New System For Tokamak T-10 Experimental Data Acquisition, Data Handling And Remote Access

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Abstract. For carrying out the experiments on nuclear fusion devices in the Institute of Nuclear Fusion, Moscow, a system for experimental data acquisition, data handling and remote access (further "*DAS-T10*") was developed and has been used in the Institute since the year 2000. The *DAS-T10* maintains the whole cycle of experimental data handling: from configuration of data measuring equipment and acquisition of raw data from the fusion device (the *Device*), to presentation of math-processed data and support of the experiment data archive. The *DAS-T10* provides facilities for the researchers to access the data both at early stages of an experiment and well afterwards, locally from within the experiment network and remotely over the Internet.
The *DAS-T10* is undergoing a modernization since the year 2007. The new version of the *DAS-T10* will accommodate to modern data measuring equipment and will implement improved architectural solutions. The innovations will allow the DAS-T10 to produce and handle larger amounts of experimental data, thus providing the opportunities to intensify and extend the fusion researches. The new features of the *DAS-T10* along with the existing design principles are reviewed in this paper.

Keywords: nuclear fusion, tokamak, experimental data, acquisition, remote access.
PACS: 28.52

INTRODUCTION

The experiments on T-10 in the Institute of Nuclear Fusion, Moscow, including the JE (http://t10.fusion.ru/je) carried out in 2006, have proved the T-10 experimental data acquisition, handling and remote access system (DAS) to be effective. The large amount of the data have been collected, stored and presented to the NFI researchers and their foreign colleagues, who have opportunities to access the experimental data locally and remotely via the Internet for data processing and analyzing, using unified program instruments of DAS T-10 and user applications (including MATLAB) connected to T-10 database via DAS program libraries.

DAS-T10 OVERVIEW

The *DAS-T10* maintains the whole cycle of fusion experimental data handling, which can be divided into the stages:

- Setting up and testing the data measuring equipment before an experimental session.

- Measuring the data from the *Device* during the session, buffering the data and saving it to data-files in a shared disk storage.
- Collecting and integrating the individual data-files from the storage, processing the data, adding attributive information, transferring the data to a database.
- Maintaining experimental data archives in the database, providing data export/import/converting operational interface.
- Serving user requests for the experimental data, displaying the data to the users in various presentation ways and access modes.

An outline of the *DAS-T10* design conception with regard to the data handling stages is presented on Fig. 1. A set of software human interfaces is provided for the users, allowing them to control data measuring process and to access the experimental data.

The *DAS-T10* is used for carrying out the experiments on T-10 fusion device in the Institute of Nuclear Fusion, Moscow (http://t10.fusion.ru). The *DAS-T10* has accumulated a large amount of T-10 experimental data, it is intensively used both by the local researchers and by their colleagues from other Institutions. Also, the data from other fusion devices have been imported into the *DAS-T10* database and are used by the researchers.

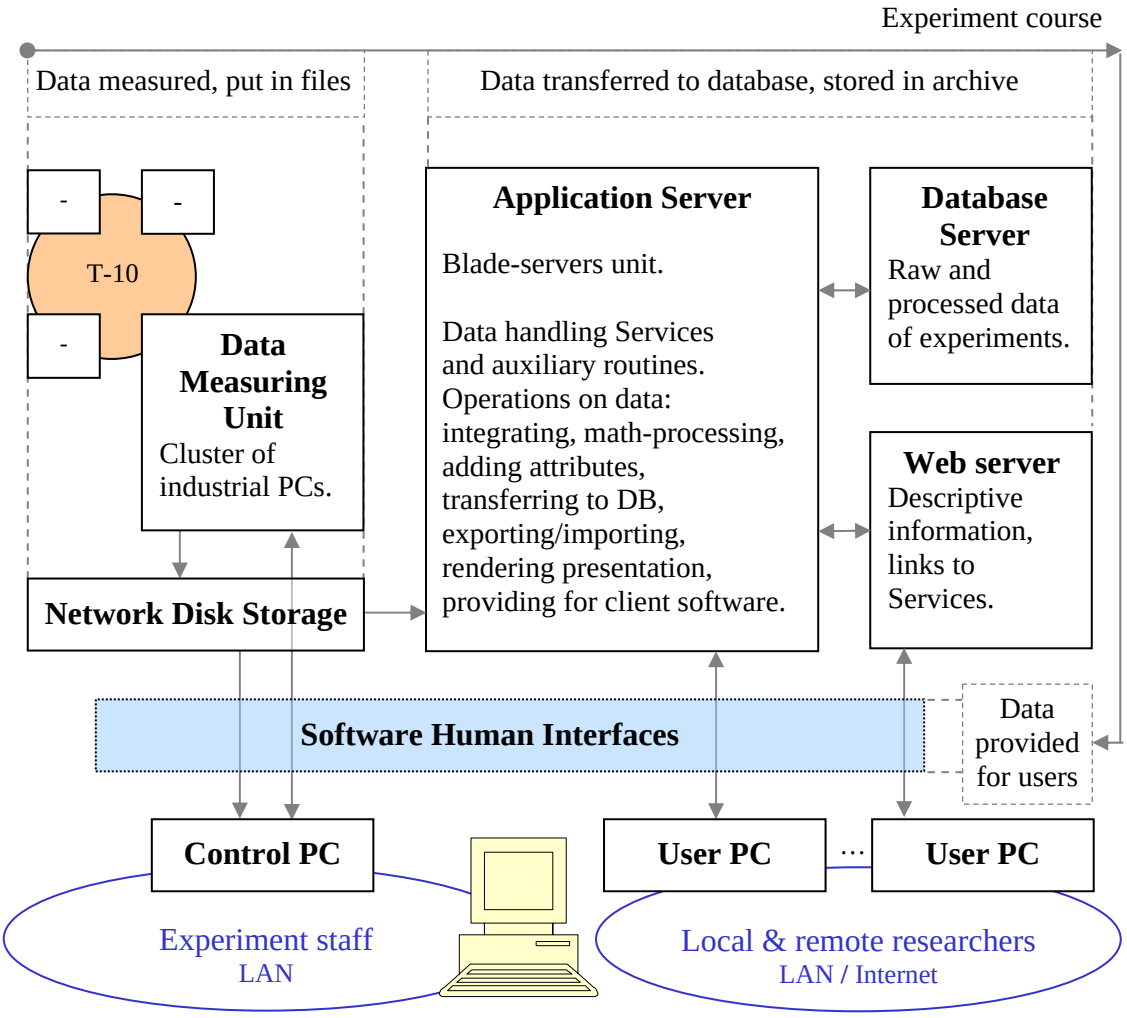

FIGURE 1. DAS-System outline and data handling stages.

DATA MEASUREMENT AND SAVING FILES

The architecture of DAS-T10 is based on parallel data processing. The new equipment is proposed for the *Device* data measurement: clusters (units) of industrial-standard PC-modules boarded with up to 8 ADC cards on the internal USB2.0 bus, totally up to 256 channels for a cluster. The ADC cards have sufficient RAM buffers onboard and can operate at up to 40 MHz frequency (a maximum for individual channels). Being uni-clock synchronized, the modules simultaneously measure the correlated data from multiple channels of the *Device* in the course of an experimental session, thus a distributed parallel data acquisition scheme is implemented. This scheme ensures (1) scalability of the data equipment, (2) high frequency of multiple channel measurement, (3) short time of the preparation for the data providing and saving. The data is saved by the PC-modules to individual *DAS-T10*-specific data-files (*DASFiles*) in the shared fast disk storage, in the parallel mode also.

Data-measuring PC-modules are accessible via network and are subject to manual control, as well as they can follow specific program instructions during the experiment. The scientists and engineers leading the experiment can use the software human interfaces: data measurement control utility ***DASUnit*** for setting up the channels, and data view/analyze utility ***DASTools*** for displaying the experimental data, as soon as it is saved to *DASFiles*. The ability to view the early experimental results makes it possible to control and arrange the experiment more effectively.

DATA STORAGE

As soon as the data portions in the course of an experiment are stored in individual *DASFiles*, a proper *DAS-T10* procedure collects and integrates them into the *current Shot* ***DASFile***, and then transfers it to a database. ***DASSQL*** database stands as a long-term storage for the experimental data. It contains an archive of all the experiments on T-10, as well as the data from several other fusion installations. At present the database contains over $4*10^6$ records (200Gb of data). *DASSQL* database supports full set of SQL operations for data manipulation, allows large multi-type data amounts to be stored and fetched, contains special data structures for facilitating data selection out of broadest data sets assortment.

The experimental data values when stored in *DASFiles* and *DASSQL* database are accompanied with sufficient attributive and descriptive information. The data in the database is hierarchically organized and can be addressed as the following:
Device->Shot->Diagnostic->Header-Record.
A *record* can hold data of various types: linear and multi-dimensional arrays of values, texts, images, video. The *header* contain attributes (meta-data) for defining the type and properties of the data stored in the *record*. The data value arrays are time-scaled/scheduled. It is possible to split long arrays into fragments, thus enabling arbitrary large value arrays to be stored. The data value arrays and the *headers* can be compressed. The data compression and the usage of deliberately designed non-redundant data structures and formats are destined (1) to reduce the storage size, (2) to

raise the performance of data operations, (3) to increase the transfer rate when the data is transmitted over networks.

DASSQL database is capable of effective handling any large arrays of data of any types, which can originate from fusion experiments. The database is ready to accommodate to the increasing data flows to be generated by the new data acquisition equipment. As *DASSQL* database is considered as a storage for the data of different experimental installations, and as its own data are suggested for use by other researchers world-wide, there is a need for additional database management utilities for data export/import/converting operations. These utilities *have been and will be* developed and included to the *DAS-T10*.

APPLICATION SERVER

A renovated concept of an application server (*Appserver*) is proposed for the *DAS-T10*. The functions the *Appserver* is intended to perform are numerous. It monitors the individual *DASFiles* generated by the data measurement modules during the experimental session, integrates them into the *current Shot DASFile*, applies heading information to the data and commits the data to the database server. Interacting with the latter, the *Appserver* performs various tasks on the data handling, which include data selection, insertion, update, converting, math processing. Thus, the *Appserver* implements data control and data providing *Services*, which performs the *DAS-T10* internal tasks and respond to user requests for data manipulation. The *Services* run concurrently, interacting with each other.

In addition to the specific experimental data handling functions, the Appserver can run various mathematic routines to meet user demands in calculations and data processing, particularly a Matlab server can be deployed on the Appserver, which facilitates the collective research works in the labs.

As the range of the tasks is sufficient, the *Apserver* is supposed to be based on a high-efficient hardware platform – the blade-server unit, which stands as a set of computational modules with common power supply and i/o devices set. This solution allows a number of tasks to be performed concurrently and with appropriate efficiency, when the computing load is redistributed among the processors of the unit. Other advantages of the blade-servers are their low space/power demands, high reliability and scalability, meaning that required computing power is achieved by adding/removing the blade-server modules.

CLIENT SOFTWARE AND DATA-PROVIDING SERVICES

After the data have been stored up in the database, a wider circle of researchers can view/analyze the experimental results. As depicted on the Fig.2, the DAS-T10 data can be accessed using various means, both from within the experiment local network and remotely over the Internet. The following software human interfaces can be used for the data access: **DASTools**, a full-featured program utility with a graphic user interface for the data selection and viewing in a rich variety of presentation ways: tables, graphics, scaled views, profiles; moreover, some mathematical data processing can be carried out by the utility with the settings being interactively adjusted. The

utility (1) can run on users local computers with the source data downloaded over LAN or the Internet, when the server-side **DASTCP** *Service* provides the data to the clients, or it (2) can run on the *Appserver* in remote desktop (remote terminal) mode. The latter is more preferable, as it features much less network traffic. In this mode a user is provided with the full program interface, while all the actions (data fetch, calculations and rendering) are performed on the server and the result (the screen image) is displayed on the user PC.

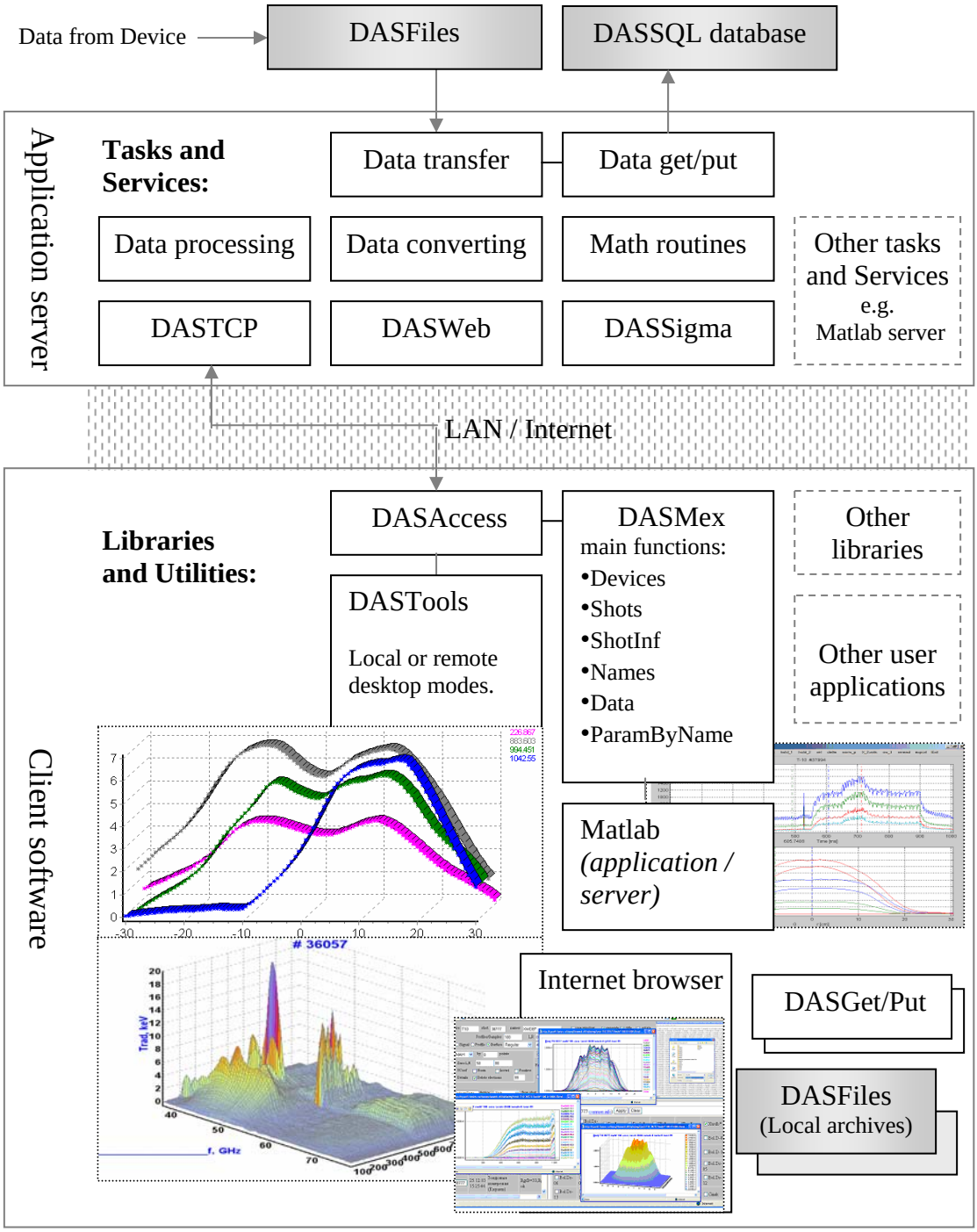

FIGURE 2. Simplified scheme of DAS-Services and client software interactions.

An **Internet browser** with a DAS-T10 specific Web-page, containing HTML-input forms, acts as an interface to request the experimental data from the server for viewing. The data are selected and rendered on the server and the text/graphic results are displayed in the user's browser as HTML-pages, which are transferred over the Internet in compressed format. The data is supplied by **DASWeb** S*ervice* from the *Appserver*.

An **Internet browser** with another DAS-T10 specific Web-page allows users to run certain mathematic routines on the server with user-defined initial data. The calculations are carried out on the server and the results are displayed in the browser. The task is performed on the server by **DASSigma** service.

Other user applications for data view/analysis can integrate **library modules (DASAccess)**, which connect to the **DASTCP** *Service*, receive the data over the network and provide it for the applications. The libraries can be integrated into Matlab, or any Pascal, C++, Python-written software.

The following scheme is used for data exchange between an application and DASSQL database:

{Application – DAS Access} -- Internet -- {DASTCP - DASSQL}

For short access to the DASSQL/DASFile-data from Matlab environment, the set of mex-functions DASMex has been developed:

{Matlab - DASMex- DAS Access} -- Internet -- {DASTCP - DASSQL}

Remote users can access the DAS-T10 data in two ways:

(1) Using remote terminal mode of the Application server, when data selection, processing and visualization are carried out on the server side; this way features high performance and low network traffic allowing large data amount to be transferred.

(2) Using Net-services DASWeb and DASTCP running on the server; the user works via Web-browser or download the data on the local machine for its on-place processing and visualization.

SOFTWARE PLATFORMS

Currently, the *DAS-T10* server components are based on Microsoft Windows software platform. As the existing platform solutions have been proved to be appropriate for the fusion research data handling tasks in the *Institute* for the past years, they remain a basis for the renewed *DAS-T10* and are to meet the requirements of increasing data amounts and processing speed.

The client-side user-specific software for interaction with the *DAS-T10* can run under Windows and Unix/Linux, as the libraries *DASAccess* are provided for the both platforms as DLL and SO files. The *DAS-T10* main data viewer/analyzer *DASTools* is provided for Windows only.

All the program codes of the *DAS-T10* are written in Pascal language.

For diversifying the *DAS-T10* installations, the usage of Unix/Linux platforms is considered by the *DAS-T10* developers. This would extend the scope of the fusion research, involving into it a wider circle of scientists and students from scientific and educational institutions.

SUMMARY

DAS-T10 has proved to be effective in maintenance of the fusion experiments during the years of its being in operation in the Institute of Nuclear Fusion, Moscow. Many existing design principles remain valid for the renewed version of the *DAS-T10*. Some new solutions are going to be implemented:

- The new data-measuring modules combined into distributed uni-clock synchronized structure and connected to the shared network disk storage will allow the larger data amount to be acquired and collected during the experiments, which is estimated up to 10-30 times as much as the current amount.
- The improved database management utilities and the capability of effective data handling will allow the increased amounts of experimental information to be stored and exchanged.
- The usage of blade-servers will provide the appropriate performance and scalability both for the internal *DAS-T10* tasks and for user data requests serving.
- The improved data control/providing service architecture will accommodate to the enlarged and diversified user demands for the experimental data.

The *DAS-T10* new ability to acquire and handle larger amounts of data along with its improved performance will supply sufficiently enlarged volumes of experimental information to the researchers. The *DAS-T10* software human and program interfaces, existing and future, will provide the effective means for the experimental data processing and analysis.

DAS-T10 developers are eager to keep up cooperation with the international community of fusion data-system developers for working out standards and interfaces, aiming at improving the collaboration of different research labs and integration into the global research infrastructure. The new program utilities and services for connections and compatibility with other data-systems can be developed and incorporated into the *DAS-T10*. The technical solutions used in the *DAS-T10* design may be suggested for use in joint fusion research projects.

More information on *DAS-T10* can be found on the Internet (1) and in published conference and meeting materials (2,3).

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