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Blue sky thinking meets green field usability: Can mobile internet software engineering bridge the rural divide?

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Abstract
Mobile applications (apps) are becoming more commonplace as mobile phones and tablets begin to replace traditional desktop devices. Software developers are usually located in areas where good connectivity is the norm, but large numbers of users are located in other areas where 3 G connectivity is at best poor or non-existent. This results in app development which is unsuitable for many areas of the world and, as well as being a problem in rural areas of the UK, has ramifications for mobile app use in third world countries where fixed broadband services are largely absent. Drawing on experiences of users on the margins of connectivity, this paper discusses difficulties of mobile internet access in Wales and recommends changes to app development methodology to maximise bandwidth in areas of limited network coverage.

Keywords
digital divide, mobile internet, rural economy

Introduction

In 2012, UK was ranked as the world's sixth largest economy (Aldrick, 2012), but

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research suggests the 3 G coverage even in large areas of population can vary considerably (BBC, 2011a). The mobile provider Everything Everywhere (EE), previously known as Orange, suggests 98% of UK population is covered by a 3 G signal (EE, 2013), but population coverage does not equate to land coverage and many of those users who live in an area with good mobile signals find as they travel through rural areas that they are unable to access services on the move. This problem is even more acute for those who live in these areas, and in particular, rural Wales has both poor broadband and mobile coverage.

This could be viewed as a minor irritation if it were not that IT has become an essential or significant part of many areas of personal and business life. Furthermore, lack of access tends to correlate with factors such as age, remote and rural communities, and socio-economic status (RSE, 2013). In other words, the digital divide is exacerbating existing divisions in society, selectively disadvantaging the weak and those at the social, economic or physical margins of society.

In this paper, we look at some of the factors influencing this issue. We focus principally on the situation in Wales which has particular problems within the UK as it has a relatively high rural population and difficult topography for data transmission. However, we hope that the lessons are applicable more widely.

The paper draws on two major sources of primary data as well as existing published material from others. The first is a programme of testing of tourism-related apps in both rural and urban areas; as these were designed for tourism use, it would be expected that these would be usable in scenic areas outside the major centres. The second is a 100 day, 1000 mile, walk by the second author, Dix, which took him around the entire periphery of Wales including border areas between England and Wales and the entire 870 miles of the Welsh coastline (Dix, 2013). Methodologically, this was a technically and socio-economically focused version of what ecologists call a 'foot transect' (Cressman, 2001; Macfarlane, 2012) and took him through many rural coastal communities as well as the waterside areas of major cities. One of the main purposes of the walk was to explore issues of digital (*non*)-inclusion in rural communities through which he passed.

In both of these, connectivity proved to be an enduring issue with data-hungry apps hanging either due to low bandwidth or a failure to build into apps a mechanism to monitor and respond to varying levels of connectivity.

As well as emphasising problems of connectivity and software design that bedevil life 'at the margins', we outline potential solutions and ameliorating strategies for government policy, community action and software design.

The need for IT

Over recent years, the internet and web have become deeply embedded in every aspect of business and civil life.

For business

Software creation in developed countries relies on a solid IT infrastructure to deliver internet-based products to consumers. A study in Japan found that affluent young people have the most positive attitude to the use of mobile internet services (Okazaki, 2006), yet profits that can derived from delivering services to this demographic cannot be realised without a robust and readily available mobile service. In addition to youth services, Japanese housewives and company executives also understand the usefulness of mobile services and engage with them. Such ubiquity of need for mobile services in rural areas points to economic gain to be achieved where sufficient connectivity can be provided. The UK

Governments Broadband Policy emphasises this message: 'The business benefits of high speed broadband are huge. You can expand your customer base rapidly by selling online, get free marketing and build your brand through social media' (HM Government, 2013a).

For consumers

In October 2013, 10.5% of all retail sales in the UK were made online (ONS, 2013). In rural areas with fewer shops and greater distances to travel, internet purchasing is even more important than in towns. Furthermore, it is increasingly the case that internet prices are cheaper and offer greater selection than face-to-face sales; for example, Ryanair's policy of charging for airport issuing of boarding passes or UK rail tickets which have a £1 over-the-counter surcharge. Consumers without the internet pay more.

For tourism

While some tourists may wish to 'get away' from technology, many others wish to actively use new mobile internet services at their holiday destination (Brown and Chalmers, 2003; Kim et al., 2008; Poslad et al., 2001; Ryan and Rao, 2008; Schwinger et al., 2005), and the evidence is that a large proportion of professionals do periodically check work emails (BBC, 2011b, 2013; Kellaway, 2013) as well as more general personal use of technology; thus, internet availability becomes a significant differentiator, especially at the high end of the market. In addition, the ability to find businesses is more important in rural areas where they may be scattered, although this is precisely where location-based services are likely to fail. The importance of mobile access for tourism is emphasised by the Geovation programme which funded a number of apps related to the Wales Coast

path. This is also evident on the ground; in Monmouth, 'the world's first Wikipedia Town', the Monmouthpedia project has placed QR codes on virtually every shop and place of interest. Similarly, small HistoryPoints markers can be found at many points in mid and north Wales (HistoryPoints, 2013), with QR codes leading back to the HistoryPoints.org website, although some of these are found in places with limited mobile signal where the QR code is somewhat redundant.

For citizenship

Government services as well as private business are making greater use of the web. As well as ease of access, there are sometimes penalties for paper-based or physical access to services. For example, VAT and Income Tax returns must be submitted a month earlier in paper form than electronically, although an attempt to make electronic VAT submission mandatory was overturned after a legal challenge (Gledhill, 2013). The UK government's flagship 'Universal Credit', which replaces most other benefits, is delivered entirely through the internet, but pilots have found that half of all claimants have not been able to complete the online forms, not least because 47% do not have access to the internet at home (Citizens Advice Bureau, 2013; Sherman, 2013).

For education

The internet has become a central part of education, but unequal access at school and at home can deepen the digital divide. In a recent survey, 50% of Welsh schools reported a problem accessing internet services required by their national curriculum (WG, 2013a) which will lead to a generation of Welsh children disadvantaged in comparison to their English counterparts. A report

commissioned by the Joseph Rowntree Foundation looked at factors that influence the lower educational attainment of children from poorer backgrounds. It found that 'access to a computer and the internet' was a key factor during secondary education, with only 46% of poorer homes having computer access compared with 97% for richer homes (Goodman and Gregg, 2010).

Barriers to rural IT

Mobile internet connectivity

In developing countries, mobile phones are often the major way in which people access the internet, but even in developed countries with high levels of established computer use, mobile data use is also growing. 'In Q1 2013 49% of adults used their mobile phones for internet access' (Mobile Operators Association, 2013). This has led to the 'mobile first' design philosophy (Wroblewski, 2011).

The Mobile Operators Association claims that 3 G coverage extends to '99.1% of UK premises' and '97.7% in Wales' (Mobile Operators Association, 2013). However, a BBC crowd-sourced map of the UK in 2011 found that users experienced levels closer to 75% despite the industry figure at the time being in excess of 90% (Wakefield, 2011). The discrepancy is partly that while the core metric for mobile operators is the number of premises covered, real use by consumers, even those who live and work in urban areas, involves travel through less populated areas where coverage is far lower. For those actually living in such areas, the picture can be quite bleak.

Ofcom's independent coverage map of the UK shows this clearly, with large tracts of land including the vast majority of Wales, Scotland and Northern Ireland in the bottom coverage with less than 25% of the area with 3 G access. For Wales, only the major conurbations of South Wales and Flintshire in the extreme North West were out of this bottom category, with most of this area at less than 50% coverage for even 2 G service (Ofcom, 2013).

This accords precisely with Dix's experience on the ground. Down the coast from North Wales until Llanelli in the South, and in the Welsh-English borders, there were only two brief periods of 3 G access and that in very localised areas of two major University cities, Aberystwyth and Bangor. The majority of the time there was either no signal at all or two bars of GSM, with very occasional 2 G.

Even in or near the city, things are far from perfect. When close to Swansea, a major city in the South, where there was a strong 3 G signal, data access was actually better when this was turned off and the phone used GSM only. We assume this was due to high levels of contention on the 3 G network with other users downloading data-intensive files such as videos. Morgan's testing of apps within urban areas such as Cardiff, the capital city of Wales, also revealed problems with delivery of high volumes of data on 3 G. That there is 'coverage' does not equate to service; a point echoed by O2's response to the BBC crowd-sourced survey: 'The results don't show the 'experience' on each network - for example, speed or the ability to hold a connection. Simply having coverage does not guarantee a good service' – O2 as quoted in (Wakefield, 2011).

Local people's experiences also matched this picture. One woman said that she used Orange as it has the best coverage in West Wales. However, when asked about 3 G, she replied 'only in Cardiff'.

In fact, EE (the merger of Orange and T-Mobile) coverage maps do show extensive 3 G availability around the Welsh coast. However, closer examination of coverage maps both in Wales and elsewhere shows that the masts are aimed out to sea,

basically to give service to shipping. This means there is better service one mile out to sea than on the land, and although it provides a very important service to small boats that may not have radio, the reason is not safety. It is that yacht owners tend to be from higher socio-economic groups than those living on the coast. Quite reasonably for profit making companies, connectivity follows money.

Fixed connectivity

Research indicates that even teenage mobile internet use is still an extension rather than a replacement for PC internet browsing (Lin et al., 2013) and that users require a similar browsing experience between mobile and desktop devices (de Reuver et al., 2013). This is backed up by global statistics on mobile use which shows that even in India, with one of the highest levels of mobile internet access, only 70% are 'mobile only', whilst in the UK and US, the figure is only 22% and 25%, respectively (mobiThinking, 2013); this demonstrates that even amongst mobile internet users, desktop use is still important. Social factors influence advanced mobile services adoption (López-Nicolás et al., 2008), yet technological issues can adversely affect acceptance. German research suggests laptop internet browsing was still three times that of iPads (Gerpott et al., 2013a), but iPhone users are more active than Android customers (Gerpott et al., 2013b); and global data suggest that still only 10% of page views are from mobile devices, although the figure is growing rapidly.

So, while mobile access is important, fixed broadband use is at least as important.

Sadly, the picture here is no better. Where it was possible to obtain WiFi access in a variety of cafes, hotels and bed and breakfasts (that is both commercial and domestic premises), the connection was not only relatively low bandwidth (compared with urban areas), but often 'patchy'; that is the service would often drop for a few seconds or minutes.

As we shall describe later, this patchiness is often more problematic than the low bandwidth, which simply makes things slower. The difference between the two may not be obvious to normal users, who will simply experience slow or unreliable connections. Indeed the patchiness will also reduce experienced bandwidth as TCP, one of lowest level of internet protocols assumes relatively stable connection characteristics, and its attempt to infer bottlenecks using 'slow start' will back off to slower rates of transfer if it experiences a temporary break (Stevens and Wright, 1994).

Although the above experiences are focused on a transect of the Wales coast, they are typical of rural areas across the UK. A DEFRA report in 2013 found that whilst 95–99% of urban areas in England had adequate internet, this dropped to 50–70% in rural areas (DEFRA, 2013); it should be noted that even these low figures underestimate the problem as they include the vast prosperous and easily accessible rural areas of the South East.

Attitudes and understanding

Above we wrote, 'where it was possible to obtain WiFi access', as it was often impossible to find any form of internet.

Sometimes this is a deliberate and positive choice; for example, although in Monmouth, the Monmouthpedia project has installed free WiFi in several areas, some teashops deliberately do not have WiFi to encourage a technology-free atmosphere.

Often the problem was with the complexity of installing and using internet equipment. In one bed and breakfast, when Dix asked for the WiFi access key, he was given

the admin password for the router box. In other establishments, WiFi would be offered, but in practice not work for a variety of reasons. At one of the largest hotels in Machynlleth, a major town in central West Wales, he was told that the free WiFi, 'may work', but that they did not charge 'because it was not reliable'.

Perhaps most worrying were the times where businesses and individuals showed lack of understanding of both developing needs of their visitors and disadvantages faced by future generations of these communities. internet availability is increasingly being used as a differentiator in holiday accommodation choice, yet, in one establishment, when asked about WiFi, Dix was told, without a hint of irony, 'we're not that modern'.

Again, this is not a problem purely of rural Wales. Townsend et al. (2013) describe a number of factors related to digital literacy and deprivation that are limiting UK rural internet adoption, in addition to the obvious lack of provision.

Happily there are counter examples, in particular many beach cafes catering for younger 'surfer' communities provide free WiFi, as do some community shops. This is not confined to the young; two elderly ladies described their attempts to get internet into their local village hall.

Sadly, the latter had been frustrated by another woman, who was the 'gatekeeper' of many community activities. She ostensibly regarded the internet as a passing fad, although this may have been a cover for fear of the technology.

Software design

Poor connectivity is a problem in itself, meaning that access is intermittent or slow. However, this is made substantially worse by the design and engineering choices in software.

Use of mobile internet was tested in a number of areas within urban and rural areas, particularly focusing on tourism apps and feedback received from other users regarding issues experienced at margins of connectivity. Mobile apps using online Google maps or Open Street Map frequently failed to deliver all the map tiles for the area, leaving a blank square where a tile could not be downloaded. These apps did not appear to be programmed to reattempt download of failed squares in areas of poor connectivity. Mere surfing of the internet in many rural areas was often a hit and miss affair with likelihood of tourists not having access to local tourist-based information.

Testing of these apps in rural locations consistently revealed limitations in both app design and connectivity with data-intensive tasks such as delivering map tiles to a mobile device failed or partially failed. Testing within urban areas such as Cardiff, the capital city of Wales, also revealed problems with delivery of high volumes of data on 3 G. Limitations to this research were in the area of connectivity measurement, lack of spatial information regarding distance to mobile masts and measurement of effects of topology on mobile connectivity.

Many of the apps now being created for mobile infrastructure rely on availability of a stable and strong connection and are often designed in offices where good connectivity is present. For example, Twitter uses only 140 characters to produce a tweet, but the app consistently fails to work in areas of low connectivity due to the amount of data which servers try to send to a mobile device. In addition, the Twitter app appears to request large parts of the users 'feed' before it initialises the screen to allow a status update, this makes the application effectively 'hang' in most areas of coastal Wales.

Similar problems were faced with Flickr's photo uploader on fixed WiFi

connections due to the 'patchy' nature of rural broadband. The desktop app seems to lack appropriate timeout or retry behaviours, so that after a short break in connectivity, the app hangs and never recovers.

The problem is often that these apps have been designed implicitly assuming 'Silicon Valley' levels of connectivity. In fact, the best application in areas of low or intermittent signal is email, probably because its protocols were designed in the 1970s with slow networks and connections often established over dial-up lines. That is, the historic underlying connectivity assumptions for email technology development more closely matched the modern-day rural context.

However, even bespoke apps designed for use in Wales experienced problems. Managers of a national website provided feedback on (un)suitability of commissioned apps and their attempts to circumvent such problems. Their feedback suggested users were not able to use The Peoples' Collection app due to connectivity and usability (our own observations suggest power consumption may also be an issue, although this is probably common to all GPS-based applications). The Welsh Government (WG) commissioned the development of The People's Collection site to create a digital repository for Welsh culture. A mobile app was developed in London to compliment the site and was supposed to be able to record and upload GPX recordings of walking trails for inclusion on this database. The app required a 3G signal to sign into the system, but most of rural Wales does not have sufficient coverage to make this possible. Online map tiles of the user's location could not be downloaded due to lack of reception.

Challenges/solutions

We have outlined some of the current problems with rural internet and, in particular,

mobile access to internet. There are many levels at which these problems can be tackled: public policy, community action or technical design. These are not independent. For example, the UK government has a fund to aid local communities in procuring broadband access.

Ameliorating solutions at a small scale can mask larger scale issues. Irani et al. (2010) discussing Ferguson (1990), note that development regimes have 'systematically avoided confronting the actions of large-scale actors such as governments and corporations . . . instead seeking behavioral, educational, and market-based solutions at the local level'.

While this statement was made in the context of the developing world, it is no less true in rural areas of the UK. For this reason, we will start our analysis with public policy and infrastructure. However, it is often the case that these large-scale solutions are outside the control of those on the ground, so we also consider issues at the level of software design and community engagement.

Public policy and infrastructure

Enabling widespread internet use is a global issue; for example, Thai research points to a need for greater competition and infrastructure improvement to stimulate mobile internet usage (Srinuan et al., 2012); in some Nordic counties, the distribution of 4 G licences have been based on breadth of access rather than maximising Government revenue; and in India, the Universal Service Obligation enshrined in the Indian Telegraph Act 1885 (and updates) guarantees 'access to telegraph service to people in rural and remote areas at affordable and reasonable prices' (MCIT, 2013).

For the UK, the European context is particularly important and currently policy decisions for mobile standards in Europe rests with over 1000 different bodies, and

to ensure workable standards are achieved, there is a requirement for an overall policy-making body to oversee infrastructure development that carries and processes mobile transactions (Funk, 2011). Such a body would need to take into account varying levels of connectivity and ensure platforms are designed to maximise low bandwidth.

It was in the UK, in the early 19th century that the Penny Post was developed, one price anywhere postage that revolutionised business and private communications (British Postal Museum & Archive, 2013). The Indian Telegraph Act is part of the colonial out flowing of this. The web has had a similar revolutionary impact in our time and is also the invention of a Britain, as celebrated in the Olympic opening ceremony. So it seems perverse that rural access is such a problem today.

Happily, the UK government has committed itself to delivering 'superfast broadband' to 90% of homes by 2015, increasing to 99% by 2018, with rural access a key part of this (HM Government, 2013b; McCaskill, 2013a). However, one of the instruments of this is planned to be via 4 G (McCaskill, 2013b); if past experience of 3 G access is repeated, this will again leave many areas lacking effective internet access.

3 G and 4 G coverage will probably never fully extend into many areas of the world where it is not economic to provide additional infrastructure. Similarly, cable-based internet provision is an expensive option, and it may never prove economic or feasible physically to connect some rural areas to the internet.

The Welsh Government has recognised the need to 'bridge the rural divide' and has announced the launch of the largest partnership of its kind with British Telecom (BT) to install 3000 new fibre optic cabinets in Wales in order to provide by 2016 'super-fast' broadband in rural areas which eventually will serve 96% of

businesses and homes (WG, 2013b). Entitled, 'Superfast Cymru', this initiative points the way for other national governments to undertake similar initiatives to ensure digital inclusiveness; otherwise, lack of infrastructure will continue to support a 'rural divide' where a large percentage of a country's population cannot access internet services.

It is not uncommon in rural areas to have emergency mobile access as there may be some telecommunications mast in range, but not that operated by one's own service provider. At a European level, legislation has forced operators to provide universal European access with regulated charging, so that when roaming abroad within Europe, the consumer can access any network with a known fixed cost. It is not impossible to imagine such a policy for access within one's own country, so that one could access other operators' masts if one's own were not available. If this were implemented, it may then be possible for local communities to set up small masts to fill in gaps, knowing that income would accrue. Similar charging-based mechanisms for local and personal electricity generation proved exceptionally effective in encouraging small-scale solar and wind generation.

Software and technical design

There will always be a gap between rural and urban services, so it is critical that software degrades gracefully rather than fail completely as is currently the situation with many major apps and bespoke systems.

There seems to be two main commercial problems:

(1) Commercial developers do not even recognise the problem as they are based in major population centres such as Silicon Valley
(2) Even if the issue is noticed, the proportion of people affected makes it

uneconomic to design systems taking poor connectivity into account

The first of these requires raising awareness amongst developer communities, but this will only be effective if the second is also addressed.

There are two potential approaches: 'carrot' and 'stick'.

First, the 'carrot' would be to provide suitable toolkits and design advice to make the development of correctly operating systems easy; that is to slew the cost–benefit trade off. There has been research in this area dating back nearly 20 years (Dix, 1995), but, overall, it has been relatively poorly studied as the perception is often that 'connectivity will get better', and it is of course not an obvious problem in well-appointed research laboratories.

Second, the 'stick' would be via public policy. Issue (2) is not unlike accessibility for disability where many countries have legislation mandating reasonable efforts to make software and websites accessible across disability groups, for example, making websites easier to use with screen readers. The legal provision in turn both raised awareness and helped encourage commercial providers of software tools, such as website builders, to include features to make it easier to create accessible websites. Perhaps similar regulations concerning connectivity-related accessibility could encourage similar good behaviour.

Community proactive and radical solutions

Although government commitment to provide fixed broadband services to residents is a welcome step to harmonise urban/rural services, it does not address needs of visitors who still need to access internet services via mobile and commercial requirements of local businesses and communities who wish to service those needs. One solution has been to provide WiFi hubs in villages (Porritt, 2012) and in venues servicing tourism (Tomaszcynk, 2012).

However, as we have noted, hotels, guest houses and cafes in practice find it difficult to set up a reliable service even where there is an underlying infrastructure available. There is clearly a need for 'easy install' kits at various scales, dealing not only with physical installation, which may frequently be managed by a local expert or knowledgeable relative but also ongoing administration. It maybe that this requires explicit commissioning by national tourism authorities or interested non-profit bodies, if the scale of such installations is too small to encourage commercial innovation.

There are also innovative local web solutions such as (Qraqrbox, 2013) a standalone web and WiFi box that provides access to selected websites, including rich media content, even when completely disconnected from the mains electricity. Qraqrbox uses solar power and batteries to allow use without an electrical supply and uses local copies of websites to transparently give access to content.

As well as community-level provision of infrastructure, there may be opportunities to create software tuned more closely to specific community concerns. For example, on Tiree, a special web portal TireeConnect was built to help youth workers connect with young people on the island using SMS and social networks via a simple uniform interface. Similarly local shops, whether privately or community owned, are often an important social hub but are under constant pressure from competition of supermarkets and online shopping which have larger turnover and so can afford smaller margins. There may be options for an 'electronic village shop' using IT to offer additional services within the physical shop (Dix, 2008; Dix and Subramanian, 2010).

Conclusions

Digital tourism and increasingly day-to-day life within a rural community is highly reliant on availability of mobile connectivity. This is particularly important to attract affluent young consumers and other adopters of mobile internet who are crucial to the sustainability of marginal communities. Although mitigation of signal deficiency is possible by provision of wired and WiFi facilities within a community and thus service the needs of residents, those on the move between communities or intending to use services while in a countryside location will still be subject to intermittent, slow or non-existent connection to services. App developers need to consider the location and possible end user experience when designing services that may be accessed in areas of low connectivity. National Governments need to consider schemes not just to deliver infrastructure but to support and engage local businesses and communities in the use of equipment such as WiFi to support tourism needs and ultimately bring economic benefit to rural communities.

Note

1. For more information about the authors' project, see http://alandix.com/academic/papers/blue-sky-2014.

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