A Review of the Current State of Chemical Laboratory Serial Connections

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Abstract - **This paper provides a study of chemical laboratory equipment utilizing serial connection (e.g. RS-232) communications and highlights the challenges associated with dissimilar communication ports. The problem studied in this paper is significant because many advanced chemical laboratories still rely on equipment with serial ports. The study starts with an analytical review of differences between replacement of laboratory equipment and Personal Computers (PC's) based upon depreciation, followed by a critical overview of serial communications and their use in chemical laboratory equipment, security issues are noted, and three suggested solutions are offered. Finally, a suggested course for future work is proposed to address the challenges inherent in maintaining chemical laboratory equipment and the connected PC's which utilize serial connections.**

Keywords - **Serial Connections, RS-232, Laboratory Equipment**

I. INTRODUCTION

A number of industry areas depend upon laboratory equipment to analyse and report results. Industry areas include biomedical, petrochemical, laboratory analysis, organic and inorganic chemical laboratories, and automated manufacturing systems. Laboratory analysis equipment found in chemical analytical laboratories can be ten or more years old with a usable life span of fifteen to twenty years in some cases. Although the laboratory analysis equipment is fully functional and provides accurate information for many years, interoperability between modern PC's and operating systems changes rapidly. PC's are often replaced every three to five years as part of a company life cycle management program or due to the scheduled depreciation of computer assets e.g. [1, 2, 3], however PC's within analytical laboratory environments may not be replaced for eight or more years if connected to aging laboratory analytical equipment. Replacing analytical laboratory equipment based upon depreciation indicates that replacement could be at least eight years and in some cases fifteen years or more [1, 2, 3] although laboratories could continue using the equipment well past the depreciation time frame.

One of the challenges to maintaining the continued use of chemical laboratory equipment consists of the continual use of serial connections. Although the RS-232 serial connection standard is over 50 years old [4], it has seen persistent use even to the present day. Cases exists where there are a number of laboratory devices with serial connections that far outnumber ones with USB connections. An example is the Process Metallurgy Group (PMG) at the University of Oulu which has 23 of 25 laboratory devices consisting of serial interfaces of either RS-232 or RS-485 [5]. Supporting the continued use of serial communication based laboratory equipment in current environments poses challenges to include the use of PC support equipment that may be outdated, laboratory equipment

originally designed to operate as "stand alone" devices, as well as security challenges.

II. SERIAL COMMUNICATIONS

Serial communications via a RS-232 port Fig. 1, 2 are sometimes generically referred to as a COM port, RS-232 port, or serial port [6]. Although the name of the port may vary, a summary of the different standards is offered by Blansit [6] which gives a high level overview of common computer connections as well as their characteristics. Common connectors such as USB, Firewire, eSATA, and D shell connectors are addressed which provide a good high level understanding of the commonly available interfaces on most PC's. This serves as a starting point to compare what is available on laboratory equipment versus what is available on PC's as many newer "off the shelf" computers may not have the appropriate connection type to support laboratory equipment. This potential lack of connectivity to newly purchased replacement PC's can affect manufacturing, the medical arena, and chemical analytical laboratories.

Fig 1. Male RS-232 Connector

Fig 2. Female RS-232 Connector

Difficulties that laboratories have to implement Information Technology (IT) solutions are hampered by the same issues within manufacturing due to a lack of data and system interoperability between hardware devices and IT equipment. Work done by Maykiv, et al identified over a dozen serial interfaces that are widely used for modern measurement and control systems (MCS). With the number of different industrial tasks, conditions, data rate requirements, and of course budget; the assorted serial interfaces provide a selection for vendors to solve specific tasks. Along with this selection of serial interfaces however is the issue of increased costs for the final piece of laboratory analytical equipment if a large range of interfaces needs to be supported by the vendor. As with previous recommendations (Vetvitskii, et al [8] for example), the USB interface is suggested as a standard, but this does not address the issue of aging equipment that do not have USB interfaces. Finally, as Blansit [6] and Bar, Hochstrasser [9] allude to, there are issues that occur if new computers do not have the appropriate connection which may lead to utilizing an adaptor, purchasing add-in cards, or even attempting to replace a computer with one that has the correct input connectors.

With laboratory equipment utilizing serial connections to pass control and data information, there could be motives from the manufacturer's perspective to continue using this type of interface. The RS-232 standard is a very well established, simple, and proven technology which is adequate for relatively low data transfer rates. The RS-232 interface is also very inexpensive and has been commonly available on desktop PC's for many years. Finally, many pieces of laboratory equipment were designed as standalone units without a connection to the Internet or intranet in mind. These factors could explain both past and current use of this interface.

III. STANDALONE BY DESIGN

In many cases laboratory equipment were designed to operate as standalone units [9, 10]. The advantage to the vendor with this

configuration is that all required software can be installed on a single PC with proprietary software, local database(s), and minimal security issues. Further to this are the challenges induced by this approach whereby the user of the equipment inherits issues with collected data in proprietary formats and physical interfaces such as RS-232 which introduce a challenge when trying to connect to controlling PC's. Where computers no longer provide a RS-232 connection, USB converters are available although an identified issue by Blansit [6] is that the USB connections may not be able to provide sufficient power to some devices. Signal levels for serial ports are typically between +12V or -12V, although some PC's may use -3V and +3V with the pins supplying power between 10 and 20 mA. USB 1 and 2 ports provide a voltage of around five volts and 100mA in total. Laboratory instruments requiring a USB connection to power the instrument are unlikely as laboratory instruments used for analysis such as chromatographs, spectrophotometers, diffractometers, and so on require external power and do not need to be powered by a USB hub or by the PC itself. Thus the concerns expressed by Blansit [6] are not applicable in these cases.

Laboratory equipment and manufacturing equipment are similar in many ways. Connecting equipment to a network is potentially useful for monitoring, gathering information, and controlling the equipment. A case study by Cena et al [10] pointed out that manufacturing uses several solutions to include a fieldbus to bridge the gaps between the standalone devices and bring them into a TCP/IP network. With RS-232 serial communication (or a proprietary scheme) to control the device, enabling an Internet/intranet set of technologies would assist in avoiding issues such as locally extracting data while allowing the capability to manage systems and run diagnostics. Although the case study by Cena et al [10] is over a decade and a half old, recognition of legacy connections had already been known and options and recommendations to mitigate their impact were being made. Since then, the impact of a lack of interconnections by legacy equipment is exacerbated as the equipment ages and older PCs cannot be easily replaced.

Liu, Chen, and Qin [11] also identified the inability to remotely monitor laboratory equipment due to a lack of network connectivity with standalone systems. The ability to exchange serial data to and from the instruments over a network would enable the opportunity to gather data, remotely access and control equipment, as well as allow remote troubleshooting for third party technicians when needed. Mitigating the dependency on using serial connections in a standalone environment and moving to using this same serial architecture in a connected environment may provide additional opportunities and capabilities that could prove attractive to laboratories. Remote monitoring, gathering information, instrument control, and as an enabler to incorporate mobile devices, may be sufficient incentives to review ways to enable network connectivity with selected instruments.

Extending the use of aging PC's and operating systems or enabling the use of current PC's with serial connections introduce other caveats to include securing the devices, PC's, and communications channel.

IV. SECURITY ISSUES

From the security perspective, fewer physical PCs results in a smaller footprint for attack and is a simpler environment to secure [12]. With laboratory equipment PCs isolated from the network (intranet or Internet), attacking a standalone system is much more difficult. If standalone laboratory equipment PCs are joined to a network, further security considerations must be taken into account to include the legacy PC hardware, operating system, and software as well as an approach to secure the serial communications. Legacy systems that support serial connections often fall outside of the Ethernet deployments and a lack of strategy and isolation can make them an attractive target for attacks [13]. To

effectively address a security program for serial devices as well as provide a more efficient network, an approach to integrate the serial devices with the central IP/Ethernet network would provide easier management and extend IP based security features to the serial edge of the network [13].

Lang [14] embraces keeping current Ethernet networking typologies, but strives for the coexistence as much as possible on various connections to include Arcnet, Modbus, and Profibus. There is potentially a large financial outlay required for converting all sensors, controls, and laboratory equipment, to an Ethernet based system. This financial outlay greatly increases if other Ethernet infrastructure devices such as routers, switches and firewalls are also added. For serial communication, Lang [14] suggests the use of serial device server (serial server/serial gateway) devices to bridge the gap between RS-232/422/485 serial devices and an Ethernet port. A serial device server Fig. 3, has the advantage where there is a need to convert from serial protocols to Ethernet but also leaves the application data unchanged.

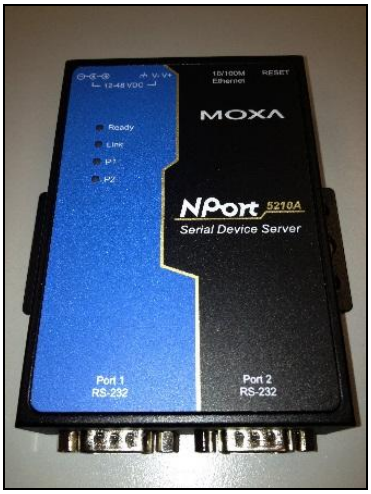

Fig 3. Serial Device Server

However, security issues are a very real concern when chemical laboratory equipment is moved from an environment of standalone devices to one where the same devices are connected to an intranet and possibly the Internet as identified by Lang [13]. Due to the installation of laboratory equipment outside of typical Ethernet deployments, and therefore also outside of the usual security strategy, both legacy systems as well as newer systems must be viewed from the perspective of ensuring cyber security is addressed. With options of traditional terminal servers and serial device servers serve the same function of basic connectivity to an Ethernet network, Linton [13] suggests that serial device servers can further mitigate the security issues while still providing connectivity with legacy systems whereas terminal servers cannot. Having an IP capability, serial device servers can support secure socket layer (SSL) sessions from remote systems and PC-based remote personnel all the way to the edge of a local network. Linton's suggestion of utilizing serial device servers may be a very viable option to the issue of connecting legacy laboratory equipment to a TCP/IP network or to physical or virtual PC's. However, specific testing with laboratory equipment combined with connecting them to physical and virtual PC's would validate this setup.

V. SUGGESTED SOLUTIONS

Establishing a connection between analytical laboratory piece of equipment and a personal computer (PC) for aging (or in many cases current) laboratory equipment may be tested using suggested solutions above. Serial to USB converters Fig. 4, would be a fairly simple solution resulting in a point to point (equipment to PC) connection. As Blansit [6] states however, when a serial to USB converter is used, the number of COM ports also increases each time a device is connected. As devices are tested on a PC, the number of COM ports also increases and therefore a user must be familiar with the Device Manager applet found in the Control Panel. This may be a deterrent if the USB adaptor is not connected to the same port each time. Testing serial to USB adaptors may identify pitfalls using this solution.

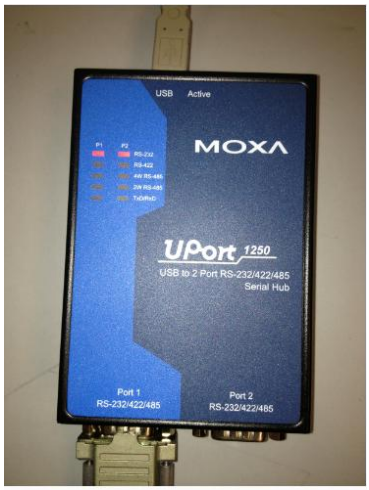

Fig 4. Serial to USB Hub

Another possible solution is using a serial device server (serial gateway/serial server) device as mentioned by Lang [14] and Liu [11] which would obviate issues with point to point connections found in serial and USB connections. Fig. 5, depicts a logical outline where the instrument (e.g. spectrophotometer) is connected to a serial device server and the instrument is accessed from the PC via a network cable rather than a serial connection from the PC.

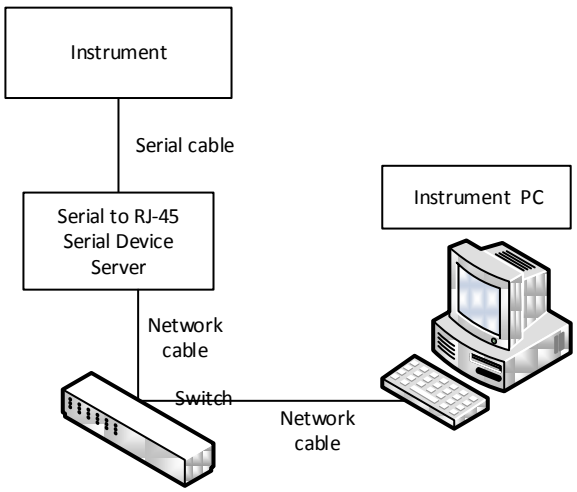

Fig 5. Serial Device Server Example

Testing on a range of laboratory equipment should be carried out and could include mapping the connections to both physical and virtual machines to receive the input from the laboratory devices. Serial device routers offer an intelligent serial to IP networking option which leverages the Ethernet infrastructure and takes advantage of performance, security and resiliency of the Ethernet architecture [13]. Serial device routers are also designed for industrial environments and can be hardened to withstand environmental factors such as temperatures, high particulates, high humidity and corrosive environments [13].

A third solution suggested by Lütjohann, Jung [15] uses a BeagleBone [16] as a "universal device connector". This solution requires a BeagleBone bridge for each laboratory instrument be written using the available manuals of the equipment for the serial data protocol definitions. This solution was designed for academic use in a chemistry laboratory to remotely connect to laboratory equipment with the motivation to propose a low cost and highly functional answer to interface with a Laboratory Information Management System (LIMS). Although targeted for academia, further exploration could yield benefits for commercial laboratories that continue to maintain aging equipment.

VI. SUMMARY

As previously noted, laboratory equipment has been designed to operate in a standalone environment where the equipment often uses a serial port to interface with a PC to pass control and data information. With the RS-232 serial standard well established, simple and well understood, the continued use of this interface seems likely for equipment not requiring large amounts of data to be transferred in short amounts of time or as an optional interface to USB or RJ-45 connections. Solutions suggested by Lang [14], Blansit [6], and Lütjohann, Jung [15] may be valid to solve some of the issues for connecting serial based interfaces to a PC via a USB adaptor or to an Ethernet network. Solutions which enable network access to the instrument and/or controlling PC will also face security challenges which can be comprised of network security, aging PC hardware/software considerations, and unsupported operating systems by the vendor (e.g. Windows 2000, Windows XP, etc.). Solutions which allow the

continued use of equipment with serial connections can assist in prolonging the life of useable equipment thus providing financial savings to laboratories. USB converters, serial device routers, or the use of a software bridge may be used or explored individually or as a mix to support a laboratory and may have dependencies on available budget, skill sets, and vendor support.

VII. CONCLUSIONS AND FUTURE WORK

Not all analytical laboratories have extensive IT technical support. This may impact the ability to utilize some or all of the suggested solutions above. Determining the cost, effort, and skill sets of solutions to address the issues set forth could be beneficial to both large and small laboratories in the commercial, research, and academic environments. The feasibility of using serial device servers and serial to USB converters could be explored to determine if data is modified during transfer from an instrument with a RS-232 port to a PC without a RS-232 port. Accomplishing this could be used to determine initial issues that may be encountered if additional information is added or modified to the data stream during the transit through the data transfer process and that modifies the resultant data sets. If testing proves successful, these results could be used to obviate the use of older standalone PC's for laboratory instruments, incorporate newer PC's, and begin incorporating these systems into a network configuration.

An additional approach to mitigate the use of physical PC's that may be replaced due to obsolescence or depreciation could also be explored. The use of VMWare, Microsoft Hyper-V, or other virtualization technology to carry out a Physical to Virtual (P2V) conversion of the existing physical PC and utilize either serial to USB adaptors or a serial device server to connect the laboratory instrument and virtual machine could also be explored. If successful, this would extend the life of the instrument while maintaining the older operating system and instrument software and allow easy backups and snapshots to be taken of the virtual machines (VMs). Snapshots of the VMs would allow quick recovery due to misconfiguration, disaster recovery, or if updates to either the instrument software or operating system render the environment less than desirable.

Recovery from a PC failure may not be eliminated by using virtual machines, however reliability is increased by providing a faster mechanism for recovery via virtualization. Along with reliability, another benefit is longer lifecycles for applications which may be critical to industrial firms. As has been previously pointed out, the life cycle of a PC and operating system may be relatively short when compared to the usefulness and depreciation of laboratory equipment. Rather than a dependence upon the lifecycle of an operating system, virtual machines are dependent upon a hypervisor which typically has a longer lifecycle. Instead of upgrading the PC hardware and operating system, the virtual machine can remain with the original tested configuration and when the hypervisor needs to be upgraded or migrated to a different hypervisor, the original virtual machine remains unaffected. This could be a benefit to laboratories which depend upon a static environment for scientific testing and obtaining consistent results.

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