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Teleoperation System Using ATM Network

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ABSTRACT

This paper examines the application of Asynchronous Transfer Mode (ATM) in a distributed industrial environment such as in teleoperation, which performs real time control manipulation from a remote location.

In our study, two models of teleoperation are proposed: the first model is a point to point connection and the second model is through an ATM network. The performance results are analysed as to determine whether the two models can support the teleoperation traffics via simulation using commercial software design tool.

1.0 INRODUCTION

Advanced manufacturing relies heavily on robots as elements of complex process for assembly and surface preparation. This promotes the suitability of simple robotic system for a variety of well specified tasks which are repetitive. The capability of these systems for adaptive behaviour could be greatly enhanced if flexible control system could be employed over the network.

The need for communication infrastructure which can cope with the demand of smoothness, feedback paradigms and the consequences of violating physical constraint is crucial. One such possible network that can satisfy the above requirements is based on the Asynchronous Transfer Mode (ATM) technology.

2.0 TELEOPERATION

Teleoperation in a simple word is to perform work at a distance. The word tele-operator is described as a machine that extends a person's sensing and/or manipulating capability to a location remote from that person or operator [1,2].

A teleoperator is usually to includes the artificial sensors of the environment, a vehicle for moving in the remote environment and a communication channel to and from the human operator. The control system is using joystick or a master slave positioning device.

Teleoperation was initially conceived for handling radioactive material, since teleoperation allows an operator to exert forces on or to impart motion using a slave manipulator and to experience kinaesthetic feedback. An operator is also provided with visual and possibly audio feedback from the remote site. With the introduction of teleoperation technology, operators are able to perform sophisticated material handling and servicing tasks with considerable danger or hazardous to human being.

If we try to perform teleoperation at considerable distance, as an example in outer space, communications delay becomes significant. If the delay between the operator actions and feedback exceeds one tenth of a second, then the system becomes unstable and it is impossible to perform tasks using teleoperation. For terrestrial communications, however, optical propagation delay is within one tenth of a second, so it is possible to provide teleoperation between any two points on the earth's surface.

Teleoperation requires a number of communication channels, each with stringent requirements. For visual information communication demands megabit bandwidth with frame rates in excess of ten frames per second. Normally, teleoperation make use of two or three video channels, each requires 20 - 30

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million bit/second, uncompressed. These video channels are capable to tolerate up to about 30 ms jitters and can accommodate 1 - 2 frames/second of lost video [3,4].

The kinaesthetic communication channel is required in both direction for the manipulator, of which there are typically two. Such channel requires the transmission of some hundreds of bits at the kilohertz rate. There are strict timing requirements on these channels and irregular or missing data will seriously degrade the system performance. Beside these channels, other channels such as for audio or tactile information may be required.

With the advent of digital wide band communication network such as Asynchronous Transfer Mode network it is possible to provide these communication channels and thus enable long distance teleoperation.

3.0 ATM

ATM technology has now established as a new generation of digital communication network which can support services either for wide area information transportation over BISDN or for the basic infrastructure of computer networks and intradevice connections. These services are:

i) High quality communications where ATM will enable the network to support real-time services such as voice, video and data transmissions.

ii) ATM is a flexible communication technology which can provide services that require different transmission bandwidths and qualities by statistically sharing the network resources.

In ATM network, all information or massages are segmented into fixed length cells consisting of 5 bytes header and 48 bytes of payload. The fixed cell size ensures that time critical information such as voice or video is not adversely affected by long data frames or packets. The header is organized for efficient switching in high speed hardware implementation and carriers payload type information, virtual circuit identifies and header error check.

ATM is a connection oriented technology in the sense that before two systems on the network can communicate, they should inform all the intermediate switches about their service requirements and traffic parameters. This will enable ATM to organise different streams of traffic in separate cells and allow the users to specify the resources requirement and permit the network to allocate resources based on these need. Multiplexing multiple stream of traffic on each physical facility, combined with the ability to send the streams to many different destinations enable cost saving through a reduction in the number of interfaces and facilities required to construct a network.

ATM is capable to handle a mix of delay insensitive, loss insensitive, delay sensitive and loss sensitive traffic over the same ATM interface and network infrastructure. ATM combines the high speed of circuit switching with the flexibility of packet switching over a single simplified network infrastructure. ATM is highly flexible and scaleable, allowing supports ranging from small private network to very large public networks. ATM offers several benefits as following:

i) Integration of multiple traffic types.
ii) Efficient bandwidth use by statistical multiplexing.
iii) Guaranteed bandwidth and resource allocation.
iv) Dynamic bandwidth management.
v) High service availability.
vi) Support multiple Quality of Service (Q_oS).
vii) Seamless private and public network technology.
viii) Automatic configuration and failure recovery.
ix) Cost effective fixed length cell processing.
x) Improved transmission utilization.

ATM will allow companies and users to build networks based on the future vision of uniting voice and video communication on ATM technology based equipment. Furthermore ATM has the potential to improve performance and to lower the overall network, equipment and operating cost in the long terms.

4.0 REAL TIME CHANNEL

Messages in a digital communication network can be categorised into two classes :

I. **Non real-time**
Messages for non real-time do not have tight-delay requirement. Loss of certain percentage of packets due to network congestion is tolerable by employing a proper packet retransmission policy.

II. **Real-time**
Messages are required to be delivered to their destinations with some specific delay bounds. Those messages which are not delivered within these delay bounds will be discarded, thus deteriorating the quality of service. One way to guarantee the timely delivery of real-time messages over packet-switched network is to use the concept of real-time channel.

4.1 Definition of Real-time Channel

It describes a three tuple (T,M,D) as shown in Figure 1, of a unidirectional connection between a source and a destination which guarantees that every message generated at the source will be delivered to the destination sequentially and in a time period no greater than D if the following two conditions are satisfied [5]:

$C\ 1$: The message inter-generation time is not smaller than T.
$C\ 2$: The message size does not exceed M.

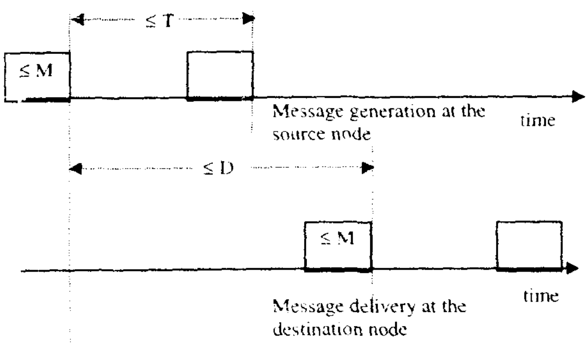

Figure 1 : Parameters of a Real-time Channel

4.2 Implementation of Real Time Channel.

The implementation of real-time channel relies on two techniques :

- Admission control via channel establishment
- Deadline scheduling of packet transmission.

i) *Admission control* requires the client to establish a real-time channel before starting message transmission. A real-time channel request may be accepted or rejected, depending on the current network load condition. Admission control is necessary because message delay bounds cannot be guaranteed without controlling the traffic load of the network.

ii) *Deadline scheduling* can minimise queuing delays and provide protection between channels. It specifies how message is divided into packets, and how deadline of a packet over the links it traverses can be calculated. For this technique, messages are split into packets which are then transmitted individually. Real-time packets are given priority over non real-time packets. Each real-time packet is assigned a deadline over each link it traverses which is calculated from the user requested end-to-end delay bound and packet's generation time. When several real-time packets contend for use of the same link, the packet with the earliest deadline will be transmitted first.

4.2.1 Implementation Protocols

Two protocols are needed to implement the above two techniques :

i) Channel Establishment Protocol.
It handles request for establishing real-time channel. It checks whether or not the requested end-to-end message delivery delay bound can be guaranteed for a real-time channel under the current network load condition. A channel request is guaranteed if the requested delay bound can be guaranteed.

ii) Deadline Scheduling Protocol.
It implements the deadline scheduling of message transmissions. It specifies how a cell is constructed from messages and how the deadline of each cell is calculated in order to guarantee the message link delay bound.

5.0 SIMULATION

In this study we use the commercial software design tool to analyse the performance and the compatibility of applying ATM technology to the existing network. Through simulation we can explore the behaviour of the proposed system and also pre-test the proposal made to modify on the existing system without compromising its on-line behaviour.

5.1 Simulation Model

The simulation model for this study is as shown in Figure 2. The basic communication system comprises of the transmitter and receiver as represented by PC and PC2 respectively. The messages from the source is represented by Control information which is generated by the user. These messages are the integration of voice, video and data which is a typical multimedia application. The first configuration is a point to point connection and the second is via the ATM switch. At the destination, the manipulator will execute the command from the control while the camera and microphone allows the operator at control side to monitor the process that occurs at the manipulator. The Cloud in the Figure 2 represent the ATM virtual circuits using low speed trunk of 1048kbps.

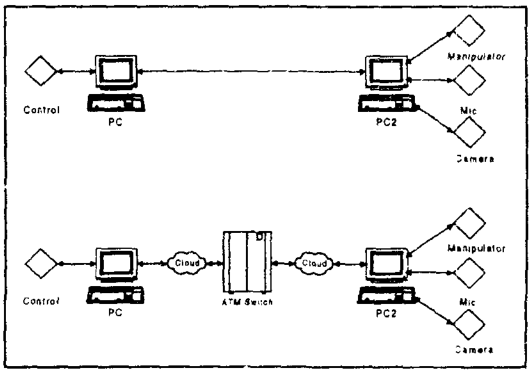

Figure 2 : ATM Network Model; the point to point model and via an ATM network model.

The models include:

i) Manipulator Control system model (Control)
ii) Communication node model (PC & PC2).
iii) Link model.
iv) ATM switch model.
v) ATM cloud model.
vi) Manipulator model.
vii) Voice model.
viii) Image model (camera).

6.0 SIMULATION RESULT

In general, real-time applications are more sensitive to the cell delay than data applications and on the contrary data applications are more sensitive to the cell loss.

In this study we evaluate the maximum message delay (cell delay) and their output buffer used for the point to point connection and via the ATM network models.

6.1 Message Delay for Response Sources

From the simulation results, we plot a graph to compare the performance of the point to point connection and via the ATM network models. Figure 3 shows the message delay against the average message assembled for the response sources.

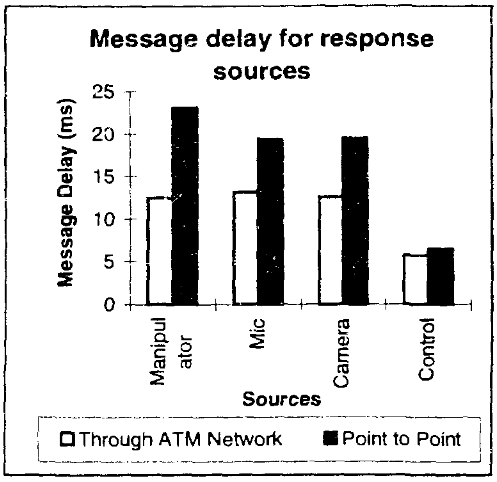

Figure 3 : Average Message Delay for Response Sources.

From Figure 3, we notice that the message delay for the point to point model is much longer then the message delay by the ATM network, even the ATM network uses low speed trunk virtual circuit.

6.2 Output Buffer use by Node

From Figure 4, the output buffer used by the node at PC2 of the ATM network is smaller when compares to the point to point connection model. While at the control side, the PC output buffer for both connections is the same.

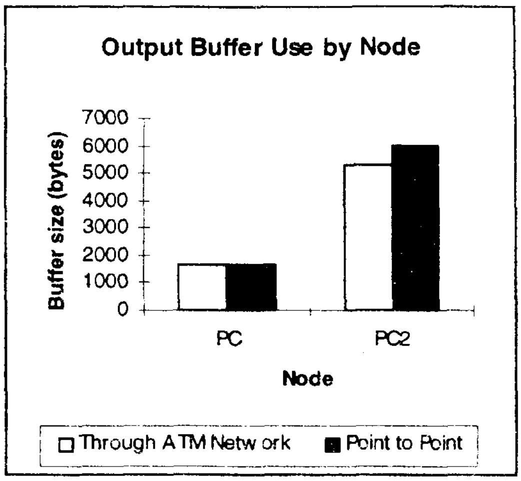

Figure 4 : Output Buffer use by Nodes.

7.0 CONCLUSION

In this paper, we have discussed the performance of Teleoperation or to perform work at a distance using ATM network. From the simulation results, we can conclude that the performance of teleoperation through the ATM network offers shorter message delay and smaller buffer size at the receiver when compares to the point to point connection model. This indicates that ATM network is capable of carrying real time messages, thus confirms ATM network can supports teleoperation system and other distributed real time system.

8.0 REFERENCES

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