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Showboater: Insight into Sustainable Rural Community Display Networks from a Longitudinal Study

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ABSTRACT

This paper describes Showboater, a simple system architecture for rural community display networks. We outline the context of our 2-year longitudinal study and outline five design goals: a functional, sustainable, scalable, resilient networked display solution which affords roles for the distribution of governance. We describe the design and implementation of Showboater and how it aligns to the design goals, as well as describing two separate deployments. We reflect on evaluation feedback and provide insight into the implications of deploying Showboater as rural community display system, respective of the initial design goals, and present our recommendations for future improvements.

CCS CONCEPTS

• **Information systems** → **Display advertising**; *Social advertising*; • **Human-centered computing** → *Collaborative content creation*; Empirical studies in HCI.

KEYWORDS

pervasive displays; community resource; social inclusion; rural community

1 INTRODUCTION

Public display technology has become increasingly prevalent within urban spaces [11]; examples include a diverse range of technologies including billboards [14], situated digital posters [6], displays [20, 22, 25] and projections [16]. There are fewer examples of embedded public displays within rural environments (e.g. [7, 23]). Installing community displays within rural areas pose a range of technical and design challenges when compared to urban installations; internet connectivity and network stability is typically poor

and coupled with frequent power outages across large geographical areas. Examples of displays within the rural context have emerged with the ever improving and further reaching geographical expansion of internet services, greater accessibility of affordable display technology and computing technology. Pervasive displays have demonstrated their use as effective tools for bolstering community cohesion and have proven to be meaningful community resources [2, 23] which help to enrich the social functions of public spaces [24].

Display networks still pose significant challenges when designing for long-term use; Taylor et al. [23] highlights issues associated with the lifespan of rurally deployed display networks and their implications on maintaining hardware whilst being financial sustainable when handed over to communities. Within an urban environment, Clinch et al. addressed problems of fragility, openness and scalability when re-designing Yarely [5], an on-campus pervasive display network. Despite the range of display network implementations that have surfaced in recent years, they typically rely on a combination of bespoke software and custom hardware to drive the individual displays, as well as requiring technical expertise to implement and configure.

In this paper, we reflect on the sizeable body of literature and evaluate a longitudinal rural community display deployment, consisting of two independent networks. We present our lessons learnt from two iterations of the system architecture design to better inform future research in Ubicomp and HCI. These provide insight into designing for sustainability, scalability and stability of community displays, particularly those deployed in rural areas. Our findings are based on a case study in Northumberland, an area spanning 5000 km^2 (approx. 3100 mi^2) located in the North East of England, UK, with an approximate population of 319,000 inhabitants. The area comprises of mostly small towns, villages, farmland and countryside.

Following an Action Research (AR) [8] approach, the first display network, GleNet, was deployed in mid-2015 and consisted of nine individual display nodes that were centrally administered by a local charitable trust. In early 2017, the software used to drive individual displays along with the server-side Content Management System (CMS) was redesigned based on the feedback received from stakeholder evaluation interviews and usage data. We named this new community display architecture Showboater. In mid-2017, we implemented the new system within a second display network,

which we refer to as CoNet, also based in Northumberland. CoNet initially consisted of five nodes but has since grown to seven, with plans in place for further expansion in future. Shortly after CoNet's deployment and subsequent time spent monitoring the performance of Showboater, GleNet network was updated to also operate on the Showboater system architecture as well. Our contributions in this paper are the technical design and open sourced implementation for the long-term rural deployment of a community display networks with reflection on future design considerations and improvements.

2 BACKGROUND AND RELATED WORK

2.1 Related Work

Public displays have existed in a range of different implementations over recent years. The majority of deployments have resided within built-up urban environments, with fewer examples of more remote and secluded display instalments. Commercially available alternatives such as Signagelive [18] and Avantech [1] offer more feature-rich and professionally supported packages but tend to be expensive and have on-going running costs. Free display software alternatives exist in an array of configurations but can often be a complex to set up, be restricted in functionality or only offer the use of software on a trial basis.

Previous studies have provided insight into architectural designs for rural display networks [3, 20]. Although not a rural deployment in itself, Yarely [5] presents a comprehensive design outlay for an urban based, campus-wide display network which addressed many of the technical challenges highlighted by Taylor et al. [21] when installing rural displays; these include issues of system resilience, but also provide insight into the openness and appropriation of networks.

Designing for sustainability and scalability are important factors in any longitudinal study. Within the Wray Photo Display deployment [23], Taylor et al. describes designing for sustained use of community-run public displays following their handover to the community, past the point of funding. Wray's display was primarily built as a standalone unit which later underwent significant architecture changes to add another display, as opposed to FunSquare [13] and Digifieds [2] which were designed from the outset to scale across the panOULU Wi-Fi [17] network in Oulu, Finland. Utilizing commercially available products can reduce the technical skills requirements for long-term use and maintenance as well as reduce running costs over time [4]. O'Hara et al. highlights the necessity for planning and factoring on-going costs, as these can become unmanageable in the absence of a formal arrangement for funding once research projects end [15].

Hearn et al. [9] identified the need to consider the human and social infrastructure for ensuring sustainability. Redhead et al. similarly stated there should be a distribution of responsibility amongst community stakeholders to avoid any one proactive individual from 'burning out' [19]; the overall workflow needs to be supported by the infrastructure so that it can be disseminated between stakeholders to ease the managerial burden and enhance community involvement [23].

2.2 Study Context

Our study began in 2015 and is still presently active. Throughout the duration of the study, our group worked within two separate areas of Northumberland: Wooler, which hosts GleNet, and Rothbury which hosts CoNet. Northumberland is a large rural area is characterized by long distances between work, education, welfare and leisure options. Communities of inhabitants are typically spread over a larger geographical area than within urban environments. The need for a community display network arose due to the lack of awareness and visibility in locally run initiatives and opportunities. Situated displays placed in public locations were thought of as a means of helping promote local activities and signpost members of the community.

From the outset, we iteratively developed the network alongside community stakeholders to ensure sustainable use and participation throughout our long-term engagement [2, 23]. Within this paper we address creating a simple, scalable, sustainable and stable display network for rural deployment.

3 REQUIREMENTS

In 2015, we were approached to design and build a simple community display network for a small charitable trust located in Wooler. We built and deployed a prototype display system which allowed template HTML files to be populated with content and then displayed via a web-browser on a node. This system was in place for two years but sustained significant issues due to the overly complicated configuration of individual display nodes and the restrictions on having to upload content into templates using HTML markdown. Understanding that our replacement system was going to be in used within the near future, we took an AR approach [8] to collaboratively outline the functionality of the display network as well as iteratively design and develop a system prototype. An important step towards community acceptance and uptake was to co-realize the system alongside stakeholders [10, 12, 23]. Our requirements distilled into five Design Goals (DG).

3.1 DG1: Functional

We arrived at the following functional requirements for the display network; a content management system (CMS) to allow people to add, edit, remove and schedule content, as well as performing more administrative tasks, such as adding and removing nodes and users from the network; display nodes should display and rotate through a collection of pieces of content. Within our design approach, we also consider non-functional factors, including the need to design for scalability, sustainability, maintainability, resilience and distributed governance.

3.2 DG2: Sustainable

The budget limitations that the stakeholder community were facing, and considering other rural communities that may be in similar situations, we highlighted financial sustainability as one of our primary design objectives. Furthermore, designing a display network that could exist as a longstanding community asset which is not burdensome to use, administer, expand and manage was also important to sustain community uptake. The cost of technology required had to be considered carefully to be feasible and allow for

maintainability to preserve the longevity of the network, especially once the display network was handed over to the community [23].

3.3 DG3: Scalable

As well as being sustainable, we sought to develop a display network that could easily scale up or down to reflect the needs of the community. For example, the presence of a business or organization who have opted to host a display node could be transient, resulting in a need to easily relocate and reposition a display node. Similarly, by allowing the network to adapt to the community's needs, we also considered the implications of how we implement technology that allows for scalability to occur across a range of different computing devices, rather than restricting it to a single or small group of devices.

3.4 DG4: Resilient

One of our aims was to design a display system which was flexible enough to leverage both LAN and cellular network connections, depending on connectivity availability, as the coverage of both of these is limited in Northumberland. Given the frequent drop-outs and disruptions to internet services in the area, we quickly realized the need to locally store a copy of content on each node to ensure there was always some content to display.

In conducting our study within such a large and remote geographical area of England, we wanted to allow for complete remote accessibility of each display node for the purposes of monitoring, updating software and timely troubleshooting.

3.5 DG5: Distributed Governance

The display network is intended to be a community asset, which affords shared responsibility and distribution of labour for all stakeholders. These include administrators, content creators and moderators, owners of public displays, as well as the general public. By sharing access and responsibility, our aim is to promote participation, but also introduce redundancy and allow for communal governance. The server architecture will afford the tools necessary for the distribution of administrative roles, such as content creation and moderation as well as the ability to direct content. By directing localized content to different areas of the network, we can better accommodate the diverse range of stakeholders and rural communities.

4 DESIGN AND IMPLEMENTATION

Showboater was developed to meet our design goals by using an Internet-based client-server model, shown in Figure 1. The system consists of: a central database (DB) accessed through a web-based Display Network Server API; web-based user interfaces (UI) for the screen display client; and a Content Management System (CMS) for stakeholders to manage the content and display provisioning

4.1 Display Network Server

The Display Network Server provides a remote Application Programmer's Interface (API) for mediating machine-to-machine access to the database. The API is web-based (over HTTP), allowing it to be directly accessed from the CMS and Display web clients.
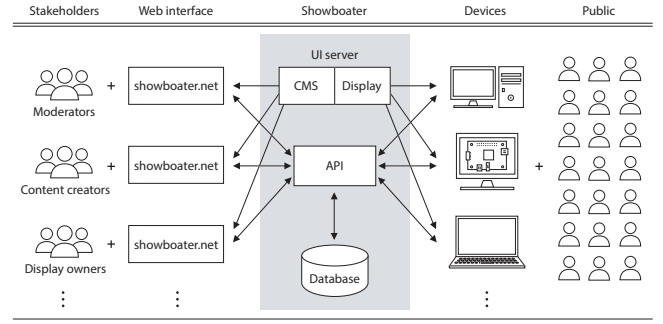

Figure 1: Overview of Showboater architecture

4.1.1 Entities. The principal entities of the system are: User, Display, Deployment, and Media. A User represents a stakeholder, their email address as a unique account identity, their name and an avatar image. A Display represents a public display screen with its own description and owner (user). A Deployment represents an intentional grouping of display media (and, indirectly, the moderators involved and displays on which they will be shown) and whether the deployment is currently active and/or open to public submission. Finally, Media, represents slide content intended to be shown on a display as part of a deployment: it has an owner (user), moderated status, and optional start and end date/times for its display. Additional entities are used to model many-to-many relationships: Presentation for assigning one or more deployments to be shown on a display; and Permission to allow one or more users to be content moderators for a deployment.

4.1.2 Permissions. The permissions of the system are rich enough to support the interests of the many types of stakeholder: content creators (who want to be able to provide new content); display owners (who want control over what is shown on their display); deployment moderators (who can judge whether media is accepted to a deployment); deployment coordinator/owner (who can choose moderators and decide on public submission policy); and administrators (who can decide who to trust to control content that is published on their system). The permissions can be summarized as follows:

Display Owner: control which deployments a display will show the media from.

Deployment Moderator: review and then publish or reject media submitted for a deployment.

Deployment Coordinator: add or remove the moderator rights of users for the deployment.

Deployment Owner: control whether a deployment is currently active and/or is open for public submissions (otherwise, moderator-only submissions). Administrator: make deployments 'active' (publicly viewable).

Super Administrator: add or remove Administrator permission for users.

4.1.3 Operations. The API facilitates a wide range of operations, each permissions-checked for the user, examples include:

User: Creating new users. Logging in/out. Granting/removing permissions.

Media: Adding new slides for a given deployment.

Display: Creating/editing/listing displays. Listing and editing the deployments shown (presentations). List published media for presentations on a display.

Deployment: Creating deployments. Adjusting permissions for a deployment. Listing/moderating media for a deployment.

4.2 Content Management System

A web-based Content Management System (CMS) acts as the user interface over the machine-to-machine API. The user flow follows familiar web site interactions: log in (creating a new account if necessary), view/add/update content, and log out. A user can manage any displays they own (adjusting which deployments are included on their display), and add new media to deployments accepting public submissions (or private deployments, if they are a moderator). Media is accepted from a range of common formats, typically preferring losslessly-compressed 'PNG' images exported from a presentation slide or image editor. For deployments in which they are the owner, users can adjust various deployment permissions. For deployments they are a moderator of, users can see and moderate submitted media, including making adjustments for the displayed date/times of the media.

4.3 Display Client

Showboater's display client implementation, Player, is purposefully designed to require only a web-browser for content playback. This flexible approach allows use with a very large range of hardware. The client is simply accessed through a web address (URL) which includes the unique identifier of the display. The page makes use of a widely supported feature (a Web App Manifest) that ensures the client is cached: it is stored so that it can be used in the future, even if connectivity is temporarily unavailable. The Player periodically asks the API for any changes to the media the display should be showing. This request is heavily optimized so that a very small amount of data is used in the common case of no changes being made: minimizing the overhead of adding a display to a network, and making it suitable for applications where data usage caps are present (such as mobile internet contracts). If there is a change to the content, the display client removes any expired content and downloads new media to a persistent storage (Indexed DB) under the full control of the page. This arrangement ensures the content presentation can continue uninterrupted in the face of network outages and/or a full restart of the display client. The display client continually cycles through the stored media as a slide carousel.

4.4 Display Hardware

Showboater's display client is flexible enough to be deployed on any devices that can run a full-screen web browser. For example, any PC or laptop running Windows, macOS or Linux; or any tablet or mobile device running iOS or Android, would be compatible as a display node (see Figure 2).

Throughout our deployments, we have opted to use Raspberry Pi's given their low price and availability; they are widely supported and highly customizable with online communities offering a plethora of guides, manuals and wikis that give insight into DIY cases, mounting brackets and accessories for the Pi. Later models,

Figure 2: Showboater operating on a Raspberry Pi, Windows based desktop and Macintosh laptop

such as the Raspberry Pi 3 and Pi Zero W, support Wi-Fi connectivity internally, and the free Raspbian operating system gracefully handles Wi-Fi disconnections and reconnections in the background. The Pi also offers both HDMI and composite video output, and can be connected to digital monitors and virtually any television.

Display nodes which are using Pi's are additionally configured using a series of scripts which operate when the devices are powered. The scripts configure the Pi to blank the screen during the boot-up process, allowing time for the device to fetch new content from the server, and ensure the browser launches successfully in full-screen ("kiosk") mode.

5 DEPLOYMENT

We were invited to present the initial concept of Showboater to the community stakeholders of Rothbury in early 2017. As a result, a trio of backers from the community expressed interest in taking the project forward. The backers firstly organised a competition alongside the local middle school where students were asked to design a logo and name the display network. From this point on, the network was nicknamed CoNet, with an accompanying logo which loosely represented the geographical area of Rothbury (Figure 3).
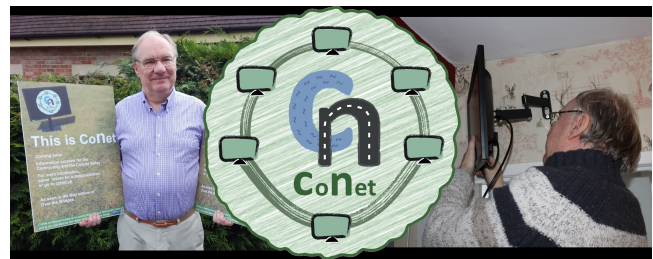

Figure 3: Stakeholder marketing of CoNet (left, used with permission), CoNet logo (centre), installation of a node by a community stakeholder (right)

One stakeholder is a particularly keen advocate of CoNet and took initial ownership of the display network. Marketing in the form of posters, flyers and articles were used in the run up to the launch in mid-2017 to promote the system; it launched with four nodes and has since grown to seven through a series of successful community funding initiatives and wider community visibility. To this day, CoNet has displayed around 1000 individual pieces of content across seven individual nodes. Content is primarily created and uploaded by the system administrator. Community members tend to pass non-digital information to the administrator who formats it digitally for displaying on the nodes.

GleNet, which had been in place since mid-2015, was updated to use Showboater in late 2017. The previous display system had been thoroughly used and had displayed over 1400 pieces of individual content throughout its lifetime. The previous system was replaced as Showboater offered a cleaner user interface for managing content as well as improved node functionality which afforded faster and more stable operation. Since the relaunch, GleNet has displayed over 103 pieces of individual content throughout its nine nodes. Content is predominantly created by the single system administrator, however display owners are more proactive and keener to upload their own content within GleNet. Content from both networks typically includes promoting rural community life, events, festivals, initiatives and important bulletins (Figure 4).

Figure 4: Sample content from the display networks

In total, there are 16 display nodes (Figure 5) currently active across the two Showboater networks.

6 REFLECTION AND DISCUSSION

Our reflection took the form of audio recorded interviews, observations and field notes which took place 3-6 months after initial installation of Showboater; system usage logs were also used. We gathered insight into how Showboater's implementation supported the community as well as gathered perceptions about how the system was received. We approached significant stakeholders which included system administrators (A), content creators (B) and display owners (C); in total we conducted six interviews.

6.1 Community Feedback

Members of the community saw value in the display networks as a community resource: "Yes [it is useful], because it shows you
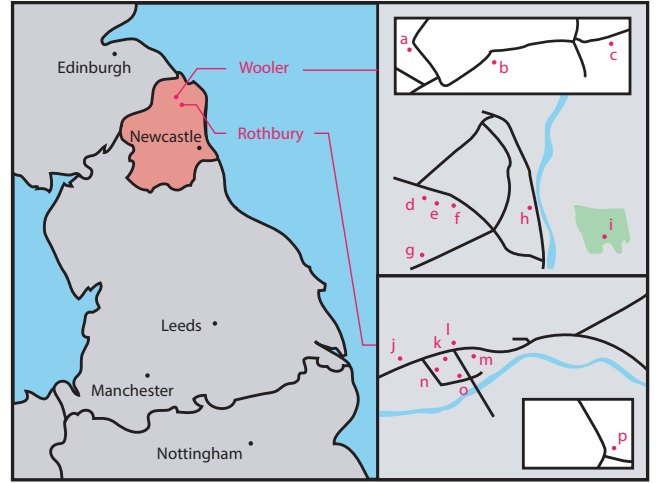

Figure 5: Location of display networks and active nodes in Northumberland, Northern England. (a)-(i) GleNet, Wooler. (j)-(p) CoNet, Rothbury.

obviously what's going on here in [the local area] and stuff, so it could help you if you're just new here" (B). Content has raised the awareness of local activities and clubs: "I've seen something about swimming which I actually went for...I followed that up." (C); individuals found employment through content displayed on the nodes: "Those lads who actually found an apprenticeship off that screen now work down at [a company]" (C). Organisations, charities and individuals based within their respective communities highlight the usefulness of the display networks as an alternate tool for local advertising and content distribution: "The project has been well received by the community who regularly send information to me to promote. We currently have over 20 separate adverts currently active." (A)

Some of our display owners who had opted to host a node would sometimes change their mind. This was typically due to the owner either re-locating, not having enough time to fully engage with the system or they had not been informed that they could upload their own content to the node and wider network. Node placement was sometimes temporarily transient until a more permanent location was found. Movements and relocations were anticipated, with Showboater's node design allowing for the easy transition and re-homing of physical display units as part of the wider network. In future, we propose to further highlight Showboater's features by providing deployment documentation to negate similar situations where stakeholders are unaware of the functionality the Showboater platform provides.

6.2 Sustainability and Scalability

During the deployment of Showboater, keen community stakeholders who volunteered their time into the setup of each network naturally transitioned into the role of system administrators. Both GleNet and CoNet have a single system administrator who predominantly oversees each network and its content, respectively. Having people who occupy this role is beneficial for each network as these

important stakeholders provide the necessary enthusiasm and drive to progress projects at the local level. Their efforts often dictating the outcome of a project in the short-term. However, as Redhead et al. [19] highlights, this can be detrimental in the long-term if no further support is provided as those individuals start to 'burn out'. Upon launching Showboater within their respective deployments, we did not initially focus on the distribution of roles despite Showboater offering a pre-templated approach to managing numerous roles as part of a display network. This is a concern we are now aware of and plan to address within future deployments as it affects the scalability of the networks. One approach is to reframe the way in which Showboater is initially marketed to prospective communities; encouraging stakeholders and communities that Showboater deployments should aspire to grow with an increased number of nodes developing over time. With scaling, node owners should take direct responsibility for their own content creation with other roles, such as moderation and administration, being distributed across other the community stakeholders.

Alternative approaches to scaling include Showboater facilitating the scalability of the networks. Drawing on social media growth models, Showboater could encourage existing users to reach out and add other users, suggest users who may be suitable to carry out specific roles, such as moderation, and suggest privilege upgrades based on usage activity.

Showboater makes it very easy to add additional deployments to those running on our server installation (almost entirely 'self-service' barring the permission to make it public). Although we continue to run own installation for any public deployments, there can be no guarantee to its long-term continuation. To combat this, we have open-sourced Showboater, so that anyone may run their own instance. Nevertheless, this represents technical and financial barriers for communities who would like to run their own instance. Additionally, servers and source code must be maintained to run long-term and minimize security risks. To minimize barriers, services can be decoupled as much as possible from the requirements of bespoke platforms: a shift towards unplatformed design, making use of existing, common public services. One possible direction for this would be to replace the database and bespoke API with a user interface layer over an existing version control repository (e.g. git version control platforms such as GitHub and GitLab). Such systems are typically free for public/open use and would provide the heavy lifting for user access control, resource storage, serving of web resources, and provide the necessary APIs such that the front-end CMS and display clients could be adapted.

6.3 Resilience

The display nodes successfully operated off cached content if an internet connection was unavailable. However, the system administrator would occasionally receive reports that a node was not updating its content for an extended period. A common cause was found to be that display owners, particularly businesses, sometimes changed their Wi Fi credentials (e.g. the Service Set Identifier, SSID, or Pre-Shared Key, PSK) of the Wi-Fi router they were using (for example, if changing service provider), and were unaware that the display would require reconfiguring. Many of the nodes within our two deployments utilized Raspberry Pi's with the nodes typically

installed by the system administrator, and display owners were not easily able to perform this configuration. This should be addressed with improved documentation and processes for the display owner.

One minor drawbacks of the Raspberry Pi is the lack of a battery-backed real-time clock, meaning that the precise real-world time is unknown after the Pi has been switched off, until it has restarted and gained internet access to contact a time service. Because of this, perfectly reliable scheduling of content when offline is not possible, which can result in out-of-date content being shown until a successful connection to the server is made. This could be overcome in the future by adding a clock module at a small additional cost, (available as an off-the shelf product). Even without this, the Pi is still a very suitable choice for long-term use within the display networks.

7 CONCLUSION

Within this paper we have described the design, implementation and deployment of Showboater, a system designed for communities to create and maintain display networks that are functional, sustainable, scalable, resilient and allow for the distribution of governance. Showboater is still currently active and has continued to grow with more deployment locations set for the future.

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