Industrial Multimedia put into Practice

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Abstract

Recent developments in the factory floor technologies together with the widespread use of TCP/IP and the Internet are increasing the eagerness to support a new wide class of devices and applications, such as industrial multimedia applications, in factory floor networks. This paper presents how this new field of applications can be put into practice, via a manufacturing cell field trial being implemented. This manufacturing automation field trial involves the use of traditional distributed computer control systems and 'factory-floor-oriented' multimedia (e.g. voice, video) application services.

1. Introduction

Fieldbus networks are increasingly popular in industrial computer-controlled systems, allowing field devices like sensors, actuators and controllers to be interconnected at low cost, using less wiring and requiring less maintenance than point-to-point connections. PROFIBUS [1] is one of the most popular fieldbuses, and has been granted the status of an international standard by CENELEC [2]. Research efforts [3-4] on the timing behaviour of PROFIBUS networks have proved the capabilities of this fieldbus standard to support distributed computer-controlled systems with stringent real-time requirements.

The recent technological developments are pulling fieldbus networks to support a new wide class of applications, such as industrial multimedia applications. Examples of such applications for the industrial environment include video, audio, file transfer, http, etc. These applications can be supported by the TCP/IP protocol, which is widely used, vendor independent, standardised, and interoperable with almost every operating system.

One example of the integration of wireless and multimedia in PROFIBUS is reflected in the IST (Information Society Technology) project RFieldbus (High Performance Wireless Fieldbus in Industrial Multimedia-Related Environment) [5], supported by the European Commission.

This paper presents a field trial that was specified to validate the RFieldbus approach for integrated wireless and wired communication in the factory floor, and to support multimedia streams and mobile nodes. The focus is given to the support to the new industrial multimedia applications and devices.

The paper is structured as follows. The remaining of this section provides an overview of the RFieldbus system, particularly its capabilities to support TCP/IP traffic over a PROFIBUS network. Section 2 presents the specified manufacturing field trial, while a description of the required multimedia streams is presented in section 3. Section 4 presents an overview of specific technologies that are used to support the required multimedia applications, which are then detailed in section 5.

1.1. The RFieldbus Approach for Wireless Communication

One of the major targets of the RFieldbus system is to extend the traditional industrial communication platforms in the direction of the wireless industrial networking. The aim of this extension is to integrate an extended set of services and some additional functionality in the traditional real-time and dependable communication services, ranging from industrial multimedia capabilities to the mobility of services and devices.

Since the underlying communication platform of RFieldbus is PROFIBUS, only one node is able to communicate at a given instant of time using a token passing mechanism. This implies that the requests must be broadcast to the entire network. In this scenario the handoff mechanism may be reduced to channel assessment and switching. Thus, a simpler handoff mechanism was proposed [6]. One specific station - the *mobility master (MobM)* - must support some additional functionality, since it is responsible for triggering the mobility management procedure. The Mobility Master starts this procedure sending a beacon trigger that is received, and relayed, by the Base Stations, which then start sending a sequence of special frames called beacons in their own frequency (this special frames are not relayed to the wired segments). Mobile stations use these beacons to assess and switch to best channel available.

1.2. TCP/IP over PROFIBUS

Integration of TCP/IP traffic within the RFieldbus system must be correctly specified, in order to provide not only the adequate Quality of Service to the supported TCP/IP applications but also to guarantee the timing requirements of the PROFIBUS control-related traffic. Furthermore, other details that were assessed are:

- Performance issues due to the small maximum transmission unit size of PROFIBUS (when compared to typical TCP/IP environment)
- A solution to adapt the master/slave paradigm of PROFIBUS to the symmetric nature of a IP network
- The integration must be transparent from the application point of view

Thus, the most effective way to integrate such applications within the PROFIBUS communication stack is to tunnel the TCP/IP telegrams into PROFIBUS telegrams [7]. The solution uses a dual stack architecture (Fig. 1) with a Dispatcher sub-layer connecting the TCP/IP stack and the PROFIBUS Stack over the PROFIBUS Data Link Layer (DLL). This architecture adds extra sub-layers to the standard TCP/IP and PROFIBUS stacks.

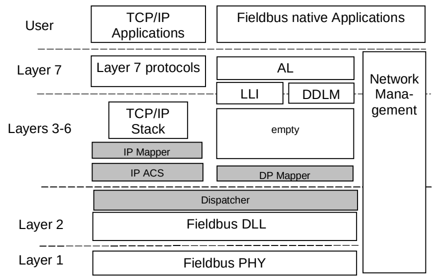

Fig. 1. PROFIBUS and TCP/IP integration

2. The Manufacturing Field Trial

The manufacturing automation field trial involves the use of traditional distributed computer control systems (DCCS) and 'factory-floor-oriented' multimedia (e.g. voice, video) application services, supporting both wired and wireless/mobile communicating nodes (mobile vehicles, for example). It is also a major goal that the manufacturing automation field trial provides a suitable platform for RFieldbus timing (e.g. guaranteeing deadlines for time-critical tasks) and dependability (e.g. reliability) requirements to be tested and assessed.

RFieldbus mobility requirements impose the use of wireless nodes such as transportation vehicles and handheld terminals for supervision and maintenance. The manufacturing automation field trial also involves the use of wired segments, i.e. a hybrid wired/wireless fieldbus network.

One very important issue to be addressed in the manufacturing automation field trial is to bring multimedia applications into the factory floor. Applications such as (mobile) on-line help for maintenance purposes and hazardous or inaccessible location monitoring are examples. The manufacturing automation field trial intends to be an adequate test-bed to assess the suitability of the RFieldbus system to support both real-time control data and multimedia data in the same transmission medium.

To have an application gathering all the previously referred characteristics, an industrial (sub)system that transports, classifies and distributes parts according to a certain criterion was specified (Fig. 2). The mechanical system imposes stringent timing and fault-tolerance requirements for the communication network supporting the diverse I/O points (sensors/actuators/servos).

When a new part arrives (is transported to this subsystem), it must be classified according to a certain criteria and must be distributed to storage buffers or to the next stage of the manufacturing process. This next stage could be further processing (cutting, drilling, etc.) or just transporting a storage buffer to a warehouse. Roller belts and different pneumatic equipment are used to transport and distribute parts to output buffers, according to their type. When output buffers are full, they are moved (either by an automatic vehicle, a robot arm, or an operator) to the respective unload station, in order to be emptied. Considering the classification criteria, for simplicity it is assumed that a part is distinguished by its colour.

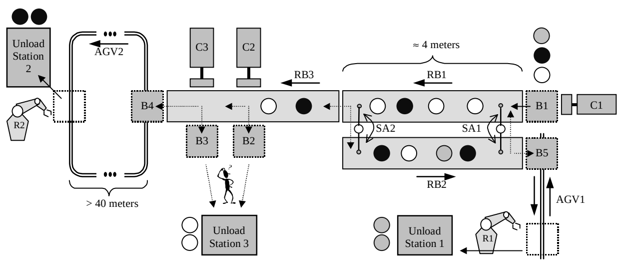

Fig. 2. Mechanical system layout

The input buffer (B1) stores black, white and grey (defective) parts, which are sequentially pushed into the roller belt (RB1). SA2 (a swivelling double arm with suction cups) pushes grey parts to RB2. Grey parts go into B5. If this buffer is full or in transit grey parts must circulate around RB1-RB2. When B5 is full, AGV1 moves to U1, for unload operation carried out by a robot arm (R1) and an operator, and then returns to the initial position. White and black parts go into RB3, and white parts are pushed into output buffer (B2). When B2 is full, an operator is warned, in order to unload it. Meanwhile B3 must be used to receive white parts. If both B2 and B3 are non-operational (full or in transit), white parts must circulate in RB1-RB2. Black parts go into B4, until it is full or if it is in transit. When B4 is full, AGV2 moves to U2, for unload operation carried out by R2. Black parts must circulate around RB1-RB2, if B4 is unavailable.

The RFieldbus Communication Subsystem includes all the RFieldbus equipment necessary to interconnect all the wired and wireless components of the distributed system. In order to test, validate and demonstrate the technical capabilities of the RFieldbus approach, a network infrastructure (Fig. 3 Left) including a wired segment and two radio cells is envisaged, forcing communication between wired and wireless nodes and the handoff between radio cells. In order to have a structured wireless network supporting mobility, the RFieldbus network infrastructure is composed of two Link Base Stations (LBS1, LBS2) that interconnect the two wireless domains (WL1, WL2) and the wired segment (WR). All nodes are PROFIBUS slaves (PC2-6, I/O1-2, PLC1 and Drive1-2), except PC1 and MobM (Mobility Master), which are PROFIBUS master stations.

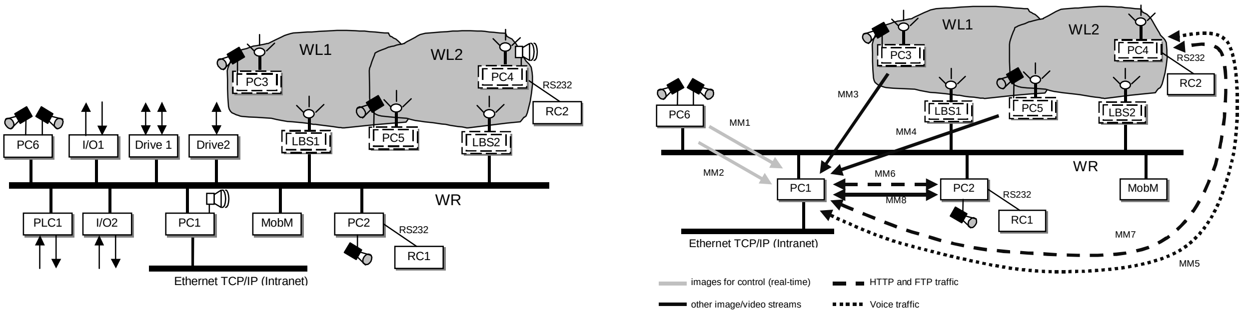

Fig. 3. RFieldbus network topology (left), Multimedia streams (right)

3. Multimedia Streams

Several multimedia applications will be used for control, monitoring and interpersonal communication. The correspondent message streams on the RFieldbus network are presented in Fig. 3 (Right).

TCP/IP Remote Part Classification (MM1, MM2): Two cameras in PC6 acquire images of the moving parts at a predefined rate. These images are downsampled and compressed to greyscale JPEG files. This data is then sent using TCP/IP connection to the remote machine (PC1). On the monitoring side (PC1), each received image is decompressed, processed to identify the presence of a part and classify it.

TCP/IP Remote Video Monitoring (MM3, MM4): This application will be used in order for the operator in the central control PC (PC1) to visually monitor the area in the trajectory of the AGVs (AGV1 and AGV2). It must also have basic control facilities such as to start and stop the stream.

TCP/IP Voice Connection (MM5): This is a simple point-to-point TCP/IP bi-directional voice application connecting PC1 and PC4. The only controls needed to the operator are "dial", "answer" and "hang-up".

TCP/IP Remote Position Detection (MM6): The autonomous vehicle (AGV1) may slightly deviate from the ideal loading/unloading position. Therefore, a visual position detection mechanism was devised in order to make the appropriate position corrections for the robot arm to manipulate the buffer. On the capture side (PC2), images are captured by request of the monitoring machine (PC1) and sent to PC1 using a TCP/IP connection. Each received image is decompressed and processed to identify the presence and location of the buffer in the Robot 3D co-ordinate system.

Remote Robot Control Services (MM7, MM8): In order to be able to remotely control the two robots of the field trial, support to FTP and HTTP is provided (in PC2 and PC4). The FTP servers are configured to enable the transference of program files to a specific directory on the computer. The WWW application enables the transfer of these files to the robot and interacts with the Robot system itself.

Intranet Interface Services: Several services will be available for system monitoring and control using standard TCP/IP stations in the Intranet attached to PC1. Two ways to access this information are being deployed: The **WWW Server** provides several HTML pages and forms that an user can browse to check the current system status and interact with the system (given the proper credentials). Any WWW browser can access this information. The **UDP Server** will support efficient broadcasting of information to several stations on the network. Specific clients are being developed to interact with this server.

4. Supporting Technologies

In order to exploit the multimedia characteristics of the RFieldbus field trial several additional technologies are being integrated with the industrial system. Some of these technologies are not currently common in the factory floor but there is a clear eagerness to start their widespread use in this area with clear benefits.

802.11b Wireless Network: IEEE 802.11b is a wireless network standard with a maximum speed of 11Mbps and a range up to 500 meters outdoors (at 1Mbps). There are 802.11b interfaces available for several Operating Systems and form factors (PCMCIA, PCI, etc) as well as “stand-alone” bridges to Ethernet networks.

Head Mounted Display: The Head Mounted Display (HMD) technology opens a new level in the way information is presented to the user. The display is in front of the user’s eye giving (due to the lenses it uses) the sensation of a big monitor. HMDs can range from a monocular low-resolution (320x240) grey-scale monitor up to full colour, high-resolution (1024x768), high-luminosity and fast refresh rate binocular systems.

Video Conferencing (one-to-one): With the dissemination of PCs and affordable Internet connections, this technology is becoming more accessible. The only additional hardware needed is a webcam (see next paragraph). One of the most popular is Microsoft NetMeeting (free for Microsoft Windows) that supports one-to-one video conferencing and is compatible with H.323 video conferencing standard.

Video Capture: Nowadays the simplest and cheapest method to capture real word video sequences into a computer is to use a USB webcam. However due to development constrains the field trial is limited to use Windows NT and USB webcams are not available for this OS. So a video camera + video capture board combination had to be chosen.

Personal Data Assistant: Available since more than a decade, Personal Data Assistants (PDAs) have been used almost exclusively for they main purpose: as an electronic version of the traditional pocket agenda. However, in the last years new applications for several operating systems have appeared. The latest generation of Pocket PCs has advanced features like: fast processors, full-colour displays, TCP/IP and WWW support, connectivity (irDA, 802.11b, Bluetooth), expandability (using PCMCIA, SecureDigital, etc), and much more.

5. Implementation Aspects

5.1. Intranet Server Application

At this phase the Intranet Server Application only simulates inputs from RFieldbus system. A GUI was developed, in Visual Basic, where the operator can change the text information and access/change/define the parameters of each PC. It is also possible to send alarm messages to the Intranet and to configure the messages that are to be accepted by the information devices (HMD and PocketPCs) and the SMS gateway. All the information is exchanged using UDP packets. This solution was selected to enable the broadcast of information to all the devices connected in the Intranet, including the Augmented Reality Client (HMD) and the SMS Gateway.

Each PC in the field trial has a Text Information field, with status information, and up to 6 read/write parameters. Each of the parameters has a run-time definable label and a text value.

Alarm messages have 5 classes and several type identifiers. Alarm classes are used to filter the presentation of alarm messages in the Intranet devices. Type identifiers are used only to illustrate the alarm using images and/or sounds. The alarm message itself is a text string.

Since this is a simulator of the real Intranet Server, this version only supports broadcast of images from a single camera at a time. The Intranet system supports up to 6 cameras, and each video presentation device can be configured to accept images from one to all of these cameras. There are also commands to turn on and off the video streams at the server.

To support output-only devices like HMD and SMS gateway, Intranet commands are used to configure them. For the HMD and Output-Only Clients it is possible to select a video stream to be displayed as well as the alarm classes. For the SMS gateway it is possible to configure the destination cellular phone number and the alarm classes.

5.2. Intranet Client Applications

There are two versions of the Intranet Client Application: one for the Pocket PC and the other for desktop Windows. They offer the same services and user interface. Both applications are developed in Microsoft Visual Basic (Embed version for the Pocket PC clients). In the current development status the application provides access to (Fig. 4) images from cameras, text information from PCs, read/write access to selected parameters in PCs, alarm messages and SMS and HMD message selection.

Fig. 4. Pocket PC Client Application snapshots: (from left to right)
main menu, camera selection schematic, camera image, PC text information, PC parameters.

The Pocket PC client was developed so it can be used with a finger (no need to use the pen for all operations except changing parameters) or using the hardware 4-way cursor.

5.3. Windows CE UDP ActiveX component

Since the Microsoft Winsock ActiveX component for Windows CE does not support UDP communications, a UDP ActiveX component had to be developed in-house for Embed Visual Basic. Additionally it also enables the creation of and writing to binary files using strings (something that the Microsoft File component does not support). This is a rather simple component but it provides great benefits: it converts the UNICODE strings to ASCII and so all file and network data is in ASCII format; it also supports strings with null characters.

5.4. *Automatic Image Processing Applications*

There are two main Image Processing Applications in the field trial: Colour recognition and Position detection.

In the first one a colour camera continually monitors a section of the roller belts. When a part is detected the application identifies its "colour" (black, grey or white) and presents this information to the user. Colour detection is a two-phase process: first a test is made to see if there is a part or not in the vision area, checking the colour component of the image. The second phase (when a part is detected) divides the image greyscale histogram in bands (programmable) and checks which one has higher value. To avoid detection errors (in the beginning and end of the part) the final result is only output when the part has left the vision field, by selecting the greater number of detections. This algorithm has been tested successfully with several roller belt speeds (full range supported by the field trial hardware) and with very small distance (down to 3 cm) between parts.

Due to changes in the transference buffers, the position detection application development has been postponed and has just started. At this moment it detects the position of two colour circles in an image. The colour circles can be easily distinguished from the parts (white, grey, black) and the buffer itself (white plastic and metal). By using two circles, the centre point where the gripper must pick up the buffer can be interpolated.

5.5. *Augmented Reality Application*

At this moment a small proof-of-concept demo is available, having a great feedback from the users. The HMD used is a low-cost, monochrome 320x240 TekGear M1 (Fig. 5) connected to a PC running a Visual Basic application. The type of information that the HMD will receive will be controlled from the Intranet Client Applications (in Pocket PC or desktop PC). This information includes image streams and alarm messages. Alarm messages have several background images depending on the type of alarm and feature animations so the user will notice the new message even without looking directly at the HMD.

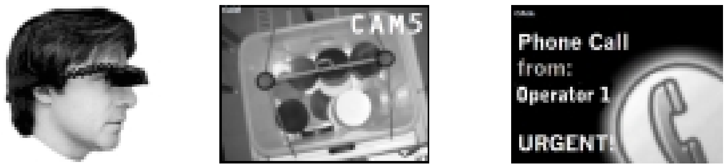

Fig. 5. The TekGear M1 HMD (left). Views at the HMD: camera view (centre); phone call (right)

5.6. *SMS Gateway*

A mobile phone is being used, connected to a PC by using a RS232 data cable. The SMS are sent to the network using standard GSM commands. Unfortunately, "standard" should be used with care in this area: each phone manufacturer has implemented several nuances of the standard and a COM port sniffer had to be used to identify the exact format of the messages. The application forwards alarms received from the Intranet network according to the configuration commands received previously.

6. Conclusions

This paper presented an overview of a field trial that was specified to validate the RFieldbus approach for integrated wireless and wired communication in the factory floor, with a particular focus on the support to the new industrial multimedia applications and devices. The deployed system supports multimedia streams and mobile nodes not only in the field network but also on the attached Intranet. Applications have been presented for several input and output devices ranging from standard Desktop PCs and PocketPCs to HMDs and Mobile Phones. Albeit most of the implemented system was designed to be in the Intranet side of the system, the techniques used will be extended to more devices inside the field network.

Acknowledgements

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