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Abstract. This paper presents a novel integrated architecture of measurement system for the new requirements of measurement collaboration, measurement resource interconnection and transparent access etc in the wide-area and across organization in the context of a grid. The complexity of integration on a grid arises from the scale, dynamism, autonomy, and distribution of the measurement resources. The main argument of this paper is that these complexities should be made transparent to the collaborative measurement, via flexible reconfigurable mechanisms and dynamic virtualization services. The paper is started by discussing the integration-oriented measurement architecture which provides collaborative measurement services to distributed measurement resources and then the measurement mechanisms are discussed which implements the transparent access and collaboration of measurement resources by providing protocols, measurement schedule and global data driven model.

1. Introduction

The remote operation of measurement instruments and devices has a strategic role in many scientific and industrial processes in the phases of data acquisition and data analysis among far sites of wide area networks, which has brought great changes in the network measurement technologies [1,2]. Nevertheless, it is still difficult to share measurement instrumentation and exchange measured data among organizations. Each one has its own security policy and adopts a proper technology in accessing and controlling measurement devices. An effective measurement supporting system, offering interoperability, collaboration, intelligence, dynamic interconnection and seamless access to all the distributed sharing measurement resources, is the main challenge in order to implement the network measurement integration among organizations.

The grid technology seems very promising to meet the requirements of measurement integration in the context of the complexity of the scale, dynamism, autonomy, and distribution of the measurement resources [5]. Based on the integrated measurement environment, measurement resources can be accessed transparently with high interactivity. The relevant grid projects [4] mostly deploy computational environment to meet the resulting data-intensive computational needs by focusing on the extraction of complex scientific from massive data distributed for storage and computation to the scientists but not direct access to the measurement resources online. Yet, another grid projects [6,7] aim to provide common middleware to facilitate access and management of instrumentation, storage and computation resources, exposing them as grid services and the main goals are metadata
description of the instruments and the development of the standard methodology for grid-enabling instruments.

The proposed grid based measurement integration system provides a dynamic and reconfigurable environment for measurement applications, which implements the effective organization of the distributed, decentralized and heterogeneous measurement resources based on the open, scalable and extensible grid measurement architecture. The system encapsulates the heterogeneity of the measurement resources (e.g. devices and invocation interface etc.) and implements the transparency of the resource location and access.

2. Measurement integration architecture

The grid based measurement integration is implemented by encapsulating and organizing heterogeneous measurement resources, grid virtual measurement services and then meet the transparent access needs of users. In this section we present the main components of the measurement integration architecture as is shown in Figure 1.

![Figure 1. Grid based measurement integration architecture.](image)

2.1. Measurement application end (MAE)

Basically, MAE provides three kinds of functions: information exchange, data exchange and dynamic reconfigurable virtual instrument (DRVI) panel [4] to carry out teleoperation to grid measurement services by users.

To carry out measurement access to the global measurement resources, users should submit measurement requests to the grid service process and receive the feedback information (e.g. measurement tasks scheduling information and the subtask executing information etc.) via IEI (Information Exchange Integration). IEI not only encapsulates the measurement requests but parse and analyze the query results and measurement information from the scheduling process.

The AEMS_BUS (Application End Measurement System BUS) is combined with DRVI_tools and Data turbine to provide data buffer pools for client VI, as is shown in figure 2. The AEMS_BUS firstly implements the local data stream drive among the VI pipes built via DRVI_tools; secondly is used as data buffer for the data turbine which is a high-performance multi-channel data driven buffer used to store and stream data from the grid scheduling process. The data turbine provides a uniform interface in concern with the grid system for subscribing to and accessing streaming data originating from the online measurement or the processing nodes during the measurement execution according to the DTP (Data transformation Protocol). This data will be processed by the local VI or permanently stored automatically into the repository.
2.2. Virtual Measurement Services (VMS)
The grid provides a dynamic open measurement service environment with extensible and scalable mechanisms which can accept more organizations and more measurement resources; secondly provides the more effective resource management schema which implements resource interconnection, query and location; finally implements the global data drive, as is shown in Figure 1 and Figure 7.

In the grid environment, measurement system integration services (MSIS) provide the core services for the global measurement applications. The measurement information integration management (MIIM) of MSIS implements the resource register and update globally according to the notification of the measurement resource nodes. In addition, MIIS provides query services to execute the query request for users and measurement scheduling services.

In fact, measurement teleoperation control protocol (MTCP) plays an important role in remote control to physical heterogeneous instruments and devices with the uniform access schema. The AE, MSIS and measurement services must read the MTCP to exchange measurement requests and the dynamic executing information of the sub-tasks. In addition, MSIS provides data driven mechanisms for users to subscribing to and access streaming data originating form measurement instruments via Measurement Streaming Data Services (MSDS) with a uniform interface. Streaming data allows users to observe and analysis the raw data or results remotely as the measurement activity take place. The core services of MSDS provide a subscription interface to the data streams available at a given node.

2.3. Measurement Services (MS)
The distributed measurement instruments and devices present heterogeneous, dynamic and autonomous in independent authorization and access mechanisms to carry out transparent access and provide effective multi-user measurement services, the measurement services must provide open and uniform access interfaces to all the sharing measurement resources.

The measurement services provide two kinds of components: static service and dynamic service components, as is shown in Figure 1. The components such as MRRS (measurement resource register services), RAIE (resource access interface encapsulation) and MRM (measurement resource monitor) are combined to wrap the local physical instruments. MRRS provides information services which register the resource information (e.g. access constraint, service interfaces, status and even addition and deletion of the resources) via MRM to the parent resource management dynamically. RAIE masks the heterogeneous measurement instrument by providing uniform invocation interfaces to implement the transparent access to the DUT (device under test). Yet, the components of MRSS (measurement resource scheduling service), MTM (measurement task monitor) and MIDE (measurement information and data exchange) are work together to execute the measurement invocation. The MRSS creates concurrent measurement services for multi-users, and then MIDE exchange the execution information of the measurement tasks monitored by MTM and creates pipes between local resource node and data driven portals created by virtual measurement services to transfer the measurement data. In addition MRSS provides resource queue and reservation and share mechanisms to ensure the measurement process exclusively.

3. Measurement mechanism and implementation
The measurement requests are implemented in terms of grid virtual services and measurement services based on MTCP. In this section, we describe the measurement mechanism to be used to carry out the
proposed measurement targets based on the grid measurement integration environment accompanied with an instance of multi-laboratory collaboration.

3.1. The virtual measurement schema (VMS)
As shown in Figure 4, the measurement schema comprises two principal components: Virtual Instrument Catalog which provides global measurement services of sharing resource; MTCP Interpreter and scheduling services which implement a variety of measurement tasks in terms of invocations to virtual instrument catalog operations.

The virtual measurement applications are reconfigured dynamically in the grid environment when the users login successfully. The grid creates a measurement serving process on the grid server which assigned by the load adjustment mechanism of grid. The users can access the measurement resources and exchange data with the distributed measurement environment via the standard and uniform MTCP, which is transaction-based and supports both information query which carries out the location and discovery of measurement resources and requests definition statements to schedule the measurement tasks.

The VMS defines a set of relations used to capture and formalize descriptions of how a measurement task can be executed, and to record its potential and/or actual executions. The entities of transactions, schedule and measurement services are as following:

A transaction is a set of measurement tasks implemented by submitting requests. Associated with a transaction is information that might be used to characterize and locate all the included tasks and information needed to invoke them (e.g. parameters, arguments.).

A schedule service presents an execution of a transaction, which presents an ordered sequence of invocations of a number of distributed measurement resources with right order and proper parameters.

Measurement services provide the standard interface according to the resource mapping mechanism which wraps the hardware resources. The services are implemented via multi-user ways based on multi-thread programming and execute measurement tasks according to the MTCP.

3.2. Measurement protocol and implementation
This section introduces MTCP according to measurement collaboration among laboratories. Actual measurement operation is implemented by submitting the measurement requests to the scheduling process, and all the subtasks included in the transaction must be described in MTCP and then to be scheduled at the matching measurement resource nodes. Figure 5 presents the protocol formats of the measurement requests based on MTCP.

The following statement defines a transaction to carry out remote measurement on acceleration of both rotary machine experiment system and compressor experiment system distributed in Huazhong
University of Science & Technology and Wuhan Institute of Technology with uniform measurement service interface.

| Protocol | Res_Info | Meas_Parameters |
|----------|----------|-----------------|
| Type     | Key      | Res_Name        | Paras | pTimeout | stdout |
| Node_Name|          | ResID           |       | tTimeout |        |
|          |          | Meas_Point      |       | mTimeout |        |

Figure 5. Requests formats of MTCP.

```xml
<?xml version="1.0"?>
<SysJob TransName="Trans_name" Type="2">
  <Request>
    <Task Protocol="Meas" NodeName="MG_HGIM" ResName="EQU_ROT"
      ResID="ROT_VA" AccPara="t/fs/len" TP="pT/tT/mT" stdout="url">
    </Task>
    <Task Protocol="Meas" NodeName="MG_WITPM" ResName="EQU_COM"
      ResID="COM_VA" AccPara="t/fs/len" TP="pT/tT/mT" stdout="url">
    </Task>
  </Request>
</SysJob>
```

The definition reads as follows. The second line assigns the transaction a name “Trans_name” with the request type. The node of “Request” of the definition lists all the sub-tasks that will be executed on resource nodes. Each sub-task node comprises task attributes (e.g. protocol, node name, res-name, resID, and invocation parameters etc.) which will be interpreted by MTCP interpreter of the schedule process. The “protocol” of attributes presents the command code and the “stdout” is used to specify a standard output port which the online measurement data will be directed. The executing process of the given example is presented in Figure 6.

With the benefit of the distributed barrier approach, as is shown in figure 6, we can show the feasibility of the system. The scheduling process is started to send resource query requests to all the resource nodes for resource status and access authorization (e.g. res_info1, res_infor2). Then all the sub-tasks will be scheduled and executed by relative measurement services. In the measurement integration, we propose two kinds of data driven pattern via data turbine: one is peer to peer model which transfers the measurement data to the AE directly, another is indirect pattern that is the measurement data is directed to another analysis nodes, data repertory and multi-user collaborative data exchange nodes to implement synchronizing collaboration among users (e.g. data-stream).

3.3. The data driven model of measurement integration

The execution of the multi-tasks is implemented via scheduling services (SS) and measurement services (MS). Generally, the measurement tasks are distributed at several resource nodes and the data exchange with Application End are carried out by data driven mechanisms scheduled by SS.

Figure 6. MTCP implementation.

Figure 7. Global collaborative data driven scenario.
Measurement is data centric. Figure 7 shows the global data driven scenario of multi-users and multi-sites collaboration measurement application accompanied with the given example. The pattern is indirect pattern as discussed in 3.2. To implement the data exchange, the SS as measurement coordinator creates data exchange pools according to the measurement tasks. The pools are controlled by the Data Driven Coordinators (DDC) which created two sets of data pipes: DDCs to AE and measurement services to DDCs. The DDCs may be distributed different grid nodes according to the load balance rules and the data buffer pools carry out the synchronizing data exchange between AE and measurement resources.

4. Conclusion
In this paper, the virtual measurement integration system based on grid is presented. To explore the proposed ideas, we presented the integrating architecture with a description on different components of measurement services in the integrating system. To demonstrate the feasibility of the approach, the measurement mechanisms and the relative implementation are discussed in details based on the application of multi-laboratories. The development and application shows that the presented approach can meet the needs of the measurement requirements in measurement resource interconnection, collaboration and transparent access etc.

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