Remote fieldwork: Using portable wireless networks and backhaul links to participate remotely in fieldwork

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Abstract

Fieldwork is an important means of contextualising knowledge and developing subject-specific and generic transferable skills. However, field locations are not always accessible. To address this problem we present a remote fieldwork approach that makes use of a portable wireless network and other mobile technologies to support fieldwork at a distance. As well as improving access to fieldwork, this approach can also be used to provide communication tools to fieldworkers, enabling them to share their findings and talk to their colleagues while in the field. This paper presents the portable communications toolkit we have developed and reports on three recent trials.

Keywords

Fieldwork learning and teaching; Wireless Local Area Network (WLAN); 3G mobile broadband; Broadband Global Area Network (BGAN) satellite terminal; Voice over Internet Protocol (VoIP); MPEG4 video streaming

1 INTRODUCTION

Fieldwork is a general concept used to refer to "all outdoor teaching and learning activities" (Butler 2008, p.10). It is considered a central and critical element of geoscience learning and teaching (Fuller et al. 2006; Boyle et al. 2007; Maskall & Stokes 2008). Within the geosciences it "enables students to contextualise knowledge and make sense of the world through hands-on interaction with their environment, and to become proficient in a range of subject-specific and generic transferable skills" (Stokes & Boyle 2009, p.291).

As part of the Enabling Remote Activity (ERA) project at the Open University (OU), we have developed the educational use of mobile and network technologies to improve student access to fieldwork (Gaved et al. 2006; Gaved et al. 2008; Lea & Collins 2009). Through this work we have produced a generic portable communications toolkit to support mobile learning in a range of fieldwork contexts. While not attempting to replace direct fieldwork experiences, the remote activity approach can be used to improve access to fieldwork for nearby students (within a few kilometers) over a local area network (see Figure 1), and distant students on the internet (see Figure 7).

An important aspect of the project has been to ensure that the technology is developed in response to the needs of our students and teaching staff rather than being lead by technological innovations. Through use on successive residential schools, developmental trials, and evaluation studies we have also refined our use of the toolkit for learning and teaching (see Section 3).

Figure 1. An example of remote fieldwork used on an OU residential geology course. The field geologist shown on the left is taking a photograph for the remote students to work with (shown on the right).

The ERA toolkit is used on a third level OU residential fieldwork course in Scotland to improve access for mobility impaired students. The project began in 2006 and the approach adopted was to provide a local temporary wireless (WiFi) network that could relay photographs and video from a field site to a nearby remote student. Two-way radios were used to support converstaion between the remote student and the field geologist. Since then we have improved the components of the toolkit as more cost-effective technologies have become available.

As well as providing access for nearby remote students the toolkit can be connected to the internet using any available Wide Area Network (WAN) link, such as an ADSL broadband connection, a 3G mobile broadband modem, or a Broadband Global Area Network (BGAN) terminal (see Section 4). Having connected to the internet anyone online can get remote access to the field location and the field workers can also access anything on the internet (subject to the bandwidth available over their WAN link).

In this paper we give an overview of related work, introduce the toolkit we have developed, describe the objectives and outcomes of three recent trials, and discuss these with respect to mobile learning through fieldwork. While not replacing direct fieldwork teaching, the remote approach offers a significant opportunity to introduce fieldwork learning to more students, to improve access to fieldwork, and to give fieldworkers improved access to online resources and collaborators.

2 RELATED WORK

In May 1991 the Wireless Coyote field trip was one of the first examples of the use of a wireless network to support fieldwork learning (Grant 1993). This involved 21 (6th grade) secondary school students working at Sabino Canyon in five groups: three groups of three students collected field data; one group of six students coordinated the data collection at a field base; and one group of six students at a school who collated the data and associated photographs and video clips to illustrate the dataset. Wireless Coyote used two-way radios for communication in the canyon. (Grant 1993) reports that analysing the data immediately, in the context of the canyon, helped the students relate the numerical data to their physical environment.

A more recent example of the use of a temporary wirless network to support data collection and analysis is the Virtual Environments for Research in Archaeology (VERA) project at Reading University [1] (Warwick et al. 2009). In this case, a wireless local area network is set up each summer at the Silchester archaeology dig site. As artefacts are uncovered they can be recorded and classified immediately using mobile technologies, such as digital pens and PDAs. Throughout the dig, the database of artefacts is updated and used to further support interpretation by the field researchers.

The Remote Accessible Field Trips (RAFT) project explored the benefits of students in schools accessing field trips through live participation over a communications link (Bergin et al. 2007). In separate trials different technologies were explored for sharing information, such as video conferencing for expert-interviews by the Canadian partners and data file transfer with students assigned to roles (e.g. a data gatherer, field communicator, and analyst) by the Slovakian partners. It was found that RAFT provided an engaging and motivating learning experience, in addition, the use of roles helped to motivate the students, and the field and classroom students had similar levels of participation and interaction when using video conferencing.

These examples illustrate the potential and versatility of applying standards compliant mobile and wireless network technologies to support fieldwork. We have developed a portable communications toolkit that can be used in a range of mobile learning contexts. Building on these examples we have tailored our tools to support a problem based learning approach where tutors act as facilitators to help students understand and solve practical problems in authentic contexts. To this end we have prioritised support for audio communication (using VoIP) and used visual communication tools (both live video and stills photographs) to support the dialogue between learners.

[1] VERA project website http://vera.rdg.ac.uk and blog https://vera.rdg.ac.uk/blog (last accessed June 2010).

3 PORTABLE WIRELESS LOCAL COMMUNICATIONS TOOLKIT

In the ERA project we use standard (802.11b/g/n) wireless network access points to provide local WiFi coverage, and point-to-point links between the field tutors and remote students. Using a netbook computer as a server we run XAMPP services (specifically the Apache web server, MySQL database, ProFTP file transfer server, and PHP script language). We also run a VoIP server (namely, Asterisk) on the same machine which acts as a telephone exchange handling calls between people on the network.

A wireless digital camera is used to take photographs which are sent by the camera to the server using the WiFi network and the FTP (File Transfer Protocol) service. IP based security cameras and IP video encoders are used to generate compressed video streams, which can also be accessed using a web browser by anyone on the network. Students and tutors use netbook computers and smartphones (such as the Google Nexus, HTC Desire or iPhone) as client devices to view the photographs and video streams from the server in a standard web browser (see Figure 2). VoIP softphone applications (such as Twinkle, Ekiga, or Sipdroid) are used for making voice calls by the students and tutors on the same devices (see Figure 3).

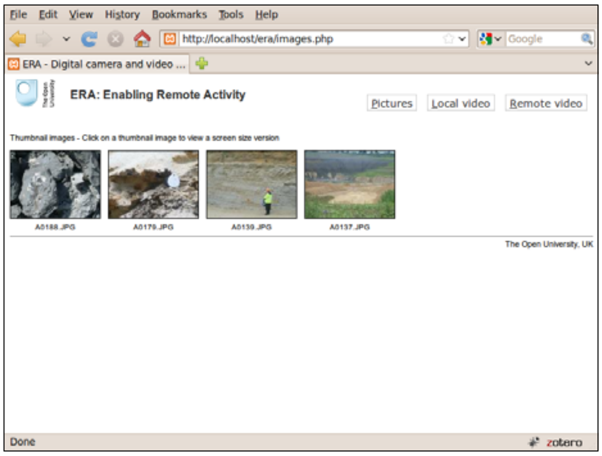

Figure 2. Example screen image showing four photograph thumbnail images. When more pictures are uploaded they are added to the page at the start of the list of thumbnail images (top left). To view a full-size picture the student clicks on a thumbnail image. The three links at the top right of the web page are used to switch between the pictures and live video streams.

The network access points are waterproof and are powered from external laptop batteries (placed in waterproof drybags). The access points are mounted on (lightweight) lighting stands and are placed at appropriate points throughout the field site to ensure connectivity between the field and remote locations (see Figure 4).

Figure 3. An example of a netbook's in built web camera and VoIP softphone being used to show a remote student some details from a field site.

Figure 4. An example of a field location using a WiFi router on a lighting stand to provide a link to the field geologist at the top of the hill.

4 BACKHAUL OPTIONS

Internet connectivity is provided over a WAN link, which can be used to access online resources and collaborators. Three options are considered applicable for this:

- ADSL (Asymetric Digital Subscriber Line) broadband phone line,
- 3G mobile broadband modem, and
- BGAN (Broadband Global Area Network) satellite link.

The suitability of each option is dependent on the location of the field site. An ADSL broadband connection is the least expensive option and typically provides a better data rate than 3G or satellite links. Within the UK, the majority of homes and businesses have some form of ADSL broadband link. However, these are not often accessible from fieldwork locations. So, although this can be a preferred option where available, it cannot be taken for granted.

Third generation (3G) mobile broadband links typically provide a lower data rate than ADSL, but depending on the coverage of the corresponding mobile phone network they can be a valid alternative. For short term use in fieldwork locations the data rates are not prohibitively expensive. Again, network coverage cannot be assumed. A selection of SIM cards for a range of network providers can be tested in a given location in order to select the fastest.

Satellite terminals (such as BGAN) have a significant equipment cost and the ongoing data rates are expensive when compared to ADSL or 3G mobile broadband (see Table 1). However, the network coverage is extremely good and can generally be relied on. The data rates (on standard data tarrifs) are comparable to mobile broadband. Although expensive, satellite links are reliable and in a critical situation can be an essential backup option.

Table 1. A comparison of the data rate and pricing of internet connections (based on UK services in June 2010).

	Backhaul link option		
	ADSL [2] phone line	**3G [3] mobile broadband**	**BGAN [4] satellite link**
Typical UK data rate (max)	512Kbps (up to 20 Mbps)	512 Kbps (Max download speed: up to 7.2 Mbps. Max upload speed: up to 2.0 Mbps)	256 Kbps (Max download speed: up to 464 Kbps. Max upload speed: up to 448 Kbps)
UK pricing	£15.99 per month (Min 12 month contract) Data max 10GB per month	£29.99 dongle (includes SIM card and 1GB) Data £10 per GB	£2,500 terminal SIM card £500 Data £411.25 for 52 MB (£7.91 per MB)

Table 1 shows the typical (and maximum) data rates and the current pricing (based on UK services) of ADSL, 3G and satellite links. The actual data rates vary according to the network load, but one point worth raising is that the 3G mobile broadband networks typically shape the data rate delivered to each device into bursts. That is, the data rate is higher for

[2] Example taken from British Telecom 'Just Broadband' offer http://www.productsandservices.bt.com/consumerProducts/displayCategory.do?categoryId=CON-TOTAL-BB-R1 (last accessed June 2010).
[3] Example taken from 3 'ZTE MF112 Pay As You Go + 1' http://threestore.three.co.uk/payg/?modem=1 (last accessed June 2010).
[4] Example taken of 'Inmarsat Prepaid Airtime' from Satphone http://store.satphone.co.uk/Catalog/Inmarsat-Prepaid-Airtime (last accessed June 2010).

the first few seconds of each data request, when used for email and web browsing this gives a good level of service, but is less effective for longer data downloads, such as data files and video streams.

5 FIELD TRIALS AND EVALUATION

The recent developments of the remote activity toolkit have been motivated and informed by three trials during the last year. At a one week OU residential school at Durham (UK) in August 2009, we carried out a set of field tests working with OU tutors and students. This focused on improving the configuration of the local wireless network and support for VoIP telephony. As part of a two week EarthWatch[5] field trip in February 2010 to Masaya Volcano (in Nicaragua) we explored backhaul connectivity from the volcano to the OU for VoIP telephony, live video and photograph sharing. In June 2010, in collaboration with researchers at the Experiential Learning Centre of Excellence in Teaching and Learning (ELCETL), we ran an evaluation trial comparing direct and remote fieldwork with lecturers and students from the University of Plymouth at Devon Great Consols Mine. The following subsections describe each of these trials.

5.1 DURHAM

Alongside a one week residential school in Durham, four ERA researchers spent a week field testing and developing the local wireless network configuration and VoIP services. At the beginning of the week we worked at two separate field locations to explore the suitability of VoIP and video to support remote access for one of the OU courses. After further tests at other field locations, we finished the week by working with a demonstrator and tutor to help a group of eight mobility impaired students to complete part of the course using the remote access toolkit (see Figure 5).

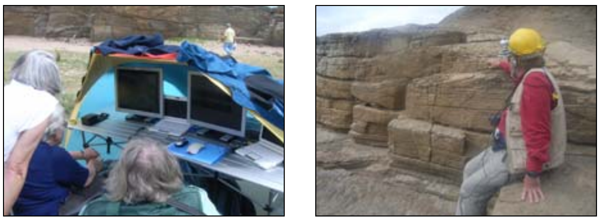

Figure 5. Remote fieldwork set up at Howick Haven (part of the Durham residential school in August 2009).

During this set of field tests we refined our use of the wireless network access points in order to maximise the data rate across the network. We generally use a linear network topology to link two (or more) locations (see Figure 6). By wirelessly connecting two access points we create a wireless link. If needed, we can connect two links together using an Ethernet cable and set the two links to different radio frequency channels (e.g. channel 1 and channel 6) to avoid any radio interference. In this way we are using two access points to create a radio repeater: one to receive the data and the other to transmit it. If we were to use a single access point to act as a radio repeater we would halve the data rate every time we added another link to the network. This is because the single access point would have to both receive and then transmit each item of data using the same radio transceiver.

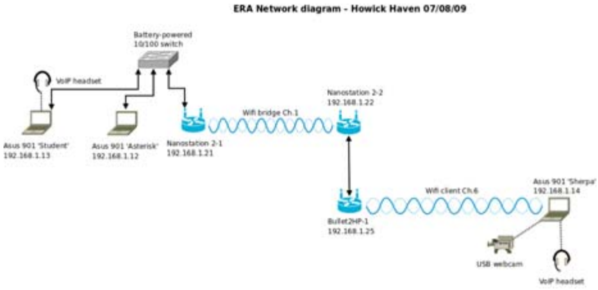

Figure 6. A typical network configuration used during the Durham field trials.

We used the Asterisk VoIP server with Ekiga and Twinkle softphones on netbook computers. Ekiga softphones had the advantage of also supporting video calls using either in built or external web cameras.

The feedback from the staff and students was very encouraging, for example:

> "I got a lot of information about the rocks - probably more than I would have done with my own observations" (residential school student).

Using the above network configuration, we consistently achieved local data rates of around 15 Mbps throughout this set of trials. The VoIP service performed well over the network. In several locations we did have problems seeing the screen in bright sun light, and a cover to provide shade alleviated, but did not solve this problem. Suggestions for improvements to the system included ways of tracking the tutor's location or marking the locations of interest on a map of the field site, in order to help orientate the students and improve their sense of the tutor's position. Further details of the Durham trial are available on the Portable VoWLAN blog site http://projects.kmi.open.ac.uk/era/vowlan (last accessed September 2010).

5.2 NICARAGUA

In February 2010 one of the ERA researchers joined a team of OU volcanologists for two weeks, as part of a six week EarthWatch field season at Masaya volcano. During our two week field trip we planned to test the potential backhaul internet links from the volcano to the OU. During the preparation for the trip we tested ADSL broadband, 3G mobile broadband, and BGAN satellite connections in the UK. This helped to guide the researcher in the use of the equipment and develop their fault finding techniques. We had already arranged to make use of the hotel's cable broadband connection during the trip, identified potential sources for purchasing 3G SIM cards and mobile broadband USB dongles near Masaya, and checked with our BGAN terminal supplier to ensure the Inmarsat SIM card and credit would be suitable for use in Nicaragua.

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[5] EarthWatch field trips to Masaya volcano in Nicaragua involve OU researchers http://www.earthwatch.org/exped/rymer.html (last accessed June 2010).

We were unable to source a 3G broadband SIM card or USB dongle in Nicaragua, although advertised online they were only recently released and were unavailable in the Masaya region at the time of the trip. The hotel ADSL link was comparable to that available in the UK and supported file transfers as well as Skype voice and video calls. The BGAN terminal also performed well, and was used on the volcano to send photographs and live video back to the OU, and to make two-way VoIP calls (see Figure 7). Further details (including clips of photograph downloads, video streaming and VoIP calls) are available on the Portable WLAN blog http://projects.kmi.open.ac.uk/era/jawlan/?p=414 (last accessed June 2010).

Figure 7. ERA local network, IP video camera, web server and clients used in Nicaragua.

5.3 DEVON

In June 2010, in collaboration with the Higher Education Academy's Geography, Earth and Environmental Sciences Subject Centre (GEES), and the Experiental Learning Center for Excellence in Teaching and Learning, we ran an evaluation trial at Devon Great Consols Mine. This involved two of the members of the ERA team, and two lecturers, a researcher coordinator and a research officer from the University of Plymouth. Over two days we ran two half-day remote fieldwork trips and two half day direct fieldwork trips. Each field trip involved around 10 undergraduate students studying GEES subjects at the University of Plymouth.

The focus of the evaluation trial was to investigate cognitive and affective learning in remote and direct fieldwork. The teaching involved two lecturers taking the students on a tour through a mine and asking them to complete an Environmental Impact Assessment activity (see Figure 8). In the direct fieldwork sessions, the students worked alongside the two lecturers in the field, and in the two remote sessions the students stayed in the car park at the mine with one tutor. They spoke to the other tutor (as a single group) using a VoIP phone with a loudspeaker that everyone could hear and a single shared microphone. The tutor's tour was watched by the students on a single 24-inch LED screen, which displayed a live video stream from a camcorder connected to a video encoder carried by the research officer.

Figure 8. ERA evaluation trial at Devon Great Consols Mine. The remote students and tutor (left) work with the field tutor and camera person (right) to complete a half-day Environmental Impact Assessment (EIA) scoping sheet activity.

A pre and post questionaire was completed by all of the students, and a 40 minute focus group was held with each of the four groups after the fieldwork was completed. The analysis of this data is ongoing and will be presented at the conference, but the initial findings are generally positive. Unlike in the previous two trials where we used the network to provide a point-to-point connection between the remote students and discrete field locations, this trial required us to set up a continouous network throughout the mine area (covering about two square kilometers). As this was also a previously unused site it required some field testing (on the previous day) to identify suitable positions for the network access points.

From a technical point of view, the system performed well, but of particlar interest to us was the use made of the toolkit by a different set of lecturers. The teaching mode followed an active approach that involved the students and tutors in a discussion of the site (in both the remote and direct sessions). Surprisingly, the video camera and VoIP call were used exclusively. Although available (and verbally prompted) the students did not request any photographs to be taken. This contrasts with the use made of the toolkit on OU geology courses where both video and still images are used extensivly. This difference could be due to subject differences between geology and environmental science. Further information on the evaluation trial is available on the Portable VoWLAN blog site http://projects.kmi.open.ac.uk/era/vowlan (last accessed June 2010).

5.4 SUMMARY

Throughout the three trials we have adopted a participatory approach to development involving both teaching staff and students. The ERA toolkit has been developed iteratively over successive trials and applications, both in terms of the technology used and teaching approaches that have been explored. Table 2 summarises the approach, technology used, teaching mode and outcomes of the above trials.

6 DISCUSSION

In developing support for both nearby and distant remote fieldwork a number of trade-offs are evident. One is the trade-off between network type and data rates, specifcally the distinction between a local area network (as used in nearby remote fieldwork) and a wide area network (necessary for distant remote fieldwork). As network technology and the relevant infrastructure systems improve the data rates available on local and wide area networks will increase. Nonetheless, this is unlikely to improve dramatically in the next five years.

The data rates currently available in a local area network can support two way (full frame) video and multiple voice calls, as well as photograph sharing and other data. When using a wide area network connection (such as a 3G or BGAN link) the lower data rates means that the quality of thie video image should be reduced. For example, when we used a BGAN satellite in Nicaragua we found it necessary to limit the data rate for the video to 200 kbps, a half or quarter size video at lower frame rates (such as 5 frames per second) are possible at this data rate. We have been using MPEG-4 (hardware) compressed video streams, h264 video is an aternate format that could offer better compression and thereby the possibility for a better quality video stream at these lower data rates.

Table 2. A summary of the three trials highlighting the approach, technologies, teaching mode and outcomes.

	Trial		
	Durham	**Nicaragua**	**Devon**
Approach	Nearby remote access	Distant remote access	Nearby remote access
Technology used	Local WiFi, VoIP, video, photos	BGAN satellite link, VoIP, video, photos	Local WiFi, VoIP, video
Teaching mode	Sherpa and tour guide	Sherpa and field research	Tour guide
Outcomes	Photos, VoIP and video over local network point-to-point	Photos, VoIP and video over BGAN point-to-point	VoIP and video continuous throughout site (photos not used)

Voice services are another example of time critical data. In this case the size of the data packets being passed are quite small (16 kbps), but any delays in the network can lead to the audio breaking up and becoming uninteligable. Therefore, the quality of the network connection is important not just in terms of the data rate, but also the number of lost packets. We have found the local network configuration described in Section 3 to be effective for VoIP. As noted above we have also used VoIP over 3G and BGAN connections. In these cases we have been using the Speex audio codec, improvements in the audio compression algorithms (as with the video codec) can lead to improved quality at similar data rates (or comparable quality at lower data rates).

Another trade-off relates to the resolution of still photographs and the speed of downloading them over the network. Larger resolution images generally result in larger image files which take longer to download. We use JPEG images at a resolution of 1280 x 960. The corresponding images files are usually between 350 KB and 800 KB (depending on their content) and only take a second or two to download.

In the work to date we have focused on giving remote access to individual or small groups of students. In order to work effectivley with larger groups it may be necessary to use a multicast service (such as a Shoutcast server or Wowser Media) to recieve and rebroadcast data from the field site. Such services provide a technical solution to scalability, but in addition to this the social dimensions of large group interactions need to be taken into account when designing remote access at a larger scale. For example, voting polls, text chat or email may be more effective than audio calls for supporting live communication when more than two parties are involved.

The ERA toolkit offers a range of communication options, as with many mobile learning platforms the appropriate selection these tools depends on the nature of the activitying being undertaken and the form of network connections available.

7 CONCLUSION

We argue that direct fieldwork versus remote fieldwork is an unfair comparison. As with many technology mediated activities remote and direct fieldwork are different activities. The costs of introducting technology needs to be outweighed by the benefits realised through its effective use.

Fieldwork helps to contextualise a student’s knowledge or the knowledge shared within a fieldwork group. The remote fieldwork experience improves the accessibility of fieldwork and enables more people to activley participate in fieldwork. Distant remote fieldwork extends such an opportunity for anyone to access fieldwork events over the internet, and for fieldworkers to consult online resources and colleagues at apropriate times during a field trip.

8 ONGOING WORK

Two activities related to this work are ongoing: the analysis of the Devon evaluation trial data, and the application of the ERA toolkit in the EPSRC funded Out There and In Here (OTIH) project. The analysis of the evaluation data will help us to further understand the distinctions between direct and remote fieldwork. In the OTIH project the use of a large multi-touch display in a lab is being investigated as a means to collate and coordinate fieldwork at a distant field site. Trials in the OTIH project will be ran in August and September 2010. We will are planning to use a 3G mobile broadband internet link with a wireless local area network to support remote collaboration between a group of students in a Buckinghamshire sand quarry and a group of students at the OU.

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