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Real-Time Multimedia Data Acquisition Protocol for Industrial Applications

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Abstract: In this study the design and implementation of Real Time Multimedia Data Acquisition protocol (RTMDAP) for industrial applications is presented. The intended use of this protocol is factory environment, where the remote supervision and control of the devices (sensors, actuators) are important tasks. During control activities data is in shape of text strings and in some cases, symbols representing device state. Factory has many equipments like robots, Numerical Controlled Machines, Vision, Image processing and controllers for achieving the better quality, part tracking and assembly. By deployment of multimedia applications at plant level factory can perform all above mentioned tasks effectively. RTMDAP extends common network communications facilities into the scope of real time data acquisition. RTMDAP (The Real Time Multimedia Data Acquisition Protocol) is based on Switched Ethernet 100 Mbps. TCP/IP and RTP Protocols are employed in the RTMDAP along with UDP with acknowledgement mechanism so that better reliability can be achieved. Well-established and widely used compression techniques H.263, JPEG are also used in the RTMDAP and timely data is. Both the design and implementation are presented together with results of from measurements on a prototype of the protocol. Sampling rate in case of JPEG (live video) from 41.383 to 151.492 packets per second are obtained for various resolutions and in case of H.263 (live video) sampling rate is achieved from 10.53 to 12.374 packets per second with low resolutions. Significant contribution is to deploy the video compression in the factory environment. Well established widely supported video compression techniques H.263 and MJPEG are included in the protocol. The protocol performs the capturing of video through webcam (live).

Key words: RTMDAP, administrator, producer, consumer, switched ethernet

INTRODUCTION

The main objective of every industrial system is the remote supervision and control of devices (sensors and actuators located at remote facilities) for better quality control, assembly and better part tracking. Many factories are using SCADA (Supervisory Control And Data Acquisition) for this task (Boyer, 1999). The information provided by the devices is about few bytes. The traditionally used technologies (fieldbuses) are still suitable for the delivery of devices data which is about few bytes. The communication technologies (fieldbuses) used in industry are time-sensitive. During the two decades transmission and networking technologies are improved dramatically beside this multimedia compression techniques have also evolved in such a way that digital video and audio can now be processed by inexpensive PCS, obtaining good quality displays.

Review of existing techniques: There are many issues to be considered when dealing with computer multimedia systems.

- Video captured by cameras needs to be digitized so computer can handle them. Modern cameras, such as Digital Video Cameras (DVCAM), already provide the video signal in digital form, but other video devices needs a previous step called capturing to be performed before processing is done. Typically, frame grabber does video capturing, which has all circuitry such as A/D converters.
- Video data when on raw digitized form, take a huge amount of space. Keeping data size on practical level, multimedia data compression is required. There are many coders/decoders (normally called codecs) are available. Few of them are highlighted in this study MJPEG, H.261, H.263 for video compression.
- Sending multimedia data over computer networks is done by a process called streaming. Streaming consists of taking compressed video and chopping it off into blocks. But even when data is compressed it still requires high bandwidth links to be transmitted. A 640×480 pixels stream encoded with MJPEG codec at a frame rate of 25 fps requires 1.5 Mbps ISO/IEC 11172-2 (1993).

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Multimedia on industrial systems: Typical transmission links and protocols used on industrial networks do not fulfill the bandwidth requirements of multimedia data deployment, as data acquired from Industrial devices are usually transmitted over low-bandwidth links using serial protocols. Another important key factor is that time-sensitive requirements on the reception of the acquired data are very rigid in the industrial environment (Jasperneite and Neumann, 2001).

Furthermore transmission reliability is also very important as loss of data might cause a big impact to the system integrity. When multimedia data is deployed on the industrial environment, both multimedia data and factory will share the same physical medium where the temporal approach must be adopted. Ethernet network can integrate both on same medium, but transmission reliability must also be considered. Ethernet hub devices use CSMA/CD based medium sharing (ANSI/IEEE Std 802.3, 1998), which can lead to packet loss in high traffic scenario, due to packet-to-packet collision. Therefore, switches should be starting point on the design of any multimedia industrial system. Network management techniques such as quality of service Feng *et al*. (1998), Almquist (1992) and Zhang *et al*. (1993) might also be used to ensure factory data always gets the bandwidth it needs. QoS allows packet prioritization and bandwidth provision, based on one or more factors, such as the IP address of the sender.

Real time multimedia data acquisition protocol: The design of RTMDAP is described. The features in this design serve as the basic building block of RTMDAP. The RTMDAP deploys multimedia applications in factory environment.

Design constraints: Uses communication model which supports industrial applications: one of the goals of RTMDAP is to be used in factory environment because of this constrain the communication model will be used must meet with the industrial communication requirements.

Based on existing hardware and software protocols: Another important requirement is to use existing hardware and software whenever possible. This requires that the RTMDAP should support existing hardware. Customized hardware would drive up the price of devices considerably and take up a lot of time to design and implement.

Multimedia support: RTMDAP can perform acquisition of live video, stored video and other data type. Live video capturing will be done through webcam and stored video will be read from storage. For other data type sampling will be performed.

Non-real-time traffic: Beside real-time traffic (RT) protocol should allow the non real-time traffic (NRT), with a condition non real-time traffic should not affect real time traffic. The only constraint is that preference is given to real time traffic.

QoS guarantees: To meet with quality receiver sends the acknowledgement to sender so that next packet will be transmitted.

Error recovery: The physical layer of network generally does not provide faultless delivery of all packets. When such situation will be occurred RTMDAP should recover from network faults during transmission.

Overview: The rest of this section describes the design of the protocol in detail and elaborates on all the problems, solutions and design choices made during the development of RTMDAP.

Hybrid model: The RTMDAP is to be applied in factory environment where the communication tasks can be implemented according to two basic models: message-based and Producer-Consumer. The message-based model has at least one master and other slaves. The cyclic data run through all the slaves as polled by master. The message-based model does not allow the slaves to access the network without the master's permission. Therefore the alarms are transmitted to the master only when the slaves are polled. In the Producer-Consumer model one producer broadcasts (multicasts) the data once to all consumers. All the consumers to see the data simultaneously and may choose whether to consume (receive) the data or not. The real–time protocols designed in conformity with Producer-Consumer model have station called either scheduler or bus arbitrator. A hybrid model is proposed which contains two different models:

- Client-Server model
- Producer-Consumer model and model is shown in Fig. 1.

Low-level hardware protocol: The prototype uses switched Ethernet because of its design, which offers low latency. The original bus-based Ethernet is unsuitable for real-time traffic because of shared medium and back-off algorithm. Several approaches are used to make original bus-based Ethernet suitable for real-time traffic. The approaches falls in three categories: token based medium access control protocols, time-slot based protocols and statistical. By using time-slots and token passing techniques nodes can cooperate and in result the collision among the nodes minimized and bandwidth can be allocated. Recent enhancement (i.e., connecting system to

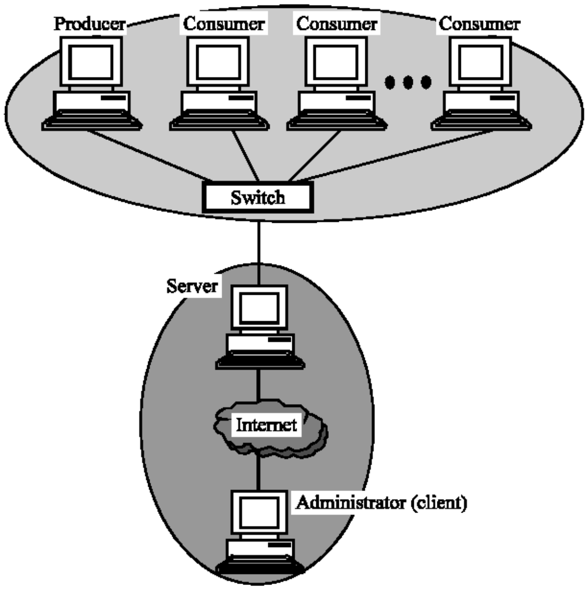

Fig. 1: View of proposed hybrid model

full duplex Ethernet switches) in Ethernet technology has eliminated the possibility of collision occurring in an Ethernet networks. A major step towards deterministic behavior in Ethernet networks to eliminate the random CSM/CD bus arbitration. This can be achieved by using latest Ethernet switch technology instead of hub-based infrastructure. Switch technology divides into simple point-to-point connection between network component and stations. Collision no longer occurs and back-off algorithm no more required.

Real-time traffic: In the RTMDAP a mechanism is adopted to make protocol suitable for real-time traffic. Non real-time traffic is assigned to TCP and real time traffic is assigned to UDP. Since UDP does not provide any reliability. Modification is done to UDP by including acknowledgement mechanism in it. Non real-time traffic, which is normally brusty, can affect real-time traffic. Leaky bucket smoother is used to control the non-real-time traffic.

Non-real-time-traffic: The protocol also has to handle non-real-time traffic. In order to do this, non real-time traffic is permitted only when no real-time streams want to transmit something. When any node ready to transmit real-time traffic, it is given the preference over the node, which wants to transmit non-real-time traffic.

Implementation: RTMDAP consists of four portions. One is called Administrator (client). The administrator is located on machine, which invokes the protocol, passes the model number and other parameters to server and also it passes the information about type of the traffic whether real time or non real time traffic. It also monitors transfer of data between producer and consumer through server.

The second portion is called server, the server is located on the machine, which connects producer and consumer after establishing the connection with administrator and also sends the information to administrator for monitoring the activity between producer and consumer. Once server gets the message from the administrator machine, which contains the model number, parameters and data type RT (Real-time) or NRT (Non Real-time). Server switches between UDP and TCP as per type of data. It multicast the same message to all producers, once the server gets the response from producer(s) which intends to transmit the data. Server sends model number and parameters to producer(s) and receives acknowledgment from producer(s). Server requests the consumer for channel and gets acknowledgement from consumer. Server establishes connection with consumer. Server requests the producer to begin data transmission and server gets the data packets and sends the same to consumer and monitoring packet to administrator. If during communication between producer and consumer which is purely real time transmission and administrator sends another request for NRT transmission server avoids it and waits for completion of transmission between producer and consumer. Server uses leaky bucket for smoothing the brusty NRT traffic.

The third portion is producer; the producer is located on the machine, which performs the data sampling. Its job is to wait for request from the server to open a communication channel, provide such a channel when asked, run a requested measurement program or start capturing images through web camera, then close the channel when data acquisition is finished. The measurement program itself sends the data packets using facilities established by RTMDAP.

The fourth portion is consumer; the consumer is located on a machine, which collects the data, which is transmitted by the producer through server. The consumer is responsible to establish a communication channel with producer through server, obtaining data packets, estimating data packets if necessary, then closing the channel when finished.

RTMDAP is developed in JAVA. It can run on Window 98, windows 2000, windows XP, Linux 7.2, Linux 7.3, Linux 8.0 and Linux 9.0 and the UNIX operating systems. It includes facilities for TCP/IP, UDP and RTP.

Figure 2 depicts the type of data packets, which are transmitted over the communication channel during a typical invocation of RTMDAP. Initially, the administrator requests that the server open a communication channel. The server responds with acknowledgement. The administrator then sends a multipurpose packet. This

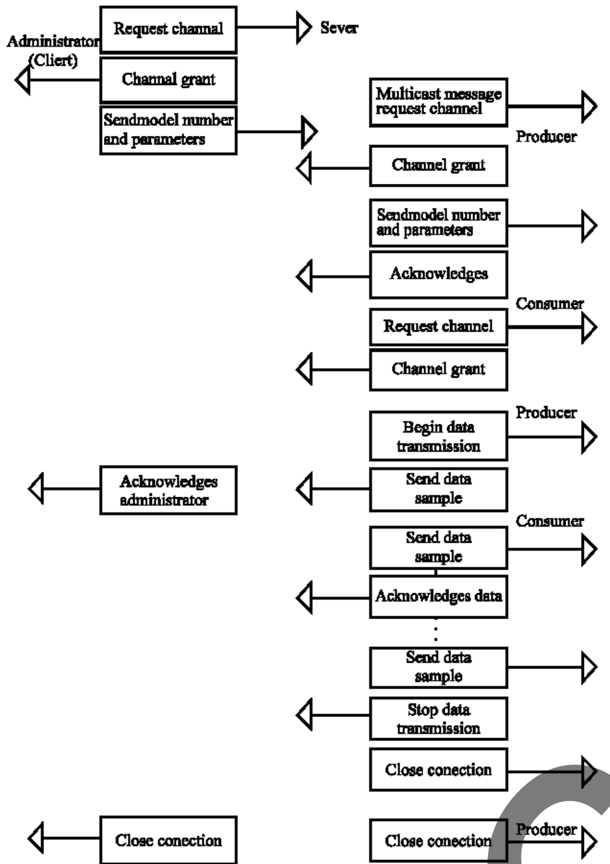

Fig. 2: Typical RTMDAP packet traffic

packet contains the name of measurement program, which the producer is to run and transmit the data to consumer through server. It also contains the type of the data whether real-time or non real time. After receiving the multipurpose packet from administrator the server sends the request to producer(s) and gets acknowledgment. Server establishes the connection with producer(s). Server requests the consumer for channel and consumer acknowledges. Server establishes connection with consumer and sends multipurpose packet to producer. This packet contains the name of the measurement program, which producer is to run. It also contains the name of the file from which the model are to be read, as well as a code identifying the class of model whose parameters needed. The producer responds with the values of the requested parameters. These packets serve to prepare both consumer and producer for data acquisition. After the producer receives the Setup Info Send and Receive packet, the required Fig. 2 measurement program is loaded. The measurement program then waits for a synchronization packet telling it when to start sampling. Similarly, the consumer initializes its internal data structures to begin data collection and estimation.

When the consumer is prepared and ready to receive data, it sends a request to producer through server asking that data transmission to begin. The producer then repeatedly sends data packets. After receiving each data packets, the consumer acknowledges reception to ensure reliable packet transmission and process the data in whatever fashion necessary.

When the user's applications on the consumer machine have collected sufficient data, it then sends a packet to producer through a server informing it to stop data transmission. The measurement program on producer then stops and RTMDAP closes the connection. The user's application on consumer may then proceed to other activities.

Experimental setup for videos: A series of experiments have been performed to examine JPEG and H.263 for collecting information for average packet size, average packet per second, average packet size, bytes, average bytes per second and average mega bits per second. These quantities were also examined for a variety of resolution: 160×120, 176×144, 320×240, 352×288 and 640×480 for both live and stored video.

The machines being used throughout the experiments are 4 machines, 2 Dell OptiPlex 400 MHZ machines; one machine uses the MS-Windows 98 another uses MS-windows The communication hardware on one machine is the 3COM EtherLink XL 10/100 PCI complete management NIC (3C 905C-TX) Ethernet card. The second machine uses the Netelligent 10/100 TX PCI Embedded UTP controller. Third machine IBM IntelliStation Dual processor of 500 MHZ uses RedHat Linux 7.3. The communication hardware on this machine is the 3COM EtherLink XL 10/100 PCI complete management NIC (3C 905C-TX) Ethernet card. Fourth Machine is Compaq DESKPRO SB 400 MHZ; machine uses the MS-Windows XP. The communication hardware on this machine is the 3COM 3C918 Integrated Fast Ethernet Controller (3C 905B-TX) compatible Ethernet card. Machines are connected through two CISCO 2500 routers and CISCO 2800 switch. UTP cables are also used. IOS for all CISCO equipments 11.0. LOGI TECH PC-CAM is used in setup.

The video capturing program is on producer which grabs the video through webCam and video player is on consumer. The measurement program is on the consumer machine. The Ethereal and winpcap are used for collecting the information.

The independent variables for these experiments are time in which packets to be transmitted and the resolution. The following values are dependent quantities which are measured. These values are collected at consumer.

A comparison of resolutions is shown in Table 1 which indicates that the numbers of packets received by

Table 1: Comparison of results for live video (JPEG)

JPEG					
Resolution	160×120	176×144	320×240	362×288	640×480
Time (min)	2	2	2	2	2
Packets	4986	4213	10655	9917	18199
Avg. Packet/sec	41.383	34.856	88.607	82.539	151.492
Avg. Packet size	749.818	919.185	908.495	945.707	1003.309
Bytes	3738595	3872527	9680017	9378580	18259221
Avg. Bytes/sec	31029.74	32039.34	80498.68	98058.08	151993.12
Avg. Mbytes/sec	0.248	0.256	0.644	0.624	1.126

Table 2: Comparison of results for video (H.263)

H.263		
Resolution	160×120	176×144
Time (min)	2	2
Packets	1425	1492
Avg. Packet/sec	10.053	12.374
Avg. Packet size	442413	480.141
Bytes	630438.53	716371
Avg. Bytes/sec	5253.6542	5941.052
Avg. Mbyts/sec	0.045	0.048

consumer, during the transmission of live video with low resolution the numbers of packets are low and with the high resolution the numbers of packets are high. Only in case of one resolution 176×144 some unusual result is achieved, where numbers of packets are slightly lesser than resolution 160×120. It may be because of compression technique. In Table 1 it is clearly indicated the average packets/sec increase with increase in the resolution only slightly decrease in case of resolution 176×144. The average packet size shows some increase. In all cases of resolutions the numbers of bytes are increased from low to high resolutions. Only some variation is seen in case of resolution 352×288. Smooth increase is achieved in the measurement of average bytes per second. Similar pattern is for average mega bits per second.

Table 2 clearly indicates that the numbers of packets received by consumer, during the transmission of live video with low resolution the numbers of packets are low and with the high resolution the numbers of packets are high. In Table 2 it is clearly indicated that the average packets/sec increase with increase in the resolution. The average packet size shows some increase, in all cases of resolutions the numbers of bytes are increased from low to high resolutions. Smooth increase is achieved in the measurement of average bytes per second. Similar pattern is for average mega bits per second. No observations are displayed for 320×240, 352×288 and 640×480. It seems the H.263 does not support high resolutions.

CONCLUSION

RTMDAP is intended to deploy the multimedia applications to current factory environment in which monitoring and quality control is achieved through text mode and symbols. Video compressions H.263 and MJPEG are suitable for factory environment because of low bandwidth support. Because of deployment of compression techniques in the protocol, it eases the life of the factory operators to perform better monitoring and quality control activities.

RTMDAP is based on switched Ethernet hardware protocol and the TCP/IP suite, UDP/IP and RTP software protocols. Significant contribution of RTMDAP is to deploy the video compression at factory environment. Well established widely supported video compressions techniques H.263, MJPEG are included in the protocol. The protocol performs the capturing of video through webcam (live). RTMDAP is implemented in JAVA 2.0, Java.net, swing and JMF. The particular protocol is designed to run under MS-DOS, MS-Windows 98, Windows 2000, Windows X_P, Linux 7.2, Linux 7.3, Linux 8.0 and Linux 9.0.

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