The use of the Oscilloscope as an Educative Tool on a Network Installation and Maintenance Unit

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Abstract

Network Installation and Maintenance (NIM) is a first year single semester unit in the School of Computing at ECU. This unit consists of a two-hour lecture and two-hour hands-on workshop. The creation of the NIM unit was based upon a survey of the needs of employers in the field of network installation and maintenance and its workshops consist of extensive hands-on exercises necessary to provide students with the initial practical background skills and understanding required. The NIM unit has no prerequisites and is a full credit unit that attracts students from a wide range of backgrounds many of whom may have had little previous education in technology or physics. Hence many NIM students have experienced difficulties in conceptualising effects such as signal degradation along media or even what a wave shape or wave train represents when drawn on a board or displayed upon a cathode ray oscilloscope (CRO) screen. The CRO was also used to measure voltages. Measurements of time periods were also subsequently used in frequency and bandwidth calculations. These investigations were undertaken as part of a normal NIM workshop and effects such as signal attenuation, crossover, phase shifting, and pulse spreading, were observed via CRO.

1. Introduction

The single semester, level 1,unit Network Installation and Maintenance (NIM) is a hands-on unit that is based on employer expectations in the field of Computer and Network support. NIM's companion unit is Computer Installation & Maintenance (CIM) which was designed to fulfil the basic hands-on requirements where students need to make changes to the insides of PCs to upgrade machines or to replace suspected faulty machines. Prior to its implementation investigations had revealed that nearly all of the final year computing science students surveyed had failed to fulfil the employer-based requirements. [4].Nelson and Morales have noted that: "*It is becoming evident that a good knowledge of networking is critical for success in many kinds of computer-based work. Understanding enough to be able to troubleshoot network problems could become a significant bargaining chip in the job market in the 21st century*" [7]. Whilst Molina III notes that: "*… we polled our junior and senior computer science students to see what they felt would help them most in a networking course. Students indicated that they desired to obtain an applicable knowledge of networking that would lead to immediate employment opportunities after graduation*".[6]

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NIM assumes the knowledge and experience of CIM however due to safety prerequisites internal change to the PC system are not undertaken on this unit as NIM students may not have attended the relevant CIM safety practicals.

The economic and other problems associated with the delivery of a hands-on unit such as NIM is described by Veal et al [10]. Maj has noted the importance of hands-on experiences in such units [3]. The NIM unit covers the installation of both clients and servers. During the NIM workshops students install their own server and client and link them together. Students assign right to users as the network administrator and then log on as various users to test their system. Shull and Vescovi have noted that: *"Unlike most physical sciences where laboratory instruction is accepted as integral to the student's education, data communications and networking are often taught without the practically of the laboratory section"* [8].

Each workstation consists of a client and a server although students can connect to two servers in the labs and also to the outside world via the Internet connection, when this is enabled by NIM staff. Each two-hour theory lecture is accompanied by an associated two-hour hands-on workshop where some of the ideas presented in the lecture can be put into practice.

Many NIM students had problems with bandwidth and throughput calculations typically leading to results in Megabits or Megabytes per second. The lectures also include information about network media such as twisted pair coaxial and optical fiber cabling, It was noticed by staff on the NIM unit that some students did not appear to have an appreciation of representations of the waveforms and of signals described in the literature and unit material. Students drawing signal sloping backwards confirmed such suspicions as this indicated that part of the signal was undergoing a time reversal. When questioned further on this matter it transpired that it was not due to poor artistic skills on the part of the student but rather a lack of understanding of the representation. Methods were sought to give students an understanding of the meaning of waveform representation. Simulation was considered as a possible candidate to fulfil this role. Simulation has been used for computer network education [1, 9]. However, Engel et al have noted that although the simulation approach can be valuable it does not provide students with some important hands-on skills and experiences [2]. In keeping with the hands-on practical nature of this unit it was decided to use a Cathode Ray Oscilloscope (CRO) to demonstrate signal degradation after traversing network cabling.

2. The use of the oscilloscope

It was decided to make the initial introduction as simple as possible. The students were first given a demonstration of the use of the oscilloscope to measure simple low voltage torch light cells. With the scan set to a low frequency so that the students could observe the trace slowly traversing the CRO screen connection of the CRO probes to the cell were made on broken. This showed the students that the CRO could be used to measure a voltage that varied over time. Using a signal generator set on square wave low frequency output extended this theme. Similarly sine and triangular waveforms at different frequencies and voltages were also demonstrated. The students then performed these measurements is small groups of three or four per group using a worksheet. The students were encouraged to read the same voltage using different Volts/Division settings so that the shape of the waveform was not seen

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as an absolute but depended on these settings. The students also made further changes in the Time/Division settings. They were informed that it may be more convenient to view a single wave or a wave train or to obtain a more accurate reading and that was why different setting were used. The students, to enable easier and more accurate readings, adjusted the horizontal and vertical shift controls. When this had been completed and the students had had some exposure to the CRO and signal generator necessary to investigate signal degradation in network cabling.

3. The experiment with Unshielded Twisted Pair (UTP) Cabling

The use of the CRO to investigate waveforms travelling along computer network category 5 UTP cabling was used. This consisted of using 400 meters of cable would on a drum. There were 4 sets of twisted pairs per cable. A total of 4 stations were provided, each with a CRO and signal generator. Each set of students had a signal generator and a dual beam CRO. One beam of the CRO was used to observe the input signal to the cabling and the other beam was used to detect the output signal after it had travelled through the cabling. Each input or output set of twisted pairs had a 56 ohm resistor across them too help to reduced impedance matching problems. Two sets of twisted pairs were used one to carry the signal to the other end of the cable where it was joined to another twisted pair to carry the signal back down the cable drum so the signals travelled a total of 800 metres. Normally the recommended length used is a maximum of about 100 metres. It was found necessary to use such a large length of cabling because the signal generators gave a maximum signal of 1 MHz. This meant that to observe the signal attenuation and distortion it needed a much greater length then 100 metres. Two workstations used each reel of cable that decreased the number of components used for this exercise. The use of reels rather than long lengths of cable meant that there was no need to have cable draped around the room, which could have presented a safety hazard if they were, near to the floor or crossed walkways in the workshop. The use of two stations for one reel of cabling also allowed the students to observe the effects of cross-talk. One signal generator was set to a square wave output and another to a sine wave output at 10x its frequency. The resulting square wave output of the first signal could be clearly seen to have a sine wave of 10x its frequency superimposed. This was also attempted at a range of frequencies. The effects of pulse spreading and phase shifting of pulses were also observed and students were encouraged to try a range of different frequencies and to note the results.

Students needed a lot of initial help to find the traces on the CRO screen during the workshop. There were also some problems with connections many of these could have been avoided using soldered joints. The students were given a wiring diagram and instructions to set up the required circuits and this also caused further problems even though the termination resistors were pre-fixed in the circuit

4. Questions from the students

Some students asked questions such as: Will mobile phones cause interference in the cabling? They were then encouraged to turn on their mobile telephones and find out the answer. This did in fact lead to a marked change in the signal output observed on the CRO. This also led on to a discussion about coaxial cabling and shielding.

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Other students asked why we used the terminating resistors? They were encouraged to get answers by adding or removing such effects from the equipment use and to note the results. They disconnected the resistors and observing the effects of the refected signals. This led on to a discussion of the method of finding where a break has occurring in a cable by noting the traversal time of the signal to the break and its reflection back to the signal source. Why do we use twisted pair wiring? Again lengths of the twisted pair cabling was untwisted and the distorting effects on the signal observed

Yet another question was does the unrolling of the cable from the reel effect the signal transmission? These students were helped to unroll the cable and spread it around the roo for a short time taking care to avoid walkways. The signal showed no major changes when about 100 meters were spread around the laboratory.

5. The Survey

A total of 21 students handed in the survey which in the form of a questionnaire. The students were asked to put down what they thought and not what they might think staff would wish to hear. No names were to be included on returned sheets and they were to be left in a part of the laboratory not under the direct observation of staff.

The survey included questions on the level of their previous education in physics. One of the survey questioned asked if they could use the CRO to note observe the signal and most of the students who had studied physics up to University Entrance level that is TEE in Western Australia and A level in the UK said that they had been able to do this. In fact most students had been able to achieve this but a comparison of the difficulties that students reported were less with those with a higher physics background, where prior experience with the oscilloscope would have been more common.

The questionnaire also asked if their understanding of the associated material in the lectures had improved. Again most stated that it had improved. Another stated that they now had more clarity when considering clock cycles and waveform shapes. When asked what they thought were the most beneficial aspects of the CRO exercise to them. One answered that they were lost and stated: *"Frankly I don't know what the workshop is all about"* and that there were *"cables running about everywhere"*. Whilst another thought that it gave them an *"understanding how signals distort in cabling"*, or even that the experience of the use of the CRO was the most useful part. Whilst others thought that their increased understanding of the waveform shapes and the frequency calculations were the more useful parts of the exercise.

The students were also asked whether they thought that the CRO should be included in future workshops. The result was almost unanimously that it should be included. A student who had work for a telecommunications company for nearly 14 years much of it spend using the CRO and associated equipment answered, not unsurprisingly, that the exercise had not improved his understanding of how signals are distorted in cabling or of the use of the CRO. However, he though that the exercises were useful for students. He suggested that CROs should be used to investigate actual signals along the UTP cabling in the laboratory, as this would be an interesting exercise. It would also be more in keeping with the real world nature of the NIM unit. This student also suggested tracing the signals through the network cards in a PC.

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Although such conditions would have led to more complication, it is a tempting idea. Another student suggested that more time was required, and a single workshop was neither long enough to adequately understand the concepts presented nor to master the CRO operation.

Another student noted that they would have liked more explanation for the use of the terminating resistors. One explanation given was that they absorbed energy from the incoming wave to avoid too much reflection of the signal. A wave analogy with water waves could be attempted in future, with wave refection caused by an obstacle, eg an impedance mismatch, whilst non-reflection could be regraded as a situation with no obstacle eg just the water e.g. no impedance mismatch. The output voltage of the reel of cable was tested by the first author for the full range of the signal generator input voltages and frequencies. This was to avoid the danger of a high voltage being caused due to the coiled cable in the reel.

Bandwidth calculations have been used to assist throughput estimation [5]. This gives results in kilobytes/second and megabits/second and megabytes/second using the fact that a square wave signal can be considered either in terms of bits/second or Hz. The initial conversion of time period to frequency conversions using SI magnitudes and scientific notation were also practiced and then the conversions to bandwidth undertaken by the students.

6. Conclusions

Not surprisingly the two hour workshop was somewhat rushed. A better scenario may have been to introduce the CRO and signal generator during one laboratory period and then to build upon this foundation in the subsequent session. Many questions and ideas for future consideration resulted from this relatively short exercise.

Both CROs and square wave generators capable of working at higher frequencies were required to more achieve greater realism when compared to an actual network. Furthermore, a range of cabling including untwisted pairs and coaxial would have allowed comparisons between the different types of transmission media to have take place. However, at least a start has been made and further work is planned for the future.

Cross-subject cooperation between staff concerned with physics and computing science teaching has enabled use of equipment and ideas to span both subjects allowing for the development of a workshop that would have not been possible with the equipment normally used on the NIM unit. The cost of the material used was minimal. Even the reels of UTP cabling could be reused as it was not cut into pieces only the ends were used to attach to connection blocks and terminal posts.

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