Supporting Measurement via the Global Computer Network

Tadeusz P. Dobrowiecki[(1)], István Zoltán[(1)], Tamás Mészáros[(1)], Ana Maria Ribeiro Franco[(2)], Gelson Martins da Rocha[(2)]
[(1)] Department of Measurement and Information Systems,
Technical University of Budapest,
Mûegyetem rkp. 9., H-1521 Budapest, Hungary
[(2)] National Institute of Metrology - INMETRO, Electricity Division,
Av. N.S. das Gracas 50, Xerém, R.J. Brasil

Abstract

The paper presents an analysis of the utilization of global computer networks in the measurement applications. The authors reach the conclusion that, contrary to the present research practice where the focus is put on the distribution of the measuring systems, it is rather the measurement maintenance and support that utilizes truly the advantages of the global network. Various scenarios of vendor - customer sessions are presented based upon the Problem Solution Protocol. The ideas are elaborated in more detail for the case of the remote support of the calibration of the precision measuring equipment.

1. Global networks in measurement

Computer networks, from local area networks to Internet-like global computer networks assumed decisive role in many technical and scientific areas [1]. They appeared also in the field of measurement as a promising, however, not yet fully utilised tool.

The importance of computer networks has been already realised by measuring equipment vendors and measurement oriented academic centres [2-10]. Publicity and technical information is already routinely offered on vendors' World Wide Web (Web) sites and networking components are incorporated in the design of some of the new products [11]. Considerable number of academic projects is related to the construction of Web-distributed measurement systems [5-10].

The potential of the new technology is not utilised fully. Vendors' Web sites reproduce the usual normal catalogue or leaflet information, LAN boards are meant solely to connect instruments to the remote hard copy or digital storage facilities. Even seemingly such a natural extension like databases of typical set-ups, typical test signals, reusable virtual instrument programs, etc. is still missing.

Academic centres are more advanced in their studies and experiment with various distributed system architectures. Global computer networks can easily connect remote but related measurement sites increasing greatly that way the dimensions of the measured system. In more advanced applications global networks can secure also connections to the essential processing resources improving considerably the quality of the results.

2. Virtual measuring systems, ... and beyond

The primary rationale for distributing the measuring system is physical distribution of the measurement object. In this respect global computer networks offer means to extend considerably the traditional programmable measurement set-ups. Dimensions of such distributed systems are, however, limited in a natural way by the size of the measured system or by the distances beyond which the indeterminate timing of the data transfer will cause problems in the execution of the measurement or the interpretation of the data.

Global networks offer also solutions when it is too costly to bring together the device under test and the measuring system and to perform a traditional localised measurements in the industrial or educational setting. Such 'distributed laboratories' or 'laboratories on demand' connect sites confined to a region or a country, nevertheless, not utilising really the world-wide possibilities of the used medium [5, 6, 8, 9].

Measurement technical expertise is something different. Expertise is already distributed in the widest

possible way from the manufacturer to the customer or among academic and industry centres. The manufacturer knows intrinsically the equipment, academic specialists know the theory and the customer is specialist in the measurement problems the equipment is used for.

Some of larger equipment providers are already present on the network. They use Web technology only fractionally, mainly to promote corporational information, still far from the required measurement technical expertise [2]. Academic specialists maintain routine Web interfaces (personal home pages), which yield access to the specialised information, nevertheless, in a passive and not in a problem dependent, possibly on-line interactive way. Equipment users, as such, usually do not maintain any particular presence on the network.

3. Global (expert) support environment

Collaborative tools on the global network, from e-mail to multi-media conferencing offer possibility of a straightforward and fast acquisition of the expertise. Measurement results, accompanied by a suitable formalised description of the experiment can be distributed to the designated experts for evaluation. Elements of video-conferencing can be used for the remote monitoring of the measurement activities, providing valuable immediate feedback with expert's comments.

Repositories of 'real' expertise, i.e. direct on-line contact with the renowned specialists, belong still to the future. The key issue is the lack of proper system/ network interface for the experts who otherwise are willing to participate. An essential and also still missing component is the suitably portable representation of the measurement problems that could be a basis for 'problem exchange' protocols.

It should be noted that the development of the global computer network into a global measurement support environment is not limited by the technical means. For the global network there are virtually no geographic limits and Web nodes can be established on the basis of simple PCs, and now even the measuring equipment itself. Consequently it is rather the lack of awareness of the hidden possibilities, which is responsible for the present situation.

In the global support environment the primary activity would be to monitor somehow in a remote way what happens at the measurement site. Using standard multi-media or video-conferencing tools the usage of the equipment at the customer's site can be supervised, the topology of the measurement set-up verified, and the customer warned in time about possible problems.

Measurement monitoring, but only passive and unidirectional was in a sense one of the first demonstrative usage of the global network and remains until now one of the most widely distributed applications [12]. Current research addresses remote monitoring of the Web browser-based applications to ensure user-level QoS (Quality of Service) goals and also the impact of distance upon the user's perception of control and of information quality [13-14]. Remote measurement monitoring as the element of the vendor's support to the customer is, however, not considered.

It must be noted that attempts are made to introduce the Web as the medium of the remote certification of the measurement sites [15]. It is nevertheless a one-time and relatively high-cost and tool-intensive contact not scalable into the support of the continuous and diversified usage of the equipment. In practice there is also a difficulty that a high-level standard is necessary during the calibration. However, in the case of self-calibration no such standard is required.

4. Measurement support - the scenarios

Turning attention to the support of the measurement, instead of the usual organisation of the distributed measuring systems, fills two gaps. One is utilising fully the geographic dimensions of the global computer network, the other is to provide support in the preparation and the evaluation of the actual measurements, especially regarding calibration, testing and putting the measurement together.

In the further analysis of the Web-based measurement support two assumptions are made, not really addressed in the research until now. Firstly, the applications are considered mainly along the vendor's expert - customer axis. Secondly, at the bottom of every application is the remote monitoring of an otherwise geographically localised measurement and forming an opinion about the soundness of such measurement. This is contrary to the present projects where the principal problem is to distribute real or virtual measuring system set-up. Three basic scenarios are considered in the following:

a.) Remote support to the calibration and/or measurement - vendor's experts monitor the measurement at the customer's site and collaborate in the troubleshooting;

b.) Remote demonstration and/or tutorial - when (potential) customer monitors the measurement at the vendor's site and learns or forms the decision about the purchase of the equipment;

c.) Remote measurement education - both vendor and the customer monitor the measurements at the respective

sites in the aim to teach and to learn how to maintain best the same equipment.

Assisting remotely in the maintenance of the measurement tasks is advantageous for both the vendor experts and the customers. Experts may influence the preparation and execution of the measurements learning also in the meantime about the typical maintenance problems and being able to get rid of them in the future. Customers can immediately receive hints or advises and improve the quality of the experiments on-line. Furthermore they can learn from the demo measurements conducted by the experts. Similarly potential customers can participate in 'live' measurement demonstrations without seeking special opportunities to get in touch with the vendor.

5. Information traffic

At the highest level of abstraction the information traffic between the vendor's and customer's Web nodes can be considered as the 'Problem Solution Protocol (PSP)'. One node provides the environment to prepare and send the description (model) of the measurement problem, the other one provides the environment to accept, interpret and send back the solution, Fig. 1.

The problem/ solution information traffic has two dimensions: the content set by the measurement context and the form dictated by the Web technology. The content of the traffic are measurement models comprising symbolic (various attributes of the problem, instrumentation, or measuring system), structured (e.g. the topology of the measuring set-up), or numerical (control commands and measurement and setting data) information. The form can involve any kind of multimedia modality, like simple text, static or animated graphics, white board images, audio records or video clips. Certain components of the measurement problem/ solution call for a particular modality (e.g. the measurement set-up), others can be passed between the nodes in the form tailored to the requirements of the particular situation.

What happens at the nodes is the product of co-operation between the system and its user. When the measurement problem is formulated the 'Problem proposing node' accepts the input from the user, processes it and prepares the structured description. The sending mechanism is activated and then the node waits for the solution to be available. When the solution arrives, the node processes it and presents it in the required form to the user. At the 'Problem solving node' the description of the problem is received, processed, and then presented to an expert. Then the node waits for the expert's input. The expert's input is transformed into a properly structured solution and then the sending mechanism is activated.

6. Technical Requirements

The variety of customers and purchased equipment configurations can be considerable, ranging from e.g. simple users of single instruments in some interdisciplinary field to the management of fully equipped, multiple service measurement labs. Consequently the solution should be a low-cost, low-overhead, scalable and generally as simple as possible.

There are several ways to implement the ideas presented in this paper. In this section we try to formulate general requirements toward an implementation, and describe different classes of solutions based on these requirements.

In order to support a wide range of application areas the following requirements seem justified:

- the system should be scalable in terms of participants and used resources,
- it should support low cost solutions,
- it should rely on standards, and utilise existing tools and techniques wherever possible,
- the installation and the operation of the system should be easy for non-professionals.

Selection of methods, tools and techniques should cover the input and output devices, and the communication methods.

The availability and price of personal computers (PCs) suggest that PC-based components should be used as I/O devices. There are several options in this environment, from the simple keyboard – mouse – monitor configuration, to more sophisticated devices like white boards, touchscreens, video cameras, and others. PC systems are scalable, easy-to-use (or at least convenient for the users), there are standards covering this field, and low-cost solutions are also possible.

Communication can be decomposed into low-level communication links and application level communication software. The implementation of the lower level should always depend on local circumstances. In most cases cable networks or modems are available, and can be used to build the basic communication system (a TCP/ IP network).

Selection of higher-level communication system depends upon the available network bandwidth and the acceptable cost of the solution. For low-cost, low-bandwidth solutions the World Wide Web infrastructure can be used [16]. This allows the transfer of multimedia documents (text, picture, video, audio, three-dimensional

models, etc). It can also be used to display such documents using a low-cost PC.

For high-end solutions in a fast networking environment a video conferencing system can be used, that allows real-time conversations and transfers all kinds of documents using the video link.

Middle-class solutions are mixed versions of both fields. There are video conferencing solutions with lower bandwidth and cost requirements, those provide lower quality pictures and movies. Integrating these systems into the Web environment allows limited-quality real-time conversions. So called Web cameras (see [17] for example) can be used to build such a mixed environment and transfer still images, and slowly changing motion pictures. These special cameras can also be used as stand-alone (without PC-s) as they can be directly connected to computer networks and contain a standard Web software interface.

7. Metrological advisory and maintenance system via Internet

To investigate the feasibility of the presented ideas an experiment is being launched between two relatively remote Internet sites aimed at the maintenance and support of the precision measuring equipment. Precision instrumentation used to calibrate other measurement instruments requires considerable care in handling and thus offers an excellent opportunity to try the ideas mentioned above.

The Sites:. In the experiment the Department of Measurement and Information Systems, TU Budapest, assumed the role of the 'Vendor', and the Electricity Division of the National Institute of Metrology INMETRO, Rio de Janeiro, assumed the role of the 'Customer'.

Precision instrumentation is manufactured in a close co-operation with the department (DMIS, TU Budapest) providing manufacturing experts who are willing to participate in the experiments. The metrological center at the opposite side (INMETRO) routinuosly uses precision equipment and provides staff of considerable experience.

The Topic: Recently a new self-calibrating current-comparator and digital ratio-meter-based multi-function standard instrument for current transformer calibration has been developed with the basic accuracy of +/- 2 ppm with 0.1 ppm resolution [18]. The built-in ratio matching unit facilitates comparison and direct calibration of current transformers of different ratios. A set of built-in auxiliary windings ensures complete on-site self-testing. The instrument can be thus tested and calibrated by various combinations of basic self-calibration methods, like zero-point test, artificial offset and anti-offset tests and ratio-meter test. Using the current-injection technique, in-phase, quadrature and complex errors can be generated for the calibration of the instrument.

The Solution: To demonstrate the feasibility of the ideas the calibration scenario of the precision current comparator has been chosen with an atempt to realize a relatively simple solution, based solely on existing Web technology, for elements see Fig. 2. Such solution means almost no costs to the 'Customer', retaining still a considerable flexibility and functionality. The same Web page describing calibration or measurement procedure (goal, set-up, settings, views, control, comments, etc.) is filled and gradually exchanged between the customer and the vendor serving as the description of the problem and the proposed solution respectively. The page is a member of a page hierarchy, presenting vendor, instrument, and function related information, which provides automatically the proper context to the processed model. The experimental solution does not call for the true (real-time) multimedia (video conferencing) tools. It reflects rather the real situation when customer, asking e.g. for the demonstration of a procedure, must still wait for preparatory activities in the lab at the other site.

Consequently at the 'Vendor's' site a PC Web node, whiteboard, and optionally the same instrument and video recording equipment is required, with suitable Web, and optional multimedia and GPIB software. At the 'Customer's' site PC Web node, the instrument, suitable PC/instrument link, and optional multimedia and GPIB software is required. In the realised situation the instrumentation is present solely at the 'Vendor' site and the 'Customer' simulates the true user of the equipment.

8. Conclusions

The analysis of how the global computer networks are utilized in the measurement led to the following general conclusions. Firstly, only the distribution of the measurement support, based upon the availability of the measurement expertise, can utilize fully the geographic potential of the global networks. Secondly, the support can be implemented by widely available and cheap technical means, assuming that the human users (equipment user and the vendor's experts) intend to cooperate. Thirdly, considerable exchange of information and the expertise can be achieved even by the simplest system solutions, which, however, are scalable and open to modification.

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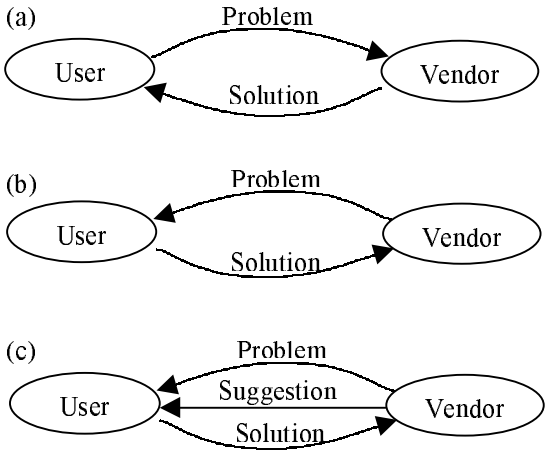

Fig. 1. Problem-Solution Protocol: (a) helping in measurement or vendor demonstration, (b) examining, (c) tutoring.

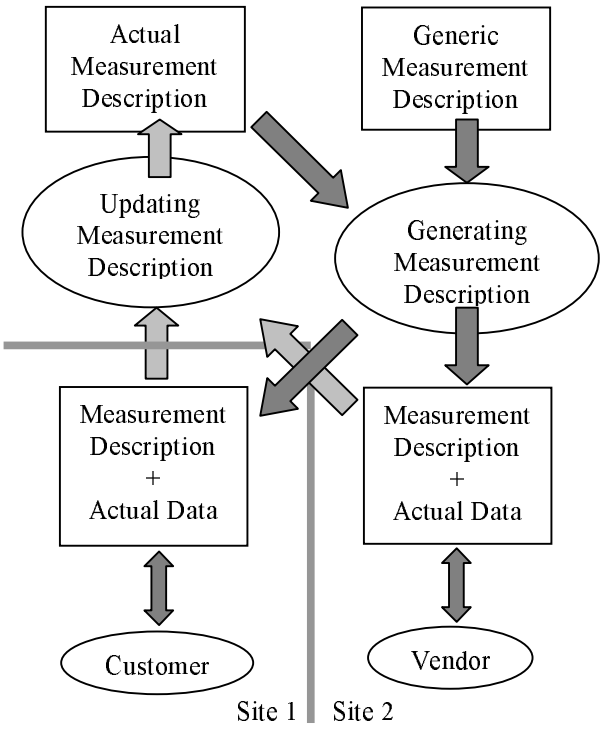

Fig. 2. Problem-Solution Protocol as the transferring of the generic measurement description.