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AD-HOC MEASUREMENT NETWORKS

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Abstract: This discussion paper presents issues in the design of ad-hoc, networked measurement systems. Key requisites are summarized at first. Then, architectural features will be analyzed in order to let a designer be aware of advantages and efforts of presented choices.

Keywords: remote and distributed measurement, ad-hoc networks, instrumentation.

1. OVERVIEW

There are several reasons beyond the increasing interest in remote ad-hoc measurement networks.

In some cases the main reason is just *a need*. In key applications in the field of telecommunications, for instance, a transmitter, a receiver and a measuring instrument have to be controlled in such a way that useful information is obtained. Usually the three pieces of equipment are located far from each other, hence some mechanism is required in order to let a test engineer accomplish the task. Less trivially, when quality of service of a network is under investigation, a common procedure consists in setting up an ad-hoc monitoring network composed of many test points at different locations. In this case, there is again the need for an architecture that enables easy set up of remote test points that, however, should be controlled from a centralized location, i.e. from where data are collected and analyzed.

Environmental monitoring is perhaps one of the most interesting fields for ad-hoc distributed measurements. In this case a rather large number of sensors are distributed in a geographical area. Procedures need to be set up in order to interact with the sensors, both for setting sensor parameters and for collecting data coming from the sensors themselves. At a higher degree of abstraction such data are used to extract more meaningful information: for instance, one may detect alarm conditions (e.g., landslides) in a given region from the survey of geological information. However, correct interpretation is only possible if each node in the measurement network is coordinating itself in a proper way with the other devices.

The field of education and e-learning is another case where remote access to electronic instrumentation and devices operating as an ad-hoc network provides new challenges. Electronic systems are becoming complex, expensive and quickly change, so that a single school or university many not have sufficient resources to keep pace with technology updates. Moreover, students (university or college students as well as graduated continuous-education trainees) often use such complex resources for a limited amount of time. Once a sufficient skill level has been gained, a certain set of instruments may no longer be necessary as the student moves to new and different measurement problems. Hence, costs are payed back only if a large number of people could share in a time-scheduled way physical resources. This means that specialized test labs can be set-up, each offering a limited number of state-of-the-art instruments and experiments via a remote access policy.

The last example shows that remote measurement architectures could probably receive a considerable improvement from grid computing technology. However, this issue and the discussion of the various services that an e-learning organizazion should offer to students and teachers is beyond the scope of this paper.

Dedicated networks have been used for a long time in the control of industrial plants. Now, the emerging trend of using ethernet also for fieldbus operations opens a new opportunity of considering classical instrumentation and field sensors or actuators from a common point of view. Although not necessary, applications can benefit from such unified view, where services kept far apart can now share resources.

In any case, in an integrated factory environment the use of remote measurement procedures allows better integration between design engineering and test engineering tasks. Wider access to testing facilities enables people to closely interact, while enabling a quicker developmement of test procedures. In fact, software code developed for testing purposes can be more easily shared providing greater efficiency.

A networking environment between test engineers and design engineers of a given product can speed up the whole design process of electronic devices. At the same time, expensive resources within test laboratories can be employed more effectively.

In any of the above examples, networked measurement architectures are needed. Despite the strong difference between the applications, some interesting common needs can be identified and general architectural features can be summarized in order to give ad-hoc networking capabilities to a measurement application.

2. AD-HOC MEASUREMENT NETWORKS

In this paper, a brief survey of the main requirements and off-the-shelf solutions that a designer might consider is given. Then, a discussion of approaches for networking measurement applications is presented, from the instrument up to the whole system. The aim of the discussion is to assess what tools are available to build a complex measurement system on an ad-hoc basis, from the combination of different instruments.

Several developments have occurred recently, from the continued development of IEEE Standard 1451 on distributed instrumentation, to the recent introduction of LXI (*LAN eXtensions for Instrumentation*). The latter represents a revolutionary shift of emphasis from a PC-centric measurement architecture, to a network-centric architecture.

The important implication of these approaches is that each instrument can operate as an independent entity, endowed with considerable intelligence and computing power. At the same time, intelligent instruments can coordinate their operation through the network. Hence, mechanisms for the setting-up of ad-hoc networks can be of interest in the field of measurement.

Of course, the implementation of a complex test and monitoring system cannot be an occasional combination of devices, but it is perfectly reasonable to assume that a given selection of instruments can be combined, on a temporary basis, to perform a given task.

Considerations on the cost of sophisticated measuring equipment, replacement of obsolete instruments, efficient use of available resources, motivate the quest for an environment where the test procedure is well defined and required measurement functions are provided on demand by available instruments.

An important function for the implementation of coordinated measurement functions will be considered: the *synchronization* of activities. In a traditional system this used to be accomplished by dedicated hardware lines. In a networked environment, on the other hand, this can also be obtained by network protocols, in particular IEEE 1588, that allow accurate alignment among different instrument timebases. It is thus possible to exactly schedule the steps of a complex measurement procedure.

A critical requirement for ad-hoc measurement networks is *security*. In the context of networking measurement systems security does not mean just prevention against hacker attacks, but the guarantee that unauthorized use of devices should be forbidden, so that at any time the consistence, accuracy and traceability of measurement information can be documented.

Another critical issue is the possibility that *multiple users* are simultaneously enabled to interact with remote instruments or devices. In some cases exclusive allocation of resources may be preferred: hence suitable schemes must be implemented. This feature has to be planned in advance, and proper policies should be enforced.

Device-independence is also an important requisite. While this is desirable for the control of devices in general, it becomes even more important for ad-hoc networked instruments. Since a system is set-up on a temporary basis, device independent interfaces are essential to allow discovery mechanisms, whereby instruments within the system each recognize each other. In turn, this makes system set-up and configuration simpler.

Finally, the *learning curve* for users of an ad-hoc remote measurement system should be kept as short as possible. One should note that networking implies a number of features and configuration parameters previously unknown by technicians in the measurement context, which should be dealt with almost automatically.

3. SYSTEM COMPONENTS

Various items contribute to making up a distributed measurement system: hardware components, interfaces toward computers or the network, software modules variously interacting with each other in order to provide the required services via suitable protocols, and so on.

The use of ethernet links opens the opportunity for direct remote control of the instrument via a TCP channel. Hence, remote control of a device, e.g., through the Internet, becomes as simple as opening a network connection and exchanging data packets.

Devices provided with the most recent interfaces, such as LXI, can directly act as simple web-servers. A web-capable instrument directly publishes web pages that enable a user to change its setup by using a browser. Likewise, measurement data are seen from other pages published by the web-server running inside the instrument. No further coding is needed to remotely interact with the remote instrument.

Tools should be provided, that enable a designer to see the whole system in a generalized form, so that attention is concentrated on the sequence of input stimuli to be provided and the processing of corresponding answers received from the device under test. Approaches proposed with this aim might be called *middleware solutions*.

Interesting features for networking measurement systems are offered by some commercial *development environments*. Two well-known examples are LabVIEW from National Instruments and VEE from Agilent Technologies. An interesting feature is that it is possible to design graphical applications that share software objects through the Internet. For instance, an application can share a knob used to control some instrument setup with other certified applications running elsewhere. The simplicity of use of these environments may have to be paid for in terms of execution speed. Hence, if speed is a critical issue, more efficient programming languages should be preferred. This still allows to build an ad-hoc measurement network in a straightforward way, if web-capable instruments and industry-standard libraries such as VISA are employed.

4. DEVELOPMENTS

The aim of this discussion paper is to help the pratictioner understand the challenges beyond the implementation of a measurement procedure by an ad-hoc networked system. It is hoped that useful guidance will be provided in efficient design of the final application or in clever selection of already-available application tools.