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ABSTRACT

Magnetic fusion experiments keep growing in size and complexity resulting in a concurrent growth in collaborations between experimental sites and laboratories worldwide. In the US, fusion experimental research is centered on three large facilities involving over 1000 researchers covering 37 states. In the EU, fusion research is coordinated by EFDA, encompassing some 25 laboratories and several major facilities, including ASDEX Upgrade, JET, and Tore Supra. Collaborative research within each group, combined with collaboration between the two groups is presenting new challenges in the field of remote participation technology. These challenges are being addressed by the creation and deployment of advanced collaborative software and hardware tools. The collaborative technology being deployed is scalable to fusion research beyond the present programs, in particular to the ITER experiment that will require extensive collaboration capability worldwide. This paper compares approaches, reviews the present state-of-the-art in remote participation capability, and identifies areas of work required for the success of future large-scale experiments.

1. INTRODUCTION

Fusion Energy (FE) research is a worldwide effort. As fusion experiments have increased in size and complexity, there has been a concurrent growth in the number and importance of collaborations among large groups at the experimental sites and small-to-large off-site groups. This will continue for ITER, which will have one physical location with have participants worldwide. The increasingly collaborative nature of FE research presents new technical challenges.

This paper presents work that has been done in both Europe and the U.S. on Remote Participation (RP) techniques, discusses where those are presently being used and areas that need further development. This paper is divided into sections discussing Grid computing, advanced collaborative environments, and the collaborative control room. The overall goal of this work is to allow scientists at geographically distributed sites to participate fully in experimental, computational, and collaborative activities as if they were working at a common site.

2. GRID COMPUTING

Grid computing refers to the large–scale integration of computer systems via high-speed networks and advanced middleware to provide on–demand access to data analysis capabilities and related functions not available to one individual or group of machines. To users, the highly integrated networks that embody grid systems are transparent so that services furnished from afar appear to be provided by local computers. This concept is illustrated in everyday life by the electrical power grid. When a user plugs a device into an electrical wall socket, the how and where of electricity generation are immaterial.

For FE research, the vision is a service-oriented architecture in which experimental and simulation data, computer codes, analysis routines, visualization tools, and remote collaboration tools are accessible as network services. In this model, Application Service Providers (ASP) provide and maintain codes as well as the resources on which those codes execute. This mode of operation frees clients from maintaining and updating software, and providers from porting and supporting code on a wide range of platforms. In this environment, access to services is stressed rather than data or software portability. Consequently, the focus is not on desktop computing (e.g. SETI@home) or distributed supercomputing scenarios that are sometimes used to motivate Grid computing, but simply on making the ASP paradigm effective for Grids.

Security. The Internet is an open system, where the identity of the communicating partners is not easy to ensure. One standard security model employs Public Key Infrastructure (PKI) to secure communication on the Internet through the use of a public and private cryptographic key pair that is obtained and shared through a trusted authority. When using a key pair, only one of the keys, referred to as the private key, must be kept secret. The other key, referred to as the public key, can be disseminated freely for use by any person who wishes to participate in a secure transaction with the person holding the private key. This is possible because the keys are mathematically related but it remains computationally infeasible to derive the private key from knowledge of the public key.

Once a user’s identity has been authenticated they are still not given open access to all resources (codes, computers, visualization tools or data). These are made available only to those users who have the proper authorization. Authorization is typically controlled by the resource stakeholder and not by a central authority. The combination of strong authentication and authorization is seen in every day life with the commercial airline industry where the government ID provides authentication and the boarding pass provides authorization.

Implementation. Within the U.S., the National Fusion Collaboratory Project [1] is deploying Grid computing for FE research (FusionGrid). Utilizing the X.509 certificate standard and the USDOE Grids CA (Certificate Authority) to implement PKI for secure communication, FusionGrid has been in production use by U.S. and European scientists for over one year. The implementation of authentication on FusionGrid is accomplished using the Globus Toolkit [2]. Authorization is being deployed using simple relational database technology and secure HTTP communication. To log into FusionGrid, all a user needs to do is issue the *grid–proxy–init* command once per day and type in the password for their private key. This single sign–on is accomplished behind the scenes by the use of a short–lived proxy certificate that is derived from the user's long–term X.509 certificate. The benefit to the user is that they need only log–on once no matter how many different services they desire to use.

EFDA JET has also created their own CA to supply X.509 certificates to their scientific staff and collaborators. The first usage of these certificates is to secure remote access to JET data but this capability is easily expandable to other computational services as required. Different Certificate Authorities can consider themselves as peers and recognize each other's certificates. It is anticipated that the EFDA JET CA and the FusionGrid CA will become peer authorities and that this should be expanded to cover all EFDA laboratories. As the worldwide FE usage of Grid computing grows, additional peer CAs can be added.

Data access on FusionGrid has been made available using the MDSPlus data acquisition and management system [3] combined with a relational database server. In the international fusion community, MDSplus is used at more than 30 sites, spread over 4 continents, and is the de facto standard for data access. Remote access to JET data is now available via an MDSplus interface. The ability of MDSplus to act as a gateway to legacy data systems (as JET does) provides a quick method of allowing remote access to any data system. MDSplus and the Globus Toolkit have been combined to create secure X.509 certificate based client/server data access using the standard MDSplus interface without any loss in speed or functionality.

The code TRANSP, used for time-dependent analysis and simulation of Tokamak plasmas, was released as a service on FusionGrid late in 2002 [4]. Running on a Linux cluster at PPPL, over 4200 TRANSP runs from ten different experimental machines (40% on European experimental data) have been completed within the FusionGrid infrastructure. This approach has drastically reduced the efforts to support and maintain the code, which were previously required of the developers and by users' sites. European scientists have begun to use TRANSP on FusionGrid although this is not yet the default. The implementation details of codes as services on FusionGrid, including TRANSP, have been discussed elsewhere [4]. The general sequence for a scientist to use a code service on FusionGrid is to first prepare and store a code's input data in an MDSplus repository. When ready, a code start command with a pointer to the input data is issued and once the run has completed the output data is written to the MDSplus repository. The entire computational process is followed via a FusionGrid monitoring system [5].

3. ADVANCED COLLABORATIVE ENVIRONMENT

The goal of the advanced collaborative environment is to use computer-mediated communications techniques to enhance work environments, to enable increased productivity for collaborative work, and to exploit the use of high–performance computing technologies to improve the effectiveness of large–scale collaborative work environments. Solutions are being sought that scale from the desktop to large-scale conference rooms. Traditional audio-only teleconferencing and ISDN videoconferencing is being augmented by additional or more advanced services, including IP-based videoconferencing (H.323, VRVS, and Access Grid) instant messaging (IM), presentation and application sharing, broadcast of control room displays, and tiled display walls. Usage examples include distributed task force meetings, remote participation in experimental operations, data analysis meetings, and formal presentations at seminars.

VRVS (Virtual Room Videoconferencing System) [6] is a web-oriented, low-cost, bandwidth—efficient, extensible means of videoconferencing and remote collaboration over IP networks. VRVS is based on the concept of virtual meeting rooms where participants “gather” as if they were together in the same physical room. VRVS transmits all active video and audio channels to all participants via a network of “reflectors.” Presently, VRVS together with H.323 is being used within EFDA JET for seminar broadcasting and working meetings. Within the U.S., it is being used at DIII-D to broadcast the pre-operations meeting and the control room screens.

Within Europe, IM is being increasingly used as a productivity tool sitting between a phone call and email in terms of asynchronous communication. Initially, the public commercial Yahoo Messenger was used but has since been replaced by a more secure, private service using open-source Jabber protocol. IM has proved valuable for direct communication as well as back channel communication during meetings. The ability to record “conferences” has proved valuable for creating meeting minutes. Note, VRVS comes with its own integrated “chat” capability.

Virtual Network Computing (VNC) [7] allows Internet sharing of a computer desktop with one or more remote clients. VNC is being used to interactively share applications during working meetings, to broadcast electronic slide presentation, and to disseminate control-room displays. VNC has also been incorporated into VRVS to provide fully integrated remote presentation sharing during interactive virtual meetings.

The Access Grid (AG) software [8] provides a complex multi–site visual and collaborative experience integrated with high–end visualization environments. AG nodes range in size from the individual desktop to the very large auditorium size meeting room. Integrated into the AG system is a modified VNC that allows for more efficient interactive sharing of complex visualizations. AG nodes are presently being used in the U.S. for meetings and working group sessions that were previously conducted as phone conferences. Presently a Macintosh OS X AG client is being implemented to go along with the existing Linux and Windows clients. VRVS also has an AG interface allowing non-AG enabled sites to participate in AG meetings.

Tiled display walls are being used to enhance the collaborative work environment of the Tokamak control room. A tiled display wall utilizes multiple projectors tiled together to build a bright, high–resolution, seamless display (Fig. 1) with 16’ x 8’, 20 million pixel displays not uncommon. It offers a larger format environment for presenting high–resolution visualizations or multi–source smaller visualizations to a collaborative group than would be possible on standard displays. In the control room, tiled displays will allow any researcher either in the control room or off–site, with proper authentication and authorization, to share any X–windows based visualization, with the entire control room. For scientists within the control room, this interactive shared visualization takes the place of “passing around” a graphical printout or “calling over” scientists to collaboratively view a normal desktop display. For scientists off–site, this service gives them the capability to interactively share visualizations and participate in experiments, something previously not possible. The software, as designed, requires no special hardware by the remote scientist and they can therefore share pieces of the larger control room display wall on their single desktop display.

Fig. 1. Tiled display walls create a unified large high-pixel count display that facilitates large group sharing of information as is required in a Tokamak control room.

4. COLLABORATIVE CONTROL ROOM

The collaborative control room supports the cyclical nature of experimental fusion research. Typically, in any given day, 25–35 plasma pulses are taken with approximately 20 to 30 minutes between pulses. Adjustments to the hardware/software plasma control systems are debated amongst the experimental team. Decisions for changes to the next pulse are informed by data analysis conducted between pulses. This mode of operation places a premium on rapid data analysis that can be assimilated in near-real time by a geographically dispersed research team. To be fully functional, the collaborative control room requires (1) secured computational services that can be scheduled as required, (2) the ability to rapidly compare experimental data with simulation results, (3) a means to easily share individual results with the group by moving application windows to a shared display, and (4) the ability for remote scientists to be fully engaged in experimental operations through shared audio, video, and applications.

The realization of the collaborative control room is dependent on technologies discussed previously. Secured computational services and data can be made available via a worldwide FE Grid. Sharing results within a large group requires a large, high-pixel-count, display like that achieved by tiled displays. To fully engage remote scientists requires an advanced collaborative environment like that being created by VRVS/H.323 or the AG systems. The time critical demands of the control room combined with the need for all of these technologies to be smoothly integrated together makes the Collaborative Control room the ideal proving ground for future technologies.

Pieces of the Collaborative Control Room are being used and tested in present day experiments. JET has run several sessions with remote participants assisting in control-room activity. Most notably, technically, a scientist located at DIII-D was the scientific coordinator on JET utilizing an AG node at DIII-D connected to a VRVS station in the JET control room with data being made available via an MDSplus interface (Fig 2.). Later this system was reversed with

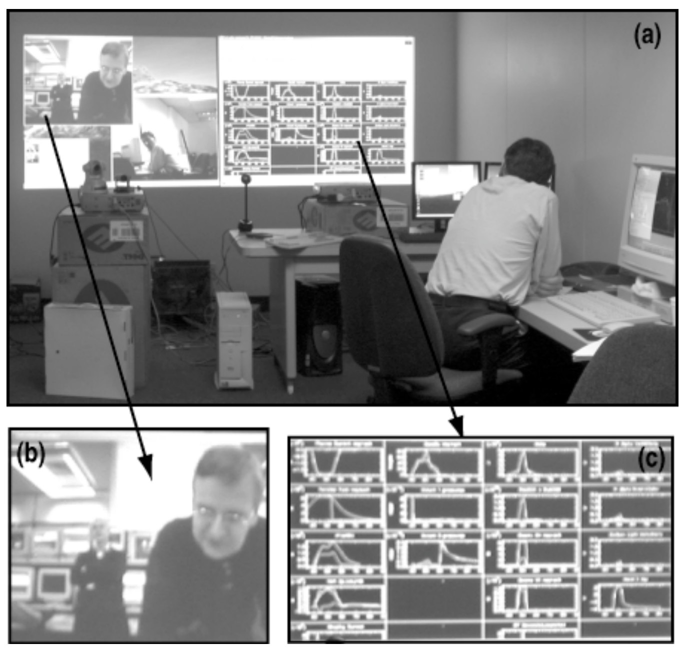

Fig. 2. (a) A scientist at DIII-D leading the JET experiment using AG, VRVS, and MDSplus technology. Audio, video, shared data, and shared applications create the beginnings of the collaborative control room. (b) Enlargement of the video from the JET control room. (c) Enlargement of the data traces from JET.

both JET and ASDEX-U scientists leading experiments on DIII-D. Other examples include the joint work of the DRFC (France) and the INRS (Canada) to jointly operate the Langmuir probe diagnostic on Tore Supra. Tiled display walls are installed and being successfully used in the DIII-D and NSTX control rooms to facilitate sharing of information amongst large groups of collocated scientists.

5. LESSONS LEARNED AND FUTURE WORK

The real world usage and testing of these remote collaboration technologies has highlighted several areas where additional work is required before large-scale adoption is undertaken in the fusion community. First and foremost, the conflicting ease of access requirement of remote collaboration and the restricted access of site security (firewalls) limits expansion of these services and results in a worldwide scalability issue. All the technologies discussed in this paper are impacted by this conflict and a unified resolution must be sought before remote collaboration becomes ubiquitous. Additionally, management of certificates by both the user community and services providers has proven too difficult and needs to be made simpler.

Efficient data management of large simulation datasets is required so that rapid comparison of simulation data with experimental data is possible in the control room. Performance testing using MDSplus to store large simulation datasets are underway and will include tests of MDSplus I/O performance comparing local LAN and WAN connections, using a variety of transport levels.

Initial testing and usage of shared applications in the control room identified efficiency issues that must be resolved before the capability is adopted. Feedback from scientists indicated that when they began sharing with remote users, they themselves began to feel as if they were remotely located since their computer response became significantly slower. Giving a remote scientist a new capability at the expense of on-site staff is not acceptable.

The difficulty in combining H.323, VRVS, and AG systems into one united remote meeting needs to be overcome as it seems unlikely that one technology will be adopted by the worldwide community. Ambient audio in the control room environment can reduce the effectiveness of the collaborative audio system.

The increasing usage of Grid resources and advanced collaborative environments will require better education, training, and documentation. Users, developers, and systems administrators will need community wide access to technical information in order to make best use of these new technologies.

6. SUMMARY

Significant work is ongoing to develop and deploy Grid computing and advanced collaborative environments to support FE research. Although substantial progress has been made, more work is clearly required to reach the point where off-site participation is as rewarding as on-site participation. With the worldwide focus on ITER as the next generation machine, its success requires advanced remote collaboration capability. This should include the use of RP technologies during the construction phase. Present day FE research provides an excellent proving ground for research to support the needs of ITER. Although ITER's first plasma is over a decade away, the intervening time should be used to continue to develop the technology outlined in this paper.

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