JUMPING JIVE

Project ID: 730884

Completed monitoring schedule

Deliverable:	D8.6
Lead beneficiary:	TU München
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Dissemination level:	Public

Introduction

Very Long Baseline Interferometry (VLBI) is a complex radio-astronomical observing technique. Individual radio receivers, geographically widely separated (spanning continents or the whole earth), collect electromagnetic radiation from celestial sources at very precisely defined frequency bands, digitize those signals, time-stamp them with sub-microsecond accuracy and record them to persistent media. In order to detect the weak celestial sources, the time- and frequency stability requirements are so stringent that only a Hydrogen maser clock, which deviates 1 second per 3 million years, suffices.

The performance of any VLBI network of radio-antennas critically depends on the observation of interferometric “fringes”. A fringe is a prominent peak in the combined computed signal that indicates that the data from the participating telescopes are properly synchronized to the exacting standards explained above in both time and observing frequency. Without these fringes there is no science: the instrument (the VLBI array) is not working. Specifically, it is not an exaggeration to say that there are numerous reasons why fringes are *not* observed but, literally, only one way to succeed.

In practice things are not always working as planned, sometimes cables are connected the wrong way around, or the earth’s atmosphere causes extra distortions to the signal due to temperature or pressure-dependent properties that must be compensated for. A fair fraction of the scientist’s time is spent in diagnosing why there were no fringes observed, why the signal is not *optimal* and whether there is a chance of fixing that. Several error categories can be fixed afterwards by rerunning the analysis software with different parameters and/or applying different calibration values, but not all.

This is where this deliverable – monitoring systems installed at the Wettzell observatory for station monitoring and at the Joint Institute for VLBI ERIC (JIVE) for network monitoring of the European VLBI Network (EVN) – comes in.

In order to be able to fix VLBI observations after the fact, as many details as possible about configuration and performance or properties of the many systems involved at a radio telescope must be recorded. Having access to the time series of many monitoring points to know exactly what happened during the observation allows a much quicker diagnosis of where (or why) problems with the data are expected and can reduce the time spent on attempting to fix the data, or focus the time spent on the appropriate error category.

Another very important feature of an extensive monitoring system is to provide insights into the telescope’s state and performance and can even be a critical component in providing a safe working environment for the on-site staff. The possibility of enabling remote monitoring thus increases reliability and reduces the dependence on on-site staff.

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Monitoring system

Our approach to remote monitoring of radio telescopes started with e-RemoteCtrl in 2008. The *e-RemoteCtrl* software developed at the TU München (TUM) is a software system to allow remote monitoring and control of radio telescopes under control of the NASA Field System software[1] (FS). The FS configures, drives, and monitors the VLBI equipment at radio astronomical telescopes. Not all on-site equipment relevant for the observations is under direct monitoring-and-control of the FS. *e-RemoteCtrl* is an overarching system that, in its latest version, allows extraction of FS monitored values as well as monitoring individual web pages for any equipment deemed relevant to the site operator. Nevertheless, e-RemoteCtrl is just one implementation of monitoring used for the system delivered by JUMPING JIVE.

Said monitoring capability is built with a specially developed toolset around the general-purpose Zabbix[2] monitoring system. The Zabbix core allows ingress of time-stamped measured values of *probe points* without attaching any meaning to the measured value. At heart it is a timeseries database allowing the user to name each sequence and build dashboard/overview pages with graphs and maps and add alerts/warnings (trend analysis) to provide the most useful status overviews, i.e. adding meaning to the numbers of the monitored equipment.

The toolset developed at TUM contains a restricted shell to allow only specific commands to be executed remotely and to inject the data into a remote server over a secure (encrypted) channel; the e-RemoteCtrl extension; helper scripts and programs to extract monitoring values from non-standard Zabbix supported data sources; pre-configured data templates; and maps as overview dashboards.

This deliverable has the following parts:

1. Installation and configuration of the operational software at two sites: the Wettzell Geodetic Observatory in Wettzell, Germany, and at the Joint Institute for VLBI ERIC in Dwingeloo, The Netherlands;
2. connecting EVN stations to the monitoring server;
3. verification of the operation of the central monitoring system.

An extensive and detailed report on the TUM project, toolset and installation, including the configuration instructions, is available as well. The specific report is not included in this document but can be downloaded from:

https:/vlbisysmon.evlbi.wettzell.de/monitoring_archive/documents/

[1] https://ui.adsabs.harvard.edu/abs/2000ivsg.conf...86H/abstract
[2] https://www.zabbix.com

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Installation

TUM has had a monitoring-and-control system running for a long time already at the Wettzell Geodetic Observatory. This system evolved in parallel with the *e-RemoteCtrl* software: successive developments expanded its usefulness and required the monitoring system setup to change accordingly. As such, new releases just focussed on improving the central monitoring server with ZABBIX.

The original plan for the JIVE installation was for TUM staff to purchase a server and subsequently travel to The Netherlands to perform on-site installation and configuration of the centralized monitoring system for the EVN in May 2020. The COVID-19 pandemic regulations effective in The Netherlands from March 16th 2020 impeded those plans.

After discussions between experts at Wettzell and JIVE, it was concluded that a better, cheaper, and more sustainable ("green") approach to providing a monitoring server at JIVE could be arranged. At JIVE, many critical services are running on Virtual Machines – independently running operating systems sharing a single hardware platform ("the VM cluster"). The plan became to consolidate the central monitoring server on the same platform, implying that no new server needed to be purchased. This immediately translates to no extra power consumption needed nor extra cooling required. Another benefit is that the VM cluster is set up as a high-availability cluster: critical services can be seamlessly migrated from one server to the other to guarantee continuous operation.

The Zabbix monitoring system has requirements on storage speed and volume, specifically in the case of multiple stations that send monitoring data every second. Both of these requirements could be addressed by expanding the VM cluster with a number of fast Solid-State Disk drives (SSDs) and assigning this storage to the central monitoring server. This expansion investment was significantly lower than the budgeted amount for a full server, which typically includes a chassis, CPUs, memory, network and storage subsystems.

A new VM was configured on the expanded cluster and the Zabbix core software installed. After assigning an external IP address, registering a public name for the server (`evn-monitor.jive.eu`) and acquiring a cryptographically signed security certificate for `https` and `ssh` access, external access to the machine could be granted to TUM staff and stations.

TUM staff, in cooperation with local JIVE staff, finished the configuration and installation of the Zabbix server, the webserver, and the TUM toolset using secure remote access.

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The delivered monitoring servers are available at the following URLs. A limited set of monitoring data is exposed[3] when logging in using the guest credentials.

https://vlbisysmon.evlbi.wettzell.de/zabbix/

guest credentials: IVS Guest/IVS Guest

https://evn-monitor.jive.eu/

guest credentials: EVN Guest/EVN Guest

Adding more stations

The developed monitoring system allows individual telescopes (or "sites") to participate in one of three levels: basic, standard or premium. These are increasing levels of involvement in how much monitoring data is shared with the monitoring system and through which mechanism.

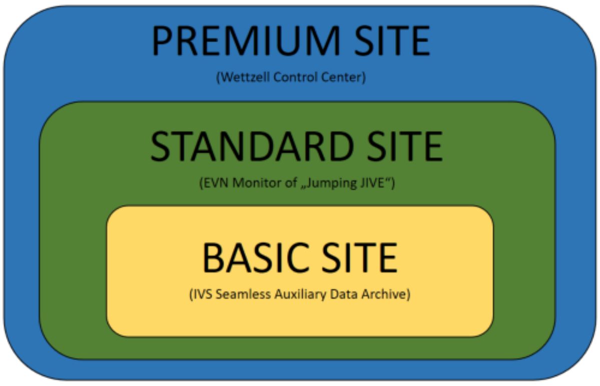

Figure 1 Participation levels for sites; a basic site monitors only a small set of values at very low system integration whilst premium sites can monitor anything but require a much deeper integration of the monitoring system into the local control infrastructure

With successive levels of involvement come more integration between the site and the (centralized) monitoring service. The payoff is that with successive levels of involvement the local usefulness of the monitoring system also increases; e.g. moving from basic to standard means that HTML status pages and alarm triggers for FS errors become available for use also by local staff. The advantage of providing a full system status and error overview in a single HTML/webpage cannot be underestimated, see the image below.

[3] The system can reveal source properties from a running observation that violate the EVN Data Access Policy – specifically the 1-year proprietary access to the data reserved to the P.I. of an observed proposal.

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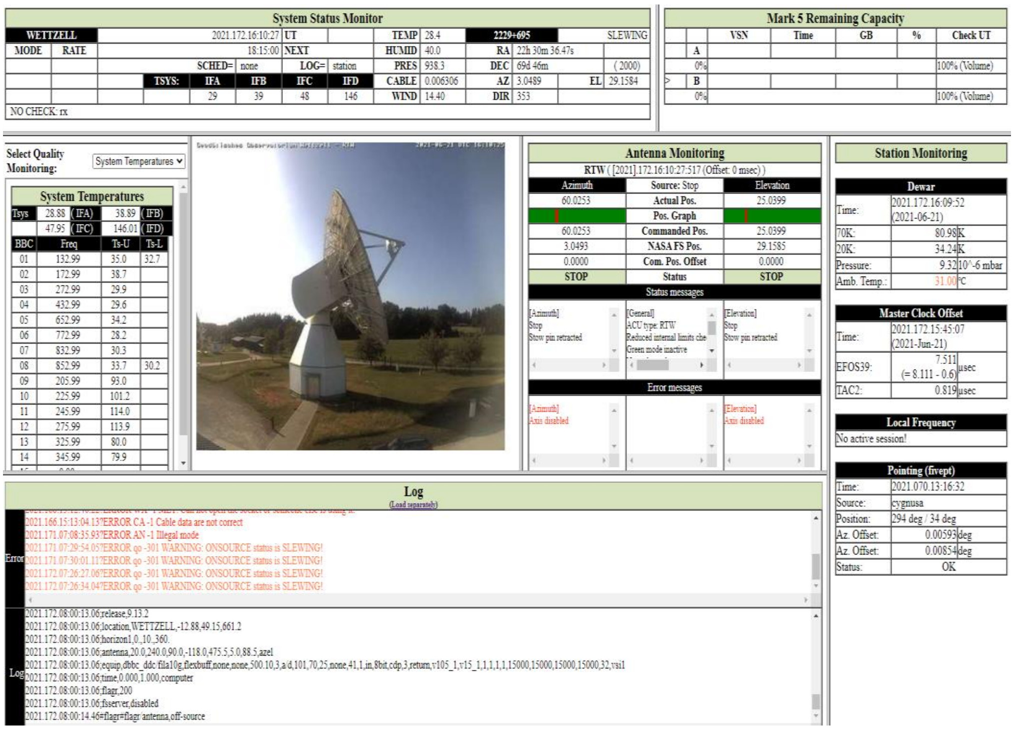

Figure 2 Single HTML/web page system status and error overview

The goal is to have all EVN stations added as Standard sites. To lower the barrier to entry into the centralized monitoring system and debug the setup, a limited set of stations will be invited to share some of their monitoring data with JIVE as basic sites initially.

Figure 3, a zoomed-in screenshot of the EVN monitor after logging in with the guest credentials, immediately shows the usefulness of a monitoring system. The Onsala telescope (Sweden) has been added to the centralized EVN monitoring configuration but no actual monitoring data (in this case, meteorological) has been received, whilst the Wettzell site is submitting monitoring data as expected. It is exactly this kind of at-a-glance overview – and the ability to dig deeper in case of errors/problems – that is the power of a (centralized) continuous monitoring system.

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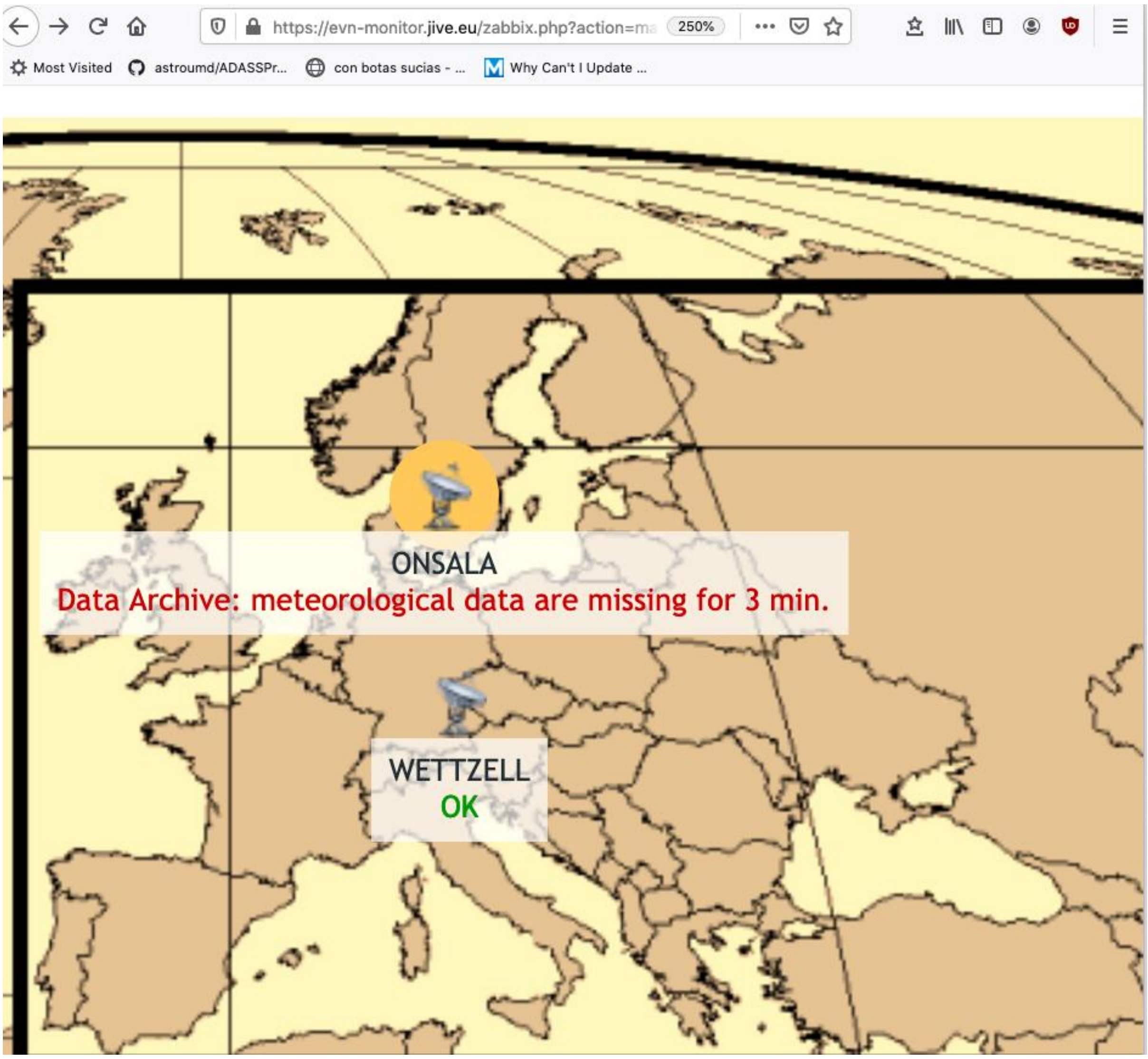

Figure 3 The monitoring service knows what it expects and not receiving it counts as an error too. Being informed about the lack of data is a powerful diagnostic.

A third site (Medicina, in Italy) is in the process of being added to the monitoring system at JIVE; staff at both ends need to build up experience with the steps to add and configure a new station. It is expected that future additions will proceed smoother because of increased experience and potential development of extra helper tools.

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Verification of the services

The Wettzell station's monitoring data served as the initial test site in migrating the single-site monitoring system to a centralized system for the EVN. During the start-up phase, some issues were identified linked to the software being deployed on a slightly different, remote, server with slightly different versions of the operating system and Zabbix software. These issues were readily fixed as these do not usually affect the structure of the program but only the environment in which it runs.

Figure 4 shows a screenshot of continuous monitoring of the Wettzell data observing time (DOT) clock offset value with respect to the GPS[4] clock as a function of time since the 21st of May 2021 on the JIVE monitoring system. Zooming in on the sequence several things can be observed:

- the sequence is continuous, the monitoring data is recorded without (obvious) interruptions, verifying that the monitoring system is working continuously;
- there is one big outlier (marked in red, "Clock jump"), something must have happened there, and this is one of the reasons why continuous monitoring is important; and
- there is a clear trend of the monitored value as a function of time: the slope of this specific line is exactly the information scientists need to take into account when trying to find *fringes* for an experiment.

It is safe to say that the centralized monitoring system at JIVE has been up and running since May 21st 2021 without interruption. Adding more EVN sites should not change this behaviour as these will be using the same mechanism to inject data into the system.

Another way of verifying the operation of the monitoring system is to inspect the update frequency of the values that are monitored. Any disruption in the service will show up as a deviation from the regular update frequency. Figure 5 shows the update frequency for the temperature monitor point, showing the update frequency distributed around 60 seconds. The spread in update frequency by several seconds is easily explained by the fact that the transmission of the value from Wettzell and injection into the database at JIVE does not happen instantaneously and is subject to operating system scheduling noise and script run time differences at both ends of the link.

[4] The Global Position System broadcasts time signals that are used as global reference clock between the sites

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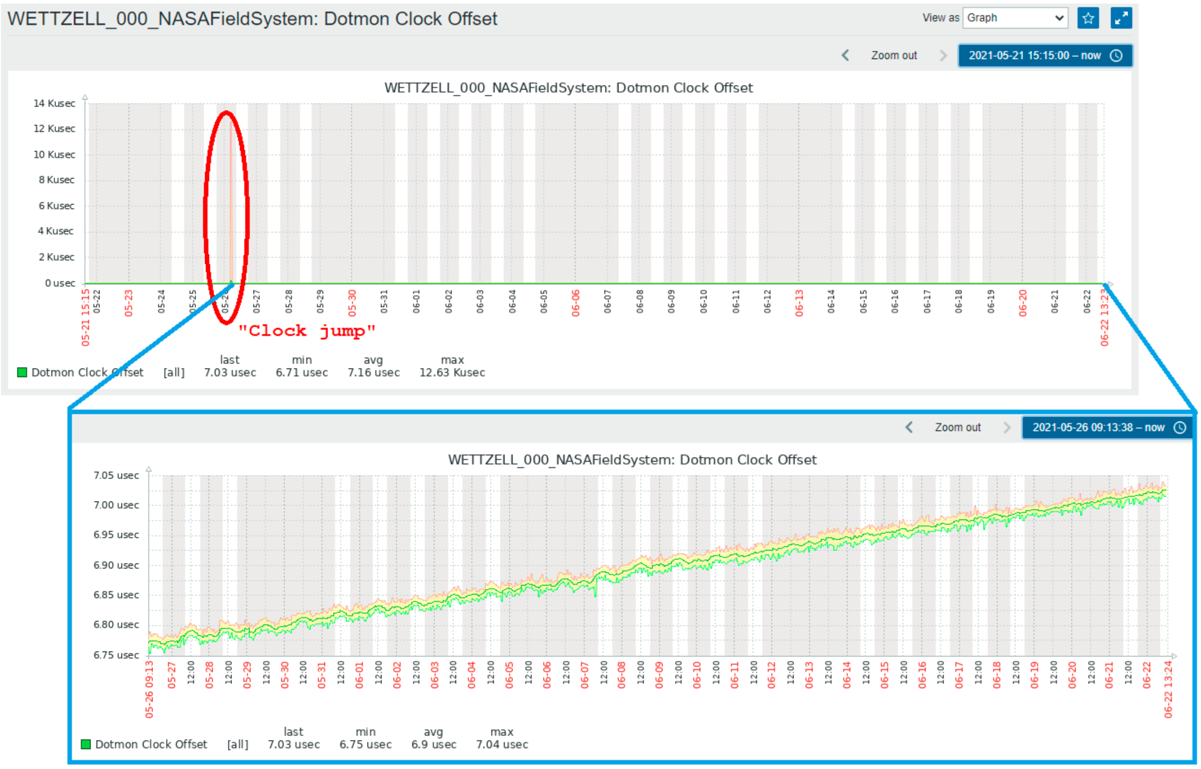

Figure 4 Continuous monitoring of the Wettzell DOT clock offset in the JIVE monitoring system

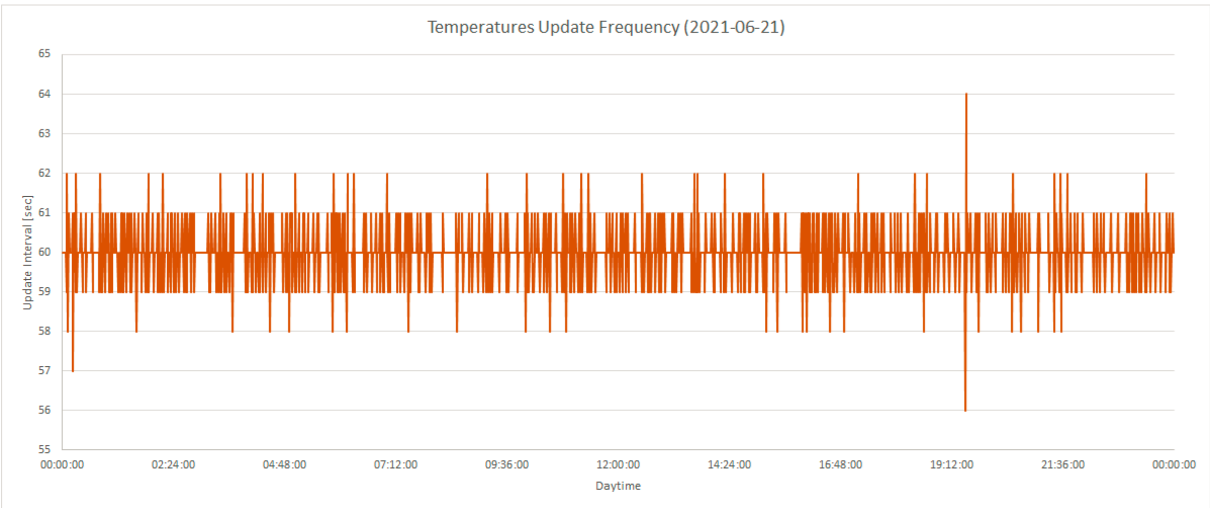

Figure 5 Update frequency of the temperature monitoring point as a function of time of day, showing very regular updates

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