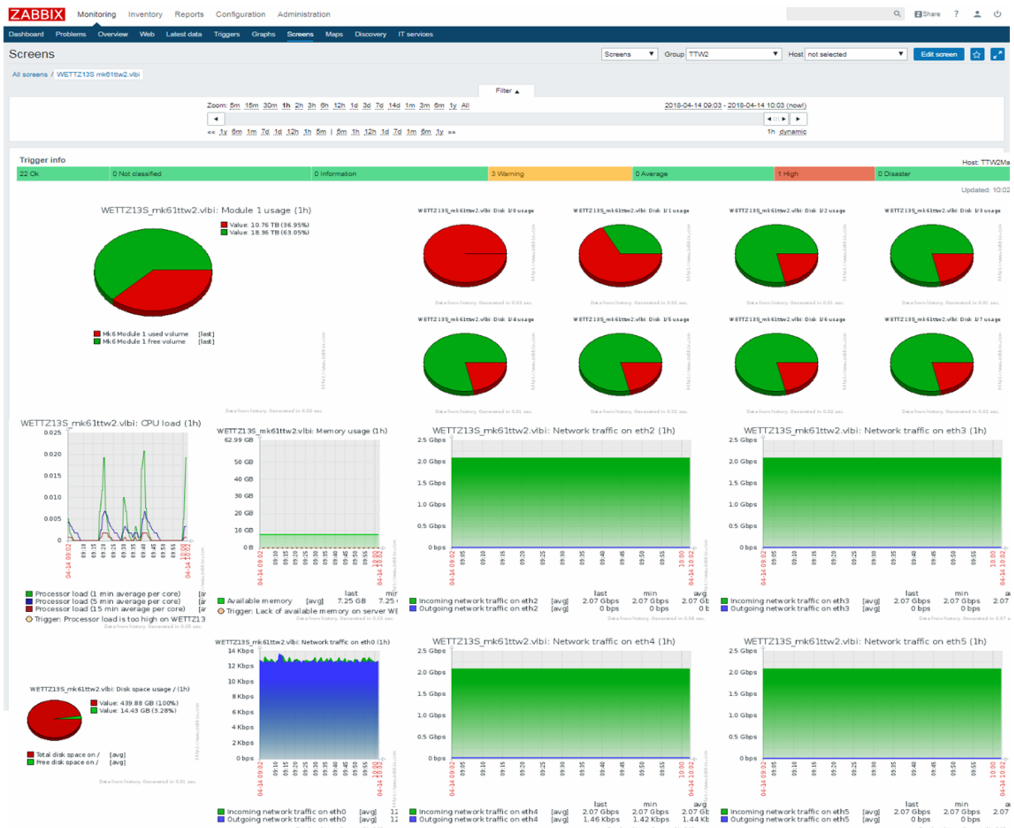

Fig. 1 The central system monitoring Web page for a Mark 6 at the Wettzell observatory.

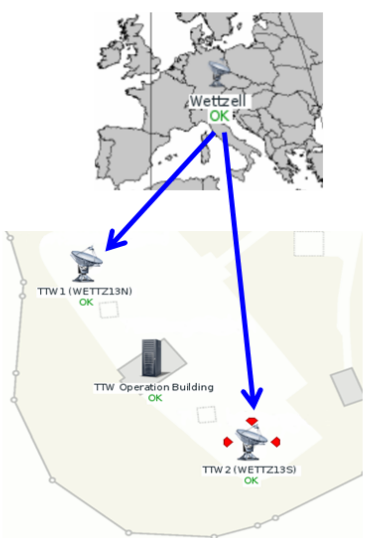

Fig. 2 Hierarchical and logical grouping of system trigger.

The states are presented on maps, which are interactive network diagrams showing relationships and structures of monitored systems. Additionally, it is possible to send out e-mails or short messages via mobile phone. Staff at the Wettzell observatory made some experiments with the Private Branch Exchange (PBX) software “Asterisk”, to send out converted Voice-over-IP messages over a Session Initiation Protocol (SIP) connection. Using the text-to-speech program “pico2wave”, text messages with error information can be sent as audio messages to phones. Staff which is on stand-by for emergency duties can receive such calls. These operators can use the ZABBIX front-end to get more details about the situation and the remote control software “e-RemoteCtrl” ([Neidhardt(2013)]; e.g., also in the new Web-based version) to get remote access to the system. Most of the problems can be solved with this remote maintenance.

4 Central Coordination (& Control)

Having central site monitoring also opens the door to global monitoring of complete VLBI networks with several antennas. If system health states and also quality parameters are available at a Data Center, it is possible to plan capacities or to react to changed conditions, e.g. if one site is influenced by bad weather. Attempts like dynamic observing (see [Lovell(2016)]) necessarily require complete information about network stations to run central negotiations and to prioritize tasks. Responsible schedulers, correlator staff, or analysts can be informed automatically to improve the quality of sessions. Received data can be stored and archived for later analysis.

Archiving data is also the intention of a central server for seamless, auxiliary data ([Neidhardt(2015)]). Because not all telescopes support ZABBIX, "e-RemoteCtrl" supports a way to send out data in the form of Web pages to be parsed and organized by scripts on the central server. Tests with the antennas of the Wettzell observatory are promising. Values which are available in the shared memory of the NASA Field System can be used. ZABBIX is used for a simple plotting of the data on the central server, while the data are also stored in daily files to be used or converted for further analysis steps.

5 Conclusions and Outlook

The telescopes of the Wettzell observatory are on a good path to be operated in a completely autonomous way. Central monitoring always gives a complete overview of the system details and does the notification if critical limits are reached. Safety and security issues are managed by the antennas. The central monitoring has huge benefit for the whole VLBI network, to support sophisticated observation strategies. Similar solutions are currently also implemented for the laser ranging systems of the Wettzell observatory. All of these techniques together are the basis for a "smart observatory", which also makes some decisions without interaction of a human being.

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