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Social Value of High Bandwidth Networks: Creative Performance and Education

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1 Summary

This paper considers limitations of existing network technologies for distributed theatrical performance in the creative arts and for symmetrical real-time interaction in online learning environments. It examines the experience of a multidisciplinary research consortium that aimed to introduce a solution to latency and other network problems experienced by users in these sectors. The solution builds on the Multicast protocol, Access Grid, an environment supported by very high bandwidth networks. The solution is intended to offer high quality image and sound, interaction with other network platforms, maximum user control of multipoint transmissions, and open programming tools that are flexible and modifiable for specific uses. A case study is presented drawing upon an extended period of participant observation by the authors. This provides a basis for an examination of the challenges of promoting technological innovation in a multidisciplinary project. We highlight the kinds of technical advances and cultural and organizational changes that would be required to meet demanding quality standards, the way a research consortium planned to engage in experimentation and learning, and factors making it difficult to achieve an open platform that is responsive to the needs of users in the creative arts and education sectors.

1. Introduction

Investment in high bandwidth digital networks enables increasingly varied user groups to develop applications. Creative artists, scientists and educationalists stand to benefit substantially. All these groups are experimenting with fruitful results but they are limited in what they can achieve. The reasons are only partly technical; they are also cultural and organizational. Multidisciplinary teams of researchers and practitioners need to experiment if substantial advances are to be made and this requires investment. Although the creative arts and education sectors have the potential to boost demand for very high bandwidth connectivity, convincing use cases can only be developed if investment is made to enable learning. Investing in hardware and software developments without simultaneously investing in efforts to reduce non-technical barriers to the exploitation of these networks is an ineffective way of stimulating demand.

In this paper we discuss an initiative to encourage the innovative use of very high bandwidth networks for online theatrical performance, interactive higher education provision, and artistic experimentation in image and sound. In all these areas, use of these networks is being hindered by technical, cultural and organizational factors. In the technical domain, latency and simultaneous interaction across distributed sites of activity is a problem. We suggest how this could be addressed by investing in modifications to the network-based Multicast protocol to create a flexible platform and software tools that respond to the needs of these sectors.

A case study of a research consortium is presented to illustrate the challenges of achieving a relatively modest innovation in the technical domain of multicasting as a basis for stimulating interest in the use of very high bandwidth networks so that they become more accessible to the wider public. The case study is based on participant observation by the first author over an extended period from 2005 to the present. During this period she attended meetings of MARCEL (Multimedia Art Research Centres and Electronic Laboratories), a network that champions technical advances in multicasting applications and multidisciplinary research. The aim of the network is to demonstrate the benefits of enhanced use of very high bandwidth networks in the creative arts and education sectors. The first author also supervised a doctoral project which examined the

activities of the leader of the MARCEL network, Don Foresta, and his efforts to secure funding to support experimentation with the multicasting technology [1]. This paper draws upon the earlier work and on a recent effort by a MARCEL-led multidisciplinary consortium to prepare a large project bid for the European Commission's Horizon 2020 programme. Notes taken during face-to-face meetings and email exchanges during the bid preparation period provide the empirical evidence for the account given in this paper. The aim is to demonstrate the importance of multidisciplinary collaboration to enable users in all sectors to develop applications with substantial social and economic value through their use of very high bandwidth networks.

In section 2 we highlight efforts to develop applications in the creative arts (artistic performance) and education (online higher education) sector using access to very high bandwidth networks. Section 3 introduces multicasting and explains how it differs from other network configurations for the management of time sensitive, high volume, distributed network traffic. The case study of MARCEL's efforts to stimulate interest in the use of multicasting is discussed in section 4. In the conclusion (section 5), we indicate why investment in this area would be responsive to the goals of the European Digital Agenda and, specifically, to the goal of creating an inclusive digital environment.

2. Demand in the Creative Arts and Higher Education

Experimentation with the use of high bandwidth networks has been underway for some time in the creative arts, especially in the field of live musical performance where remote participants must work together in real-time. Initiatives in the United Kingdom include, for example, the Tate Modern performance room which hosts artworks commissioned exclusively for an online space (http://tinyurl.com/k9llu54), the University of Newcastle's Space Time Concerto project for synchronizing musical performances (http://tinyurl.com/qxhxn48), and JISC's Edinburgh Napier University - Royal College of Music project using the JANET academic network for collaborative music performances (). In the United States, the Internet 2 Arts and Humanities academic network initiative supports collaborative live performances and master classes. It provides relatively low latency audio and videoconferencing for real-time, simultaneous performances across distances for its members (http://tinyurl.com/qxacshh).

Other examples could be given, but it is noteworthy that the majority of existing projects rely on very high bandwidth networks provided by public funding for scientific uses. Many organizations in Europe and North America have mandates to focus on the use of digital artworks to create socially and culturally valued content for a broad public (e.g. Zentrum für Kunst und Mediantechnologie and Rhizome, and SIGGRAPH, sponsored by the Association for Computing Machinery's Special Interest Group on Graphics and Interactive Techniques). These mandates are in line with Castells', sociologist of digital innovation, comment that 'the openness of the web truly democratizes art, at last' [2, p. 199]. Unfortunately, however, the existing configuration of very high bandwidth networks makes it difficult for these organisations to exploit the bandwidth that is available. The challenges presented by the limitations of software tools, combined with the lack of funding to support experimentation and learning to foster capabilities for performing in a globally distributed online space, are among the factors that are limiting what can be achieved by those with the imagination to envisage the full potential of virtual spaces.

In the education sector, similarly, there is no lack of vision of the potential of very high bandwidth networks to offer virtual learning environments that come close to replicating the experience of physical presence. Online education in higher education is a well-established field [3]. MOOCs (Massive Open Online Courses) are attracting a global student population in both the United States and Europe. Progress has been made in using available academic networks to support synchronous distant education and these initiatives are providing improved access for learners. They are struggling, however, to provide a truly interactive experience of virtual learning. This is due to technical barriers and to the need for changes in how course provision is offered [3]. Most MOOCs are web-based and technical limitations inhibit their further development because of limited connectivity with students in a way that can support real-time interactivity. This is confirmed by Schroeder, Director of the Center for Online Learning, Research and Service at the University of Illinois. He has observed that for use in subjects beyond computing science and mathematics, interactive instructor connections and feedback in real-time are essential [4]. Providing this kind of online space is a challenge for several reasons. If a lecturer needs to interact with students in real-time, for example, the video quality must meet a high quality standard. Additionally, the interaction space itself must be able to

offer fine resolution sufficient for the lecturer to gauge how explanations are being received. Visual feedback also requires higher quality streaming than generally is available.

The technical limitations of current technologies are similarly confirmed by scientists. For example, CERN's (The European Organization for Nuclear Research) scientific collaborations involve thousands of individuals around the world. They require a high level of interactivity to share drawings, sketches, and graphs across the network. Even the best available conferencing tool is reportedly not deemed by CERN to satisfy its requirements for a high standard of real-time presence.

In summary, in the creative arts, education and scientific sectors, initiatives are being held back by technical barriers and weak support for the experimentation that could foster learning about how to exploit the full potential of very high bandwidth networks. Current developments do not exploit the potential imagined by performance artists and by online higher education course developers. The result is many missed opportunities to develop convincing 'use cases' that could stimulate the use of these networks, ultimately, beyond the scientific research sector and attract investment in support of enhanced applications in these and other sectors. The next section introduces some of the principal features of multicasting and its application.

3. Multicasting as an Innovative Solution

Internet Protocol (IP) multicasting is regarded by those who have developed and used it as a means of achieving the high quality standards desired by producers of content in the creative arts and higher education. This is because it provides a way of moving towards symmetrical online connections to support performances and virtual learning. Multicast is a protocol that allows for optimal routing of traffic across the very high bandwidth network because it minimizes the network resources used by each online participant. This results in more reliable connections among very large numbers of people with reduced delay and it uses less bandwidth than other configurations. This protocol is used by internet service providers to stream television programmes to digital set top boxes, but it is not available to the 'average' internet user without access to a very high bandwidth network.

Multicasting is supported by academic institutions through their commitments to National Research and Education Networks (NRENs) such as GÉANT in Europe. In the 1990s Access Grid was developed to create a network of gateways with multicast connectivity. Access Grid was developed as a configuration within the academic high bandwidth network in 1994 by Futures Lab, a division of the US Department of Energy-funded Argonne National Laboratory. Access Grid provides a means of connecting multiple immersive and semi-immersive virtual environments using the NREN-supported 'Grid' and it is an alternative to web-based virtual reality environments. Future Lab, together with universities in the United States and the United Kingdom, designed an online videoconferencing application to support collaborative work in real-time over large distances [5]. JANET in the United Kingdom and Internet 2 in the United States have deployed Access Grid, providing a platform for streaming video and audio signals. Multicasting enables the transfer of data packets from one node to many *specific* nodes instead of indiscriminately transferring files or using multipoint 'broadcasting', or transferring packets from one point to another as in unicasting. The difference is illustrated in Figures 1 (multipoint and point-to-point) and 2 (multicasting). Figure 2 shows how routers manage traffic so that clients are not overloaded because the traffic is sent to a multicast address that all participants are able to subscribe to.

Insert Figures 1 and 2 about here

Multicast is built into IPv6 and it results in less stress on local network resources. This differentiates Access Grid from other network configurations, but IPv6 is not yet universally deployed in the public internet. For this to happen convincing use cases are needed to stimulate investment. Multicasting allows many people to participate in a distributed performance or other forms of collaboration without having to define a specific network. It offers greater potential for real-time interactivity and for delivering complex content in a cost-effective way than alternative network configurations. For instance, a virtual room supported over Access Grid allows dozens of participants to have a continuous symmetrical presence in virtual space with windows into each space, permitting constant interaction.

Access Grid's developers expected that it would decline in cost as its use increased. They envisaged that it would become ubiquitous as a means of 'coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations' [6, p.2]. In parallel with Access Grid's development, many commercial videoconferencing solutions have been brought to market. These are regarded as being technically limited as indicated in the preceding section. With the exception of very large organizations in the private and scientific sectors, the commercial solutions are beyond the means of the many institutions that could benefit from access to the multicast solution. Furthermore, they do not reach into the homes of citizens who could benefit from access to high quality interactive and distributed cultural productions. They also do not reach students who expect an enriched interactive online environment for learning. In contrast to other commercial online environments, Access Grid's supporting software tools are open source providing a basis for sharing and modification. The early dream was that 'within the near future, bandwidth, computing, and imaging power will become effectively free and that high-quality audio and video capture will be increasingly inexpensive' [7, p. 199], but this was not to be.

While Access Grid's multicasting provides a means for artists, teachers and learners, and scientists to collaborate online, the problems it experiences with latency have yet to be fully addressed. It also does not meet the quality standards that are being demanded for real time interactions. In its existing form, Access Grid cannot provide the transmission quality and applications required for managing distributed online theatrical performances or symmetrical higher education teaching. For both, latency is a significant issue. The broadcast industry uses commercial applications on private networks to mitigate this problem, but at a cost of around £55k per day for a 1-5 second delayed one-way communication. Two-way communication using satellites is more costly and produces a 5-7 second delay. This is unsuitable for live performance and intensive teacher-student interaction. Free, web-based, live streaming platforms such as Skype, Google Hangout, Livestream or Ustream have a 10 - 45 second delay. Some commercial videoconferencing solutions do better in supporting distributed interaction, but do not provide an audio and video quality suitable for audiences of live performance. Universities are equipped with the bandwidth, dedicated networks and facilities to develop platforms for simultaneous flexible interactions, but do not have staff with capabilities to work as production houses for next-generation interactive learning environments.

The multicasting solution is available on a restricted basis for use with academic collaborators. This limits experimentation that would yield use cases that could drive investment and extend the reach and use of very high bandwidth networks by stimulating demand. Projects to develop such use cases would enable artistic and educational groups to play and tinker on a larger scale. Technical innovations in the multicast platform and its software applications would be of benefit to collaborative cross-disciplinary projects, but these are not the only requirements. Taking the next steps requires changes in the cultures of creative production and educational practice to stimulate the take-up of the multicasting solution. Achieving such changes requires multidisciplinary collaborations which are always very challenging. The next section outlines the experience of one such initiative to achieve a significant advance in the deployment of multicasting.

4. The MARCEL experience

MARCEL - Multimedia Art Research Centres and Electronic Laboratories - has some 300 member organisations including universities and creative arts organisations in Europe, North America and elsewhere. It aims to mobilize investment in multidisciplinary innovation and learning to make better use of very high bandwidth networks. Its international coordinator, Don Foresta, works with partners around the world to encourage the use of multicasting to produce synchronous online events. In the late 1990s, a Charter was widely circulated by MARCEL calling upon industry to support '.. developing a partnership with institutions, governments and international organizations to build the interactive network for artistic and educational exchange and by reinforcing supportive relationships whereby industry provides artists and arts organisations with technical support, maintenance, resources, networks' [8, p. 228].

Foresta realized early on that when artists and educationalists seek new ways of engaging with digital networks, the planning and execution of their work often changes. Such changes can challenge deeply rooted cultural and organizational conventions that inform views about how art or education courses 'should' be produced [1, 9]. Through experimental practice some artists and educationalists will become leading innovators and then others will follow as they learn how to appropriate novel approaches to the use of virtual

spaces. Participants need to experience collaborating across disciplinary and practice divides. They need to tinker in the process of rethinking how to express creative works and educational content in unfamiliar ways that are appropriate to the real-time interactive virtual space. Foresta's MARCEL network participants consistently emphasize that access to very high bandwidth networks at affordable costs is only the first of many essential steps in the innovation process if use of these networks is to flourish in these sectors [10].

To promote the necessary developments in the multicasting platform, the MARCEL network engaged in fundraising. Foresta was awarded a UK Arts and Humanities Research Council Fellowship in the Creative and Performing Arts in 2000 with the London Wimbledon School of Art Research Centre. The aim was to integrate performing arts into the virtual space to support a growing presence of artistic experimentation. Funding was needed for technical developments and to support the coordination of multiple actors across physical distance. It was also needed to ensure that all the participants would be able to negotiate their integration into the multicasting environment [1]. Many attempts were made to stimulate interest and there were numerous expressions of interest among potential users. However, the significant funding that would be needed unfortunately did not materialise to support experimentation. Projects were occasionally backed by universities and some private sector funding was secured but this was not substantial enough to demonstrate the full potential of multicasting on a sustainable basis. Insufficient funding was raised because of perceptions that neither the creative arts nor the educational sector need an alternative to available proprietary platforms. It was claimed that demand is insubstantial and that multicasting is not required because web-based virtual environments and commercial videoconferencing already achieve sufficiently high quality standards. These claims were inconsistent with the views of the groups of multicast users that coalesced in the MARCEL network.

MARCEL's efforts to build momentum in the use of multicasting persisted. By 2014 a consortium had been convened to prepare a bid to European Commission's Horizon 2020 Programme's e-infrastructure theme. The consortium was comprised of participants from the nuclear research community, the software and network engineering communities, higher education institutions (science and social science), and the performance and exhibition arts. These are groups that typically do not collaborate, but the consortium participants were committed to overcoming barriers to the full exploitation of the e-infrastructure as an educational and cultural space. Their aim was to experiment using real-time educational and artistic events to engage with peers and, ultimately, once demand could be demonstrated, with the public. Multicasting was to be integrated within Europe's e-infrastructure to support the best of human endeavour in a way that would be responsive to society's cultural needs and empower a wide range of researchers to respond to societal challenges in the digital era.

By the time the consortium came together, the European network, GÉANT, was available to provide an infrastructure for scientific research collaboration, offering very high bandwidth and a high-capacity 50,000 km network connecting NRENs across Europe. This network for research activities offered a basis for promoting a significant leap forward in truly interactive digital online experiences. Through applied research, technology development and the validation of pilot projects, the consortium hoped to be well placed to demonstrate the technical feasibility of solutions to latency quality issues, the need for flexible software tools, and the benefits of multidisciplinary learning through experimental practice. GÉANT agreed to support the use of its networks by the consortium in its bid for Horizon 2020 funding.

To accomplish the MARCEL consortium's goals, it would be necessary to add software programing tools to the existing multicasting platform so that templates would be available for specific uses, e.g. lectures, seminars, conferences, workshops, concerts, theatre, dance performance, etc. These tools would be designed as open source applications that could be modified to provide bespoke modules in response to specific user needs. A substantial number of use cases would be supported if the project bid was successful and these would stimulate demand and investment, creating a virtuous circle of supply-demand interaction. The plan was to use Access Grid as the multicasting platform and a programming language, PureData, to provide high quality image and sound, gesture recognition software, and a virtual environment with an ergonomically attractive user interface.

PureData is a visual programming language with a network of 2,000 developers and a library of patches/tools for diverse creative tasks (http://tinyurl.com/pdmw8ph). These can be developed to process and generate sound, video, 2D/3D graphics, interface sensors, input devices, and a MIDI (Musical Instrument Digital

Interface). PureData works over local and remote networks and it was deemed to be suitable for learning about basic multimedia processing and visual programming methods when it is interfaced with the Access Grid platform. The open source tools combined with a flexible platform would give users the opportunity to adjust the technology to their specific needs. It was expected that the creation of novel virtual environments would demonstrate the functionality and capacity of the platform, inspiring further innovative applications of very high bandwidth networks. For instance, there was a plan to develop a mobile app for using the 4G network to access the platform from standard (current and future) mobile devices, thereby broadening the potential user base. To enhance the attractiveness of these developments for smaller private sector firms, the consortium also planned a tailored license for industry users who would pay a license fee for the use of the tools. Thus, the consortium adopted a mixed open source/commercial business model that would yield a sustainable initiative and address legal and economic issues and conflicts associated with content ownership rights and compensation for artists and scholars.

Capacity building in a multidisciplinary environment would be crucial to the success of the consortium's project. User needs would have to be identified and the digital platform would need to enable non-technical participants to learn how to devise innovative content production practices. Experimentation with high bandwidth networks has failed in the past because of the limitations of available tools, limited network access, a scarcity of collaborative skills and the challenges of multidisciplinary collaboration [11]. Non-technical participants may be dissuaded from venturing into what they perceive as a formidable technical space requiring a high level of domain-specific expertise. They may feel excluded from the development process because their involvement starts long after the technical developments have been agreed. In contrast to other initiatives, in the MARCEL case, social scientists experienced in the study of socio-technical developments and with an understanding of the need for inclusivity were involved from the earliest days of the network. The creative artists and university lecturers who would experiment were also involved in the early discussion of pilot projects. Coordinator, Foresta, worked with all members of the consortium during the Horizon 2020 bid preparation process to support them in formulating pilot projects, building the trust necessary for successful multidisciplinary collaboration.

As a result, pilot projects emerged from the creative arts and higher education participants. Theatrical performances are arguably the most demanding uses of distributed networking activities. In the creative arts sector, one pilot project aimed to analyse the requirements of real-life theatrical performance in a multicast environment. Workshops would be used to bring teams from three collaborating theatre companies together to focus on the technical *and* artistic criteria for planning a 3–node multicast theatre production. Establishing the professional quality standards for a multi-node performance, e.g. bandwidth, latency/synchronization, data transfer rates, and audio and video resolution, would be crucial to the success of the pilot. Examining factors such as the distance between performance spaces, the implications for the creative practice of writers, actors, directors, set designers, and lighting and sound specialists, as well as the creative possibilities and technical challenges for audience interaction were among the issues that would be essential to consider. Learning and experimentation would involve close work among production, performance and technical experts on the structure of the technical network, on the content and on the use of external performers. Facilitators for simulations between three rooms on one site, later to be tested on the multicast platform itself, rehearsals using new or existing texts, and innovations in performance practice were issues that needed to be tackled. Many of these issues were expected to require dramaturgical and organizational solutions and, in some instances, the radical re-conception of notions of performance and their integration with existing performance conventions.

In the higher education sector, a pilot project was designed that would implement the multicasting platform in support of the international component of a master's degree in arts and science at a top-ranked university in the United Kingdom. Classes would take place in one location and remotely in a number of others, using the platform to share and exchange information as richly as possible. Another pilot project aimed to support a semester-long seminar course on cinema and interactivity at a leading university in France that is dedicated to building students' digital literacies and capabilities in the creative arts field. Yet another project was planned to develop a course on anti-matter linking science and educational institutions in Western and Eastern Europe. For the higher education institutions and the scientific institute, the incentive to participate in the consortium was partly a reflection of pressures in higher education to develop distant online learning models for vocational and higher education that can support improved interactivity between learners and teachers to enhance the learning experience, especially, for example, through 'blended learning' strategies integrating

face-to-face and online contact [12]. In the United Kingdom it is estimated that in 2011-12, non-European Union students generated some £3.5b for the university sector. Throughout the European Union, there is increasingly strong competition in the overseas student market and providing use cases that would help to stimulate demand for improved digital applications was expected to underpin more cost-effective delivery methods. In this sector, as in the creative arts sector, it was recognised that the barriers to success are only partly technical. Changes in the organisation and culture of educational programme design and content production would also be needed.

The non-technical organisational and cultural issues associated with projects of this kind are addressed by social scientists who study the socio-technical features of experimentation and learning in online environments. The MARCEL project integrated the study of this learning dimension into its workplan from the very beginning. Real-time participant observation by social scientists was to take place in all phases of the project. The social scientists would have training in the study of cognition and learning and in the analysis of the way diverse project participants negotiate during the technological innovation process to achieve their goals. This was regarded as essential for a comprehensive evaluation of this multidisciplinary project. By incorporating social scientific expertise within the project it would be feasible to generate continuous feedback for participants to support the successful conduct of the pilot projects. The results would yield use cases that would demonstrate the demand for an accessible and affordable multicasting platform.

The goal of the social science research component was to follow the experiences of the other consortium participants and their innovative uses of objects – network hardware and software application. Social science expertise would be drawn upon to analyse existing work in closely related fields and to investigate the processes through which the subjects (persons) and the objects (the multicast platform and tools) would engage with each other over the life of the project. The analysis would attend to how decision-making can be structured and organized to enable inclusive participation of all consortium participants. The research would make their decisions about the design and use of technology explicit so that lessons would be learned as the project unfolded.

This component of the research would involve a mixed-method approach using qualitative and quantitative methods. The former would involve off- and on-line methods including participant observation and interviews with MARCEL project participants and relevant others (e.g. artists, computer scientists, software and hardware developers). The multicast platform itself would be used for observing the innovation process in real-time, with the social science researchers following all of the activities of other members of the consortium. Discourse and visual analysis would be used to examine the communicative relationships among the participants and to trace new conventions and practices as they emerged. Computational tools for 'big data' analysis would be employed to collect and analyse data relating to all the elements of the performances and educational offerings developed in the pilot projects. The use of a common spatial and temporal frame would ensure data compatibility for statistical testing of relationships between events, movements and interactions in the virtual space and of how emotions and the responses of participants (learners or audiences) were influenced by interactive online performances and courses. The mixed-method approach would allow for continuous reporting of results to all members of the consortium. This would enable participants' intentions and diverse experiences of the digital space to be discussed and reflected upon, the aim being to reduce misunderstandings that might otherwise lead to tensions and potential conflicts. Timely feedback would support an inclusive learning process for those with technical expertise and for performers, choreographers and lecturers, an approach which is atypical of most e-infrastructure projects.

The MARCEL consortium bid to the European Commission was unsuccessful and the partners continue to seek financing from other sources. Without funding the consortium is unlikely to be able to fulfil its ambitions. In the proposal evaluation process despite the Commission's emphasis on multidisciplinarity, paradoxically, the project was perceived as being insufficiently innovative in relation to technology, too innovative with respect to the pilot projects, and too multidisciplinary. It seems likely that the project was understood as presenting a threat to the interests of developers of technologies for the videoconferencing and web-based performance commercial market. Had the project been funded, the results would have provided use cases demonstrating the potential for generating traffic on very high bandwidth networks which might be expected to be in the interest of investors in the telecommunication infrastructure. However, commercial developers of internet apps that fall short of meeting the requirements of creative artists and educationalists are unlikely to want to support a project that seems to present a risk of eroding what they regard as 'their' market. As a

result, the hybrid open source /commercial business model that the MARCEL project consortium proposed was not favoured.

5. Conclusion

Research on the development and use of digital networks demonstrates that potential users do not lack visions of what could be accomplished by bringing very high bandwidth networks into a wider range of socially and economically rewarding uses by meeting exacting technical quality standards. If these visions are translated into multiple use cases, it is likely that numerous interactive creative arts and educational offerings could start to become widely available to the public [13, 14]. Commercial network developers are seeking justifications for investment and developers of applications such as Google, Facebook and Twitter are continuously innovating in a world in which the population is increasingly connected. The creative arts and higher education sectors are comparatively neglected areas of investment. This means that experimentation of the kind discussed in this paper is essential to demonstrate the potential for these areas to generate network traffic in sectors that are both economically productive *and* socially and culturally valued. Multicasting provides a means of enhancing the online experiences of citizens globally. Support for experimentation ultimately could lead to a digital environment in which more citizens can experience cultural activities and experience learning in truly interactive virtual spaces. An improved open multicasting platform would also offer sites for building the capabilities of those who have the vision to develop new applications. It would do so by exploiting a non-commercial technology platform, thereby contributing to the strengthening of digital literacies in areas such as the creative arts and education, both of which have acknowledged skills deficits.

Limited multidisciplinary experience and domain specific capabilities in key sectors, combined with weaknesses in basic digital literacies, unaffordable access to very high bandwidth networks and a perceived lack of relevance of these networks, means that barriers to greater network use will persist [15]. In Europe and elsewhere, electronic-commerce, gaming and social networking are producing a growing share of network traffic, representing a market of around 3 trillion euro worldwide. More than 10 per cent of the world's GDP is estimated to depend on the information and communication technology sector [16]. In Europe the 2020 Strategy and the Digital Agenda set out economic, social and cultural goals which include strengthening the cultural industries and education to enable learning of skills that are compatible with a digitally mediated society.

In this context the development of diverse robust use cases building on multicasting would provide a means of encouraging very high bandwidth network investment. This would be consistent with efforts to meet policy goals through support for innovative projects undertaken by multidisciplinary research consortia. The consortium discussed in this paper has the potential to support opportunities for learning by bridging between engineering, computing science, social science and practitioner expertise. It offers an alternative to the exploitation of multicasting in the commercial market, since it supports a hybrid business model. This means that the innovative technologies could be available to those who otherwise would be unable to afford access to very high bandwidth networks. Support for projects such as the MARCEL initiative would maximize opportunities for creative experimentation with a view to stimulating socially and economically valued uses of these networks with a view to making them available to a much wider public than is likely solely as a result of commercial developments.

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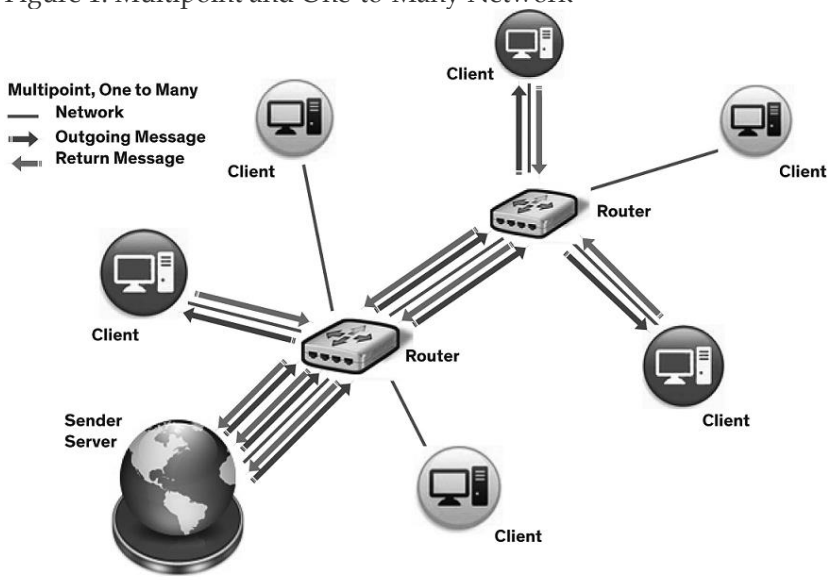
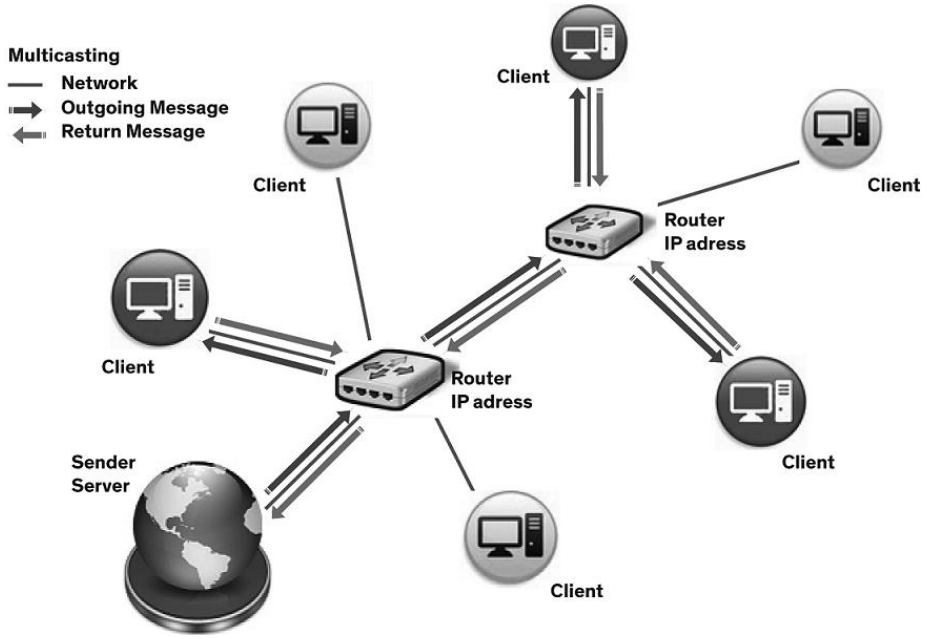
Figure 1: Multipoint and One-to-Many Network



Source: authors

Figure 2: Multicasting Network



Source: authors