REAL TIME CONROL AND MONITORING OVER THE INTERNET*

Maki K. Habib
GMD-Japan Research Laboratory
AIM Building 8F, KokuraKita-Ku, Kitakyushu-City, 802-0001 JAPAN
maki.habib@gmd.gr.jp

Abstract: *It is very useful for wide range of applications to have the ability to remotely access and monitor an environment, and control the operation of targeted equipment, facilities or integrated processes. It is also vital for hazard environments, special skills, and special equipment to be accessed, manipulated and utilized efficiently independent on space and time. The Internet technology makes such tasks and applications possible due to its cost effectiveness, ubiquity, platform independence, and its media rich interface. But, having real time data while controlling a remote environment with single/integrated processes or simple/complicated devices through the Internet is not that straight and simple, because data transmission through the Internet is often irregular and unreliable due to unpredictable time delay and possible data loss. This paper addresses the technical issues and requirements that affect the design and performance of Internet based real time control and monitoring systems. Such issues include Quality of Service (QoS) and the effect of bandwidth, time delay/latency, controllability and reliability, user interface, security, and control mechanism in relation to interactivity and operational safety. Proposals to reduce the impact of the issues that limit the performance of the real time control systems over the Internet are presented and examples are illustrated.*

Keywords: *Real time control, Remote environment, Teleoperation, Internet, Ubiquity, Bandwidth, Latency/Time delay, Quality of Service*

1 INTRODUCTION

Information, expertise, facilities and other resources are scattered across the globe and may not be available where they are needed. The quality of communication technology and infrastructures of networking are forcing a rethinking of the physical structures and spaces needed for living, working and learning as the need to look for alternative forms of physical movement of people, equipment, records and information, etc. is evolving. Equipment that has only operated and controlled locally in the past is now to be remotely controlled. Engineers want to control, observe and maintain machinery from any place they are in and at any time. People want to co-operate remotely, share facilities and equipment to save personnel, cost and make a better use of resources and expertise. Students want to attend school classes, participating in discussion and have their laboratory's experiments from any place they are. Medical and health care professionals want to remotely share equipment, experience through consultation, diagnosing medical cases, surgery, treatment and interacting with their patient. There are many applications where geographically distributed teams share single technical facilities such as unique or expensive equipment between several laboratories and institutions for collaborative research, training, and education purposes, or where a central local site needs to access and to observe multiple remotely distributed sites.

Remotely operated facilities (equipment, devices, processes, and other resources) have been desired for use in various environments and applications. The target is to extend human ability beyond the limitation of time and physical constraints and enable him to project his physical presence to perceive, reason with, and act in an environment that is too distant, hazards, and high cost. Users are given the ability to explore and interact with many remote physical

* To appear at the coming IMEKO/IFAC/IFIP World Congress - Workshop on Advanced Robot Systems and Virtual Reality (ISMCR 2000), Vienna, Austria, 26-30 Sept. 2000.

environments through remote sensing and manipulation devices. Such approach enhances performance, flexibility, quality and safety. There are numerous applications where it is advantageous for humans to perform complex actions in remote environments. Space exploration, undersea operations, surveillance, mining, nuclear power maintenance, and a wide variety of other hazardous operations are target applications. I addition, remote manufacturing and micro-manipulation, maintenance, medical care and treatment, smart office, smart home, smart school and to provide entertainment, are examples where this level of control would be of great advantage. Many applications require monitoring and controlling their systems/processes, equipment, and appliances in real time over vast distances. The need here is to have simple, fast, reliable, re-locatable teleoperated system where its accessibility should be achieved from anywhere through web browser independent on time and space. Also, it is important to understand the technical issues and requirements that affect the design and performance of real time control and monitoring systems over long distance. Such issues include Quality of Service (QoS) and the effect of bandwidth, time delay/latency, controllability and reliability, user interface, security, and control mechanism in relation to interactivity and operational safety

2 WHY THE INTERNET

The Internet as a universal network and the World Wide Web (WWW or the Web) constitute a ubiquitous network. This allows to electronically connect places that are thousands of miles apart with its media rich interface that facilitates virtual presence via electronic communications between entities, humans, and machines [9, 10, 13, 19]. The Internet and the Web can make remote and distributed resources accessible to a broad range of users for different purposes regardless of geographical location. The Internet enable to deliver seamless access to live data, which empowers users to enhance performance and safety, improve productivity, reduces costs, and increase profitability. The Web creates the social framework required for field placement of sophisticated technology, and offers a suitable infrastructure that integrate computer based services from multiple platforms and provide a flexible and effective tool for examining and monitoring remote physical environments. The adoption of the new Web based systems to provide security and monitoring services and the richness of media for communications offered through the Internet and the Web provide high level of interactivity.

The Web provides a low cost and widely available platform independent interface to applications that enable a device to become part of a seamless virtual reality linking variety of activities. The WWW model provides a flexible and powerful mechanisms to allow links and access from one document to other text, audio, image and movie documents residing anywhere on the Web [8, 9]. The availability of Web browsers for the most common platforms and the presence of the Web throughout the world ensure very wide dissemination of information and access of other resources. The prediction for the Internet was to support, online multimedia collaboration, sophisticated information retrieval and remote control of expensive or unique scientific instruments via tele-experimentation. But, the Internet of today gives access to a wealth of distributed hypertext documents. Extension already being planned to support collaboration, and attempt at teleoperation is being performed.

The advent of the Internet as a major communication channel has triggered a great deal of interest in real-time communication over packet-switched networks. While the Internet is not originally designed to handle real-time traffic, the spontaneous growth of the WWW over the past several years has resulted in having special focus on remotely controlled mechanical devices that can be accessed via the WWW. This technology enables users to maintain a physical presence remotely in any one of many remote sites.

Internet based real time approaches with tools supporting human communication and interaction with real world, will inevitably lead to many useful applications in various sectors. In addition, it will lead to learn about new ideas, share ideas with a very large community. Also, it will improve quality of services, utilize efficiently resources, minimize risk associated with hazardous and dangerous environments, access timely information and expertise that support diagnosis and decision making, and to reduce overall operational and maintenance cost. The development of the Internet as a world wide communications medium now provides an existing communications network upon which to base the evolution of remote real time control technology. In particular, it suffers from the same problems of communication delays exhibited by space-based remotely controlled systems along with other applications, and therefore can be used as an inexpensive development platform for this technology.

3 REAL TIME CONTOL AND CURRENT INTERNET

Real time applications have very different characteristics and requirements from standard data applications, and require services that can not be delivered within typical data service structure [15]. Controlling equipment, machinery and other time critical processes in real physical environment and in real time requires to monitor continuously the state of a system and its hardware through available sensors. Then, emphasizing actions by sending control commands and finally observing the results as a feedback within a suitable time to direct the process to its goal [11]. Remote control and interactive operation over long distance leads to an understanding of the complexity and difficulty in specifying action commands and perceiving remote task environment. Safety and reliability are critical factors for such systems along with robustness, fault tolerance and security. Solution should be balanced; i.e. superior performance in one area will be of little value if other factors limit overall system performance. How to increase the reality of remotely controlled and monitored systems has been a big problem for manually operated systems over a distance. The bilateral feedback is one of effective schemes, with which the force information is fed back to the operator from the remote site. Bilateral teleoperation system has a problem relating to the communication time delay. When velocity and force information are transmitted with time delay, even a small time delay easily destabilizes the bilateral teleoperation system. Poor displays, insufficient sensory information, inappropriate modeling and inefficient control inputs can all contribute to operator error [21]. Additionally, noise, power limits or signal transmission delays may affect communications. Delay is particularly insidious because it can make direct teleoperation impractical or impossible, where the remote system will exhibit positive feedback when half cycle of the input frequency equal the time delay [6]. The effect of this is that the amplitude of the output grows without bound and the system becomes unstable. Typically, this will occurs when the delay is greater than one second. Lawn [5] and others avoid such instability by only considering delays of less than one second.

Remote control and experimentation is almost trivial when there is a deterministic medium with a given or reserved bandwidth to transmit information. Controlling remote facilities in the presence of significant time delays, where the transmission delays are themselves varying with time in an unpredictable fashion does not belong to this category. Real time remote control main shortcoming is the rapid performance fall off as time delay increases. Delays are potentially destabilizing and certainly degrade human teleoperation's intuition and performance. Ideally remotely controlled system should be able to cope with varying time delays, without adversely affecting performance.

The primary constraint in using the Internet to support teleoperation and real time control is the communication link. In particular, limited bandwidth directly restricts the quantity and quality of information available to the operator for decision making. The bandwidth that a network can provide is a property of the transmission medium (fiber optics, coaxial cable, telephone wire, radio waves, etc.), the network topology, and the switching or routing devices used to guide traffic through the network. The amount of bandwidth a particular application demands is determined by the amount of data to be transmitted and the time in which that transmission must be completed. Latency is the concept represent the time required for an individual packet of data to be transmitted between communicating entities on a network. A related concept is response time, which refers to the time required for an entire message or file to be transferred across the Internet and acknowledged. The minimum latency a network can provide is influenced by the speed of its switches and routers and the physical distances across which the message is sent. Remote control and time critical applications require much lower latency that is available on today's Internet. Applications that do not require instantaneous delivery of information will not be affected even by the currently available latency. Real time interactive application demands low latency so that the users can interact with the process and with each other easily. Data transmission through the Internet is often irregular and unreliable. Under the Internet, the route followed by data packets is not fixed, and the time required to cross the network can not be guaranteed, with possible loss of data. Thus, the amount and type of information that can be exchanged between the remote system and a human operator is severely limited. There is no assurance about when or even packets will be delivered within the current Internet.

Current usage of the Internet is dominated by traditional data uses (such as TELNET, FTP, DNS, SMTP, etc.) are rather elastic in nature in that they tolerate delays and packet losses rather gracefully. Due to this elasticity, such applications can decrease their transmission rate in the presence of congestion. But, with the emerge of multimedia applications with their novel traffic characteristics and service requirements pose an interesting challenge to the technical foundations of the Internet, and accordingly the Internet must be prepared to cope with the traffic emanating from such applications. The emergence of real time applications is likely to significantly alter the nature of Internet's traffic load. Such applications are not backing off in the presence of congestion, and this will have its impact on data applications that end up to receive very little bandwidth. Some of such applications are extremely delay sensitive with hard real time requirements in which they need their data to arrive within a given delay bound. Accordingly, such rate adaptive applications that can adjust their transmission rate in response to network congestion, by keeping the delays moderate no matter what the bandwidth share. In this case the performance of the application depends completely on the quality of the signal. The quality of the signal will be low as the bandwidth share decrease.

4 REAL TIME AND CONTROL MODES OVER DISTANCE

Remotely controlled systems are generally regarded as being performed by a number of different control modes. Such control mode has been classified into control levels based on the role given to human operator and the system at the remote site [4, 6, 20].

Traditionally, remotely operated equipment and facilities evolved naturally from other human controlled systems and accordingly it adopts the use of direct and continuous control paradigm. In this mode of control, human operator controls the entire range of system functionality, from trajectory guidance to planning and acting according to the sensory information coming from the remote site and displayed in front of him. The disadvantages become quite dramatic when there is long two-way communication time delay between the operator and the remotely controlled equipment. Such approach binds completely system's capabilities to human operator skills, and subjects the system to human constraints. In addition, other control modes have been implemented range from: direct control with some functions become available at the remote site to enable human operator to teach the remote system some basic and simple knowledge functions about task environment. Reflexive control aiming to free the operator from details of the lower level control concerns at the remote site. Shared Control that enable human to control some variables or subtasks while the remote system simultaneously control others. The task instructions is shared between the operator and the remote system, where each complement the deficiency of the other and tasks can be interchanged dynamically. Traded Control: Human and machine are consecutively responsible for subtasks, that is, at one time the remote system is in complete control and at other time human is in full control. Supervisor control as a mixture of direct control and autonomous control, where the autonomous operations are performed under human supervision, and it involves a high degree of system autonomy. Human operator monitors task progress and only intervenes when the remote system is unable to complete the task correctly. This control mode suits to be used over large distances, such as in space and undersea applications, where the time delay makes direct control difficult if not infeasible.

It is clear to recognize that the dominant control paradigm has always been human as controller. However, this human-machine relationship often proves to be inefficient and ineffective. In many situations remotely controlled systems require a close integration of human and computer control signals. Human operators are highly successful at tasks that require high level reasoning (i.e. planning) including the interpretation of complex or novel environments and situations from incomplete or imprecise information. Conversely sensor-based control systems display a high degree of competence at low-level tasks which require continuous attention and fast reaction times. Constructing a system that allows both an operator and a remote system to contribute to the overall control of a task requires techniques for integrating both sources of control to produce a single output signal [3, 4].

5 INTERNET AND COMMUNICATION PROTOCOLS

Current data networks typically use packet switching as a means of dynamically allocating network resources on a demand basis. Packet switching has been widely used because it facilitates the interconnection of networks with different architectures, and it provides flexible resource allocation and good reliability against node and link failure [14]. However, packet switching provides little control over the packet delay at the switches, and hence time delay represents one of the fundamental characteristics of a packet-switched. Each packet generated by a source is routed to the destination via a sequence of intermediate nodes. Accordingly, the time to retrieve remote data is made up of many components: time for the client request to reach the server, time at the server to process the data, time for the reply to reach the client from the server, and time at the client to process the reply. The end-to-end delay is thus the sum of the delays experienced at each hop on the way to the destination. The difficulties facing real-time packed switched communication protocols can be summarized as; throughput where an application may face a congested network and not able to exchange data consistently. Delay with upper bound that depends on the network traffic. Delay jitter associated with network load may induce large delay variation and packet scrambling; and packet losses due to routing hosts may discard packets that overflow the input buffers.

Web clients typically support several protocols or access methods to communicate with servers. The most common access method is the HyperText Transfer Protocol (HTTP). HTTP is a connection oriented transaction stateless protocol that uses a connection-oriented transaction, namely Transmission Control Protocol (TCP). Each HTTP connection is built on top of a single TCP connection, with both document requests sent by the client and the response sent by the server being carried over the same HTTP/TCP connection. A Web page might in fact include a number of documents and that a separate HTTP/TCP connection will be opened to retrieve each of these documents [12]. TCP that underlies most popular Internet applications today, is designed to determine the bandwidth of the slowest or most congested link in the path traversed by a particular message and to attempt to use a fair share of that bottleneck bandwidth.

Internet-based control systems must rely on the available communication protocols to exchange real time data between the controller and the process. Today, most network protocols provide a transparent and reliable support for data exchange among computers by using the TCP. This protocol provides a full duplex stream service, with automatic error handling, retransmission, packet re-ordering, and guarantee of safe delivery. However, from the point of view of a real-time application, this protocol has the drawback of having unpredictable arrival time of the data. This limitation can be overcome by using the User Datagram Protocol (UDP), which does not require any acknowledgment message between sending and receiving packets, and therefore it is not blocking. However, UDP does not guarantee data delivery, since it provides no feedback from the receiver about lost data packets. UDP is also affected by delay jitter on data arrival [6]. This jitter is due to the combined effects of buffering in routers and of different routing policies. A compromise solution can be achieved by using UDP in applications that tolerate occasional delay bound violations and dropped packets, while using the TCP to send time critical commands and data.

6 APPLICATIONS DEVELOPMENT

A multiplatform client-server and Web based architecture, which share information and enable real time interaction through the Internet with a target process has been developed. This architecture has been implemented for remotely monitoring and controlling two real time applications. One is associated with monitoring and controlling home appliances, and the other is to monitor, program and control an industrial robot. The hardware structure constitutes, Web client, Process Server, Process agent, IO interface, and the process itself that need to be monitored and controlled. The Internet is used as a communication channel to enable any Web client to access the target process according to existing connections, authorized procedure, and available resources.

According to HTTP request sent by a user through Web browser, the server will send back to the Web client, the user client software with the related web pages that serve as a control interface through Web browser. The user client is designed and implemented based on Java applet and frame structure, and is embedded in web pages for the Web client to download through the server. This will enable easy access to the process and reduce updating time when there is a change in the target process, i.e., only applets associated with the change are updated and not the entire page. It is important to design user interface that reproduces the look of the remote task environment to the client side by combining virtual representations, video feedback, other sensory information from the remote site as necessary.

The server side receives the client commands and transmits them to the real process through the process agent. It also returns the state of the real process to the client. The process agent, IO interface, and the target process represent the process side. The process agent represents the computation power of the remote process and connects the process to the server. It has standalone application that transfer different levels of control commands received from the server to the target process through the IO interface as low level commands. It also received flow of sensory information as a feedback from the target process to the process agent. The user has been enabled to access different level of control commands to facilitate efficient interaction with the process and enhanced safety. Local control loops have been established at the target process to deal with different control levels and they are integrated with the larger control loop associated with the process side. The server caches through the process agent the most recent sensory information and status images concerning the target process. Remote experimentation requires flexible mechanisms to implement particular control algorithms and to provide comprehensive information. These functionalities are mandatory in order to control the dynamic behavior of the remote system and to supervise the ongoing operations. Protocols to manage the follow for the request and responses between the server and user client and between server and the process agent have been implemented using Java language. The architecture supports different mechanism to deal with documents and sensory information.

Real time control applications need to enable the user to keep state information by knowing what the user is doing and the status of the process and its member equipment. Such data can be stored both locally and remotely to solve and manage data size problems when they arise.

7 REAL TIME CONTROL: NEEDS AND APPROACH FOR SOLUTIONS

Limitations and critical issues have been recognized and solutions have been carried into ways to sustain stability and enhance performance. Some of the technical issues that have been considered are discussed below:

7.1 Time delay and ways to reduce its impact

Ideally remotely controlled system should be able to cope with varying time delays, without adversely affecting performance. This can be avoided by prediction through simulated modeling of task environment or by increasing the autonomy of the system at the remote site so that the frequency of commands is reduced. Another approach can be done through the reduction of information content by choosing a slow frame rate and a small frame size in case of visual information, and by avoid sending continuous information where images and large size information can be sent only on demand. Finding proper tradeoff between resolution and frame-rate of sensory information can highlight interesting aspect of this issue. The use of compression allows to trade off between the computational burden at each site and the bandwidth requirements between sites. The idea of overcoming bandwidth constraints by communicating at a more abstract level is fundamental to remote control via constrained communication. To enhance operational efficiency, sensory information for each segment of a task can be presented dynamically in a way that enables human operator to perceive the remote environment quickly and improve situational awareness by fusing data from the related sensors. Also, there is a need to have the capability to reserve bandwidth dynamically according to the need to ensure that time-sensitive data is delivered in a timely fashion. In addition IP multicast can be used to reduce bandwidth needed to communicate from one sender to multiple receivers. Also, the need to design functionality that can handle the lost of communication. It can be through handshake with specific time interval.

7.2 Control issues

There is a need to find the best way in using human valuable resources and capabilities in a proper balance with the capabilities of a teleopetated system without binding each side to the others for the purpose to enhance overall system performance. Due to the safety critical nature of the application domain, it is a fundamental requirement that the operator should always be able to exert full control on the system at any time he feels there is a need for it. The need to have different level of control that enables human operator to select any one of them that suite specific need in supporting the execution of the targeted task. The significant need to integrate a variety of sensors into task environment and to integrate the information into the several levels of the system control hierarchy. The need for simulation development environment augmented with the reality of the task environment at the remote site will enable operators/users to design, simulate and test control algorithms and before executing them.

7.3 Autonomy and Interactivity

Adding intelligence at the remote process site is one solution that will help in reducing the communication between the local and the remote site, and the demands on the operator. In the context of teleoperation, only partial autonomy in the system can be expected, with tasks allocated between the machine and human operator, i.e., there is still a need for human problem solving capabilities, particularly to configure the remote site for new tasks and to respond to unanticipated situations. The problem is how to add intelligence so as to move the teleoperated system forward on this spectrum. Autonomy can help in reducing the bandwidth requirements for control, but introduces problems of its own, particularly in the area of interactivity. Users of teleoperated systems seem to prefer hands-on control that keep them continuously tracking their task, but they will not get the same type of immediate feedback and interaction when the level of autonomy is available at the remote site. This reduces the chances for operators/users to see the system actually operating and will create feeling to worry about the safety of the remotely operated system while it is working alone. There is a need to find a proper balance by enabling human operator to interfere at any level of control while the remote site is performing autonomous functions.

7.4 Reliability, safety and accuracy issues

To enhance and increase the performance of real time teleoperation, there is a need to minimize errors due to miss-positioning, miss-trial while achieving a proper contact, slipping of an object while being manipulated, etc. Providing a localizing reference can minimize the impact of remote positioning and reduce the mental processing required to perform a task. The localization reference can be achieved through the used of virtual fixtures that are computer generated. Virtual fixtures can be diverse in modality, abstract in form, and custom tailored to individual task to user needs. Safety considerations are often highly important for teleoperated systems. In hostile environments remote hardware failure must be considered a risk. Accordingly the safety of teleoperated facilities should never be harmed or crash due to misuse, large time delay, communication malfunction, disconnection, and other types of uncertainty that may rise from the remote site, the network and the operator side. This can be achieved by enhancing the capability of the teleoperated systems with intelligent and safety guide functionality. Such functions enable remote systems to have decision-making capability that enable them to overcome urgent problems. The other important factor for teleoperation is reliability where there is a need to make sure that the remotely operated equipment/processes are functioning properly. Reliability must be improved to assure minimal consequences

7.5 Sensory dependence

The number, type and resolutions of sensors at the remote site directly influence the operator's ability to perceive, and create an illusion of physical presence at the remote site to monitor, control and identify possible hazards. The quality of the sensed information is degrading due to different factors and reasons, such as, type of sensor, resolution, active view, depth information, noise, etc. Also, many important sensory cues such as audio, visual, tactile, vibrational, and haptic that can be sensed at the remote site through selected sensors may diminish or highly affected with some loss when these cues were transmitted, processed and then displayed to the operator. Due to such degradation in the quality of sensory information they cannot be reproduced for the operator with a high degree of fidelity and consequently affect operator decision and system performance. A potential solution to this is to apply techniques of fault tolerance to enhance system reliability with some complemented and redundant sensory information through different type of sensors. Analyzing the quality of the sensed information and having a clear and efficient approach to notify the operator about any possible degraded information in the environment will be of great support. This leads to the necessity to have techniques that integrate the simulation of the task environment at the remote site with the simulation of the planned actions of the system wile projecting real sensed information at each instant on the simulated task environment. Also, it important to notice that adding more sensors at the remote site will reflect more information about the teleoperated system and task environment. These sensors provide information that can be considered as either redundant aiming to reduce the uncertainty of the measurements or to increase the reliability of the system, or complementary aiming to improve the coverage and the effectiveness of sensing. But, increasing sensory information resulting in extremely high workload that leads directly to fatigue, stress and inability to perform other tasks, and affect bandwidth demand.

7.6 User Interface and interactivity

Designing a complete man-machine interface for a teleoperation system constitutes a major effort that demand different technical expertise (e.g., mechanical engineering, human factors engineering, computer science, etc.). It determines the extent to which the operator can sense the remote environment, interact with and consequently control it. Many interfaces overwhelm the user with multiple displays while simultaneously demanding high levels of cognition and motor skill. The design of any user interface should involve a trade-off between ease of use and the capacity for complex tasks. The view presented by the user interface impacts the feeling of the user while interacting with a remotely controlled system with tools and functionality that enable users to display task environment, facilities and its surrounding with different zoom and details. Viewpoint control is affecting overall performance, and there is a need to have the ability to view the scene from different positions, orientations, and level of resolution. However to provide viewpoint control, the system must either have a 3-D model of the workspace enhanced by real time sensory information and/or moveable cameras. The user interface should permit users to explore task environment space at whatever pace and level of details they desire. Flexible control with a user interface that make it possible quickly to select parameters from any part of the system and construct a control page for monitoring and control purposes. Enable the remote supervision and remote tuning of distributed control systems, including their embedded or external control devices. These applications are among the most critical ones in industrial environments, since they handle the functions related with the dynamic behavior of real equipment.

8 THE INTERNE AND QUALITY OF SERVICE

Quality of Service (QoS) refers to the capability of a network to provide a range of guarantees about its performance, measured in terms of sustained bandwidth, latency and/or packet loss rate. The need for QoS stems from a design characteristic of networks whereby resources (e.g. especially backbone links) are generally shared among many users who are running applications simultaneously. The QoS provided by the Web, namely the access to the vast amount of geographically distributed information depends on the quality of access to the data. This in turn depends on a number of parameters, some of which are difficult to quantify. Interactive services rely on real-time adaptation of the transmitted content to the available bandwidth. To ensure a given QoS, adaptation can be performed at different levels ranging from the user interface level to the router level.

To encourage the deployment of Internet based time critical applications, there is a need to receive assurance that information will be delivered to its destination quickly and accurately. This should be supported by sustained access to high bandwidth services. In some applications both bandwidth and latency may be critical factors due to the need for rapid access to large amount of information from disparate sources connected to the Internet. Example of such application is the medical field. No capabilities have yet been developed across the Internet to ensure QoS.

There are efforts to deliver packets to their correct destination in a timely way, but no guarantees on latency or rates of packet loss. High loss rates degrade transmission quality and increase latencies as lost of packets are retransmitted. Whether the Internet will be widely adopted will depend in part on the technical capabilities it can provide and how these capabilities compare with those provided by other networking alternatives available to users for different applications. A number of technical factors need to be considered in such evaluations. The technical capabilities needed to support real time control and monitoring application-related use of the Internet vary from one application to another. The technologies of most interest to real time control application over distance are to be more readily scalable techniques to guarantee bandwidth on demand. Users should have the capability to support to reconfigure the allocation of the bandwidth as needed in supporting applications. The need for rapid re-convergence after link failures to ensure the new paths across the Internet is found quickly in the event that a particular link fails. Make sure enough network resources are available to support the anticipated workload. Appropriate dimensioning of network and server resources can do this. Optimize the flow of requests and replies between users and servers.

9 CONCLUSIONS

Real time control over the Internet as issues, applications, problems and approaches has been introduced. The paper shows that the QoS of the Internet must be improved to provide the bandwidth and latency that fulfil the need for real time applications.. Promising broadband technologies are appearing and that will enhance this direction. Real time applications and control will directly benefit from such development. There is a need for development environment to design, simulate and test control algorithms for Internet based teleoperated systems. Also, there is a need to study and understand the packet delay and loss behavior in the Internet. Understanding such behavior is important for the proper design of network algorithms both at the application level and at routing and flow control algorithms. Rigorous performance evaluation is desirable. The evaluation should include both task specific and generic experiments. The task specific will keep development of the system focused on the needs of users and applications, The generic, will provide performance measures that can be compared across systems and applications. The issues of user interface, and control levels and autonomy are critical for real time control over the Internet.

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