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Real-Time Networked Control System With Multiple-Client–Server Architecture Based On Switched Ethernet

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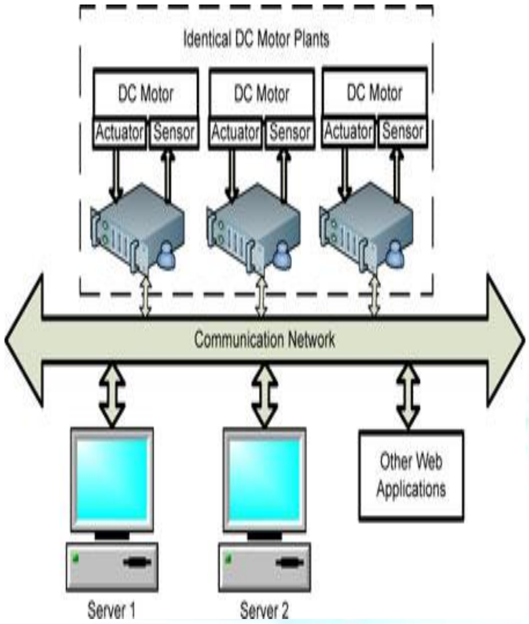
Abstract-- *The NCS experimental setup used in this research involves real-time feedback control of multiple plants connected to one or more controllers over the network A multi client–multi server (MC–MS) architecture on a local area network (LAN) was developed using user datagram protocols the communication protocol. As the link utilization increased beyond the threshold ,employing an additional server in the NCS reduced average packet delays and also overcame the negative effects of Ethernet's flow control mechanism. The MC–MS architecture is tested with artificially generated random packet loss. The standard deviation of steady-state error (SSE) at 80% utilization with packet loss is found to be 70.2% less than SC–SS and 200% less than multIclient–single-server architecture. The MC–MS architecture remained stable till 70% of control or measurement packet loss. This paper experimentally verifies that a multiple-client–server architecture based on switched Ethernet can be used as a real-time communication standard for possible applications in factory automation, by observing the effects of packet delays,network congestion, and packet loss on the performance of a networked control system (NCS).*

Index Terms— Client–server architecture, link utilization, net-work control system, real-time system, switched ethernet.

I. INTRODUCTION

T HE framework of an NCS with a single controller is shown in Fig. 1. In this setup, the communication link between the controller and the plant has to compete with the traffic from other controllers and applications on the network. Industrial communications has come a long way from a dedicated point-to-point connection to optical wireless systems . However, the high costs of hardware and incompatibility of multiple-vendor systems have become barriers in its acceptance. Recently, the computer network standard IEEE 802.3 ethernet has come up as an alternative for real time NCS. The advancements in Ethernet have made it possible to employ it in factory automation systems at the cell and the plant levels . Ethernet has been studied extensively with a Poisson traffic model in different simulation models. However, in a real-time scenario,the traffic is mostly bursty in nature. Mazraani and Palkar found that as long as the network utilization did not reach a particular threshold behavior of the Ethernet remained the same under bursty conditions. They also observed that as the utilization increased beyond a threshold, packet delay, queue lengths,and packet loss increased drastically. To address the issues of non determinism, network architectures based on switching have gained significance. Switches are network devices that operate at the data-link layer interconnecting various hosts. Contrary to a shared architecture, in switched network architectures, frames are sent only to the addressed nodes reducing the number of collision domains considerably leading to a better handling of the traffic and considerable reduction in delay. In this research, a similar switched Ethernet network is used. The experimental setup including the hardware, software, and communication network is elaborated in Section II. The devel-opment of the MC–MS architecture is as follows.



BLOCK DIAGRAM FOR MULTI-CLIENT- SERVER ARCHITECTURE

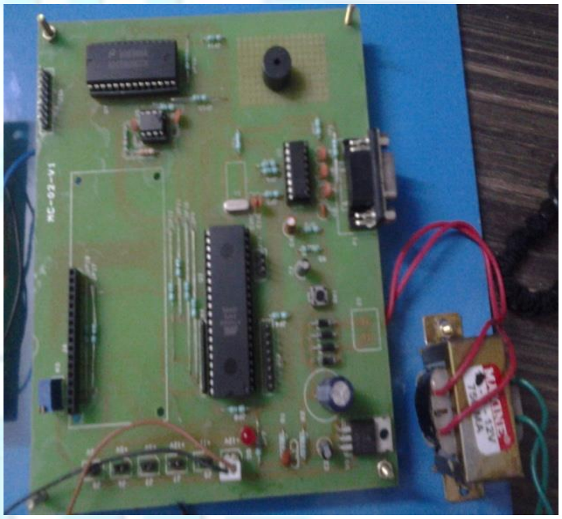
SECTION 1:
MULTI-CLIENT-SERVER ARCHITECTURE

Ethernet allows up to 1024hosts per multi segment, there is always a physical limitation on the number of clients that a single server can handle. As the number of clients being served by a single server is increased,the communication is not only affected by network-induced delays,but also by the delays caused due to the processing time at the server. If the plants connected to the clients have a high sampling frequency, then it burdens the server with heavy timing requirements. To overcome these challenges a multi server architecture as shown in Fig. 5 was developed.A multi server architecture improves the scalability of an NCS by giving the flexibility for a client to connect to a server based on the network load. In this research, the architecture is developed with the approach that the server can accept or reject clients based on the load, and the rejected client can automatically send a new request to a different server. The server decides solely based on the client's identification number. The previously developed architecture satisfies our needs because we are mainly concerned about the performance evaluation of an NCS under varying loads in an MC–MS scenario.

SECTION II:
EXPERIMENTAL SETUP:

It includes cluster node 1 and cluster node 2.cluster node 1 as temperature control system and cluster node2 as gas control system. we use switched Ethernet at the server node for MC-MS architecture.

Cluster node1:DC temperature control system as shown in Fig. are used as one of the cluster node for multiple clients in our test bed. The objective of a dc motor system is to control the temperature of the system at a certain threshold level ..the dc motor system consists of five AMAX 26 dc motors [8]connected to five HEDS 5540 Digital Encoders. A National Instruments (NI) AT89S52 board is connected at the controller node for data acquisition. The encoders are the sensors that send temperature signal outputs in terms of celsious and the controller sends back the control input as a pulse width modulation (PWM) .



Cluster node 2: Dc gas control system is the second cluster node for this experiment.It includes mq-6 gas sensor,Adc for data acquisition and pic as controller**.** The objective of this dc motor is to control the gas at certain threshold level.

SERVER NODE:

The server node includes Switched Ethernet,Uart,Pc and WSN.Switched Ethernet provides MC-MS networking.UART is used for receiving the signal at server node.Pc is for monitoring the output.

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HARDWARE AND SOFTWARE USED:

Microcontroller unit, Adc,Uart,Wireless sensor network,Temperature sensor,Pir sensor,Ldr sensor,Gas sensor,Relay,Pc.Keil compiler,Embedded c,Visual basic.

EXPERIMENTAL ANALYSIS

In server a multi server architecture for the two cluster nodes improves the scalability of an NCS by giving the flexibility for a client to connect to a server based on the network load. In this research, the architecture is developed with the approach that the server can accept or reject clients based on the load, and the rejected client can automatically send a new request to a different server. The server decides solely based on the client's identification number. This experiment includes cluster node 1 and cluster node 2 as its clients.

Our MC–MS client-rejection algorithm is as follows:

1) The server program starts and waits for requests from clients..

2) A client initiates a connection by sending a sensor packet with sensor signal values and an identification number.

3) The server checks for the identification number and decides whether it has to serve the client or not.

4) If it is found eligible for service, the server program selects the control loop relevant to the client and executes the sensor-control communication.

5) If it is found not eligible, the server sends a control packet with the control signal equal to "0." In a normal scenario the control signal is always found to be offset from zero. So, when the client receives a perfect "0" control signal, it considers it as the "reject" packet. The client then selects a different server and proceeds on with Step 2.

A general overview of the client-rejection process is illustrated in following fig.,. DC motor 1 is attached to Client and dc motor 2 is attached to Client 2. In this setup, Server 1 is programmed to accept only slower clients like Client 2 that is operating at low sampling frequency. So, when Client 2 sends a request, it gets accepted by Server 1 whereas the request from Client 1 to Server 1 gets rejected. Based on the client-selection–rejection algorithm, Client 1 sends a new request to Server 2. Because Server 2 is programmed to accept faster clients like Client 1, the request gets accepted as illustrated. Although the connection re-quests between the clients and servers are known previously,the motivation behind the client-rejection algorithm is to accommodate the dynamics of increasing network utilization and load. It is to be noted that the client rejection happens only during the starting of the connection process. From the experiments, it is found that the delay introduced between the client rejection and new server selection is in the order of 0.5 ms. This delay is both negligible and is worth the investment to have a congestion-free NCS

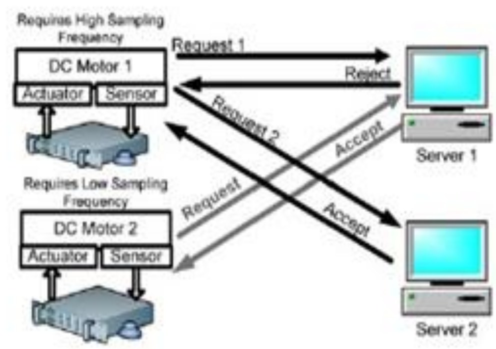

ILLUSTRATION OF CLIENT REJECTION ALGORITHM

EXPERIMENTAL RESULTS

It is found that, having an additional server in a switched Ethernet network showed 300% to 364% smaller standard deviation of SSE compared to that of the SC–SS .It also overcame the negative effect of ethernet's flow control mechanism on real-time communication. From the fore mentioned experimental results, the MC–MS architecture proved to be advantageous under high network utilization scenarios. The campus network used in this experimental research is found to be robust, and no packet losses or distortion were observed during the experiments. To further test the MC–MS architecture, artificial packet losses were introduced.

The packet losses can be divided into two types—control packet loss and measurement packet loss. Control packet loss is implemented by dropping a control packet with a uniformly distributed random
probability and applying hard control output lo

CONCLUSION:

Overall, the. MC–MS architecture performed better than other architectures because it could overcome the effects of network load and was unaffected by the packet loss. The developed experimental setup will be used to address fundamental research questions includes dynamic and optimal resource allocation and Markov-chain based output feedback method for stabilization of networked control systems with random time delays and packet losses.As long as the load on the network is kept below the maximum threshold of link utilization, the NCS showed excellent performance. However, in a real-time scenario a 100-Mbps high speed-ethernet network is seldom loaded to its maximum capacity.Based on the earlier observations, it is evident that switched ethernet holds a great potential for possible applications in factory automation

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