Social Value of High Bandwidth Networks: Creative Performance and Education

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Summary

One challenge in constructing widely accessible high bandwidth networks is the development of use cases confirming widespread demand across scientific, educational, and other groups, including the creative arts. This paper considers the limitations of existing network technologies for distributed theatrical performance in the creative arts and for symmetrical real time interaction in online learning environments. It proposes a solution to latency and other network problems experienced by these sectors, building on the Multicast protocol Access Grid, an environment supported by National Research and Education Networks. A case study is presented to demonstrate why it is essential to promote innovation in both hardware and software in a multidisciplinary environment. It highlights the need for technical advances as well as cultural and organizational change to meet a variety of user requirements. We argue that a platform is needed that better responds to user needs, offers high quality image and sound, interacts with other network platforms, allows maximum user control of all dimensions of a multipoint transmission, and is, in and of itself, a creative tool. By combining multicasting technology with open, creative programming tools, the innovative system could offer tailor-made templates for specific uses that would themselves be open-ended and modifiable.

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. This requires investment. Although the creative arts and education sectors have the potential to boost demand for 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 high bandwidth networks is an ineffective way of stimulating demand.

In this paper we discuss an ongoing initiative to encourage innovative use of 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 which includes software tools that respond to the needs of the creative arts and education sectors. We also discuss a case study of an initiative that aims to achieve a relatively modest innovation in the technical domain and to emphasize the importance of multidisciplinary collaboration to enable users in all sectors to develop applications employing high bandwidth networks with substantial social and economic value.

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In section 2 we highlight efforts to develop applications in the creative arts (artistic performance) and education (online higher education) using access to 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. A case study is discussed in section 4 profiling the efforts of MARCEL (Multimedia Art Research Centres and Electronic Laboratories). This network which has championed the development of multicasting and the crucial need for multidisciplinary research to demonstrate the benefits of enhanced use of high bandwidth networks in the creative arts and education sectors. In the conclusion (section 5), we indicate why investment in this area would be responsive to the goals of the European Digital Agenda and, more 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 (http://tinyurl.com/mlebfde). In the United States, the academic network, Internet 2 Arts and Humanities initiative supports collaborative live performances and master classes for its members, providing relatively low latency audio and videoconferencing for real-time, simultaneous, performances across distances (http://tinyurl.com/qxacshh). Other examples might be given, but it is noteworthy that the majority of existing projects rely on high bandwidth networks provided by public funding for scientific uses. There are many organizations in Europe and North America with mandates focusing on digital artworks with the aim of creating content of social and cultural value 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). Castells, sociologist of digital innovation, comments that 'the openness of the web truly democratizes art, at last' [1, p. 199]. Unfortunately, the existing configuration of high bandwidth networks and the limitations of software applications, combined with the need for learning and experimentation to foster the capabilities for performing in a globally distributed online space, are limiting what can be achieved by those with the imagination to envisage the full potential of these virtual spaces.

In the education sector, similarly, there is no lack of vision of the potential of 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 [2]. MOOCs (Massive Open Online Courses) are attracting a global student population in both the United States and Europe and progress has been made in using available academic high bandwidth networks to support synchronous distant education. Some of these initiatives are providing improved access for learners, but they are also struggling 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 [2]. 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, 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 [3]. Providing this kind of online space remains a challenge. If a lecturer needs to interact with students in real time, the video quality must meet a high quality standard, the interaction space itself must be able to offer fine resolution sufficient for the lecturer to gauge how explanations are being received, and visual feedback requires higher quality streaming than is generally available. The technical limitations of current technologies are also acknowledged by scientists. For example, CERN (The European Organization for Nuclear Research) collaborations involve thousands of individuals around the world who 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 as satisfying its requirements for a high standard of real time presence.

In summary, in both 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 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 high bandwidth networks, ultimately beyond the scientific research sector.

3. Multicasting as an Innovative Solution

Internet Protocol (IP) Multicasting offers a means of achieving the quality standards desired by producers of content in the creative arts and higher education. This is especially so because it provides a way of moving towards symmetrical online connections supporting performances and virtual learning. Multicast is a protocol that allows for optimal routing of traffic across the high bandwidth network because it minimizing the network resources used by each online participant. This results in more reliable connections among very large numbers of people with reduced delay and using less bandwidth. 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 for other purposes.

It is, however, supported by academic institutions through National Research and Education Networks. In the 1990s, Access Grid was developed to create a network of gateways with multicast connectivity. This 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 'Grid'. It offers an alternative to web-based virtual reality environments. With universities in the United States and the United Kingdom, Future Lab designed an online videoconferencing application that enables collaborative work in real-time over large distances [4]. JANET in the United Kingdom and Internet 2 in the United States have deployed it, 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 traffic is sent to a multicast address that all participants 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, there is a need for convincing use cases to stimulate investment. Multicasting allows many people to participate in a distributed performance or other form 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. 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 between participants.

Access Grid's developers expected that it would decline in cost as its use increased. They expected that it would become ubiquitous as a means of 'coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations' [5, p.2]. In parallel during the same period, many commercial videoconferencing solutions have been brought to market. These continue to be regarded as being technically limited and, with the exception of very large organizations in the private and scientific sectors, they are beyond the means of many institutions. Furthermore, they do not reach into the homes of citizens who could benefit from cultural productions and students seeking access to learning. In contrast, Access Grid's supporting software tools are open source offering a basis for sharing and modification. While 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' [6, p. 199], 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 yet meet the quality standards that are being demanded for real time interactions. In its existing form, Access Grid does not provide the transmission quality or applications required for managing distributed online theatrical performances or higher education teaching. In both cases, the problem of 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, clearly unsuitable to live performance and for intensive teacher-student interactions. 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 they do not provide the audio and video quality suitable

for the audience of a live performance. Universities are equipped with the bandwidth, dedicated network and facilities to develop platforms for flexible, simultaneous interaction, but they do not have the staff with capabilities to work as production houses for next generation truly interactive learning environments.

Additionally, the multicasting solution is available for use with academic collaborators. This limits the experimentation that would result in use cases that could drive investment. To contribute to stimulating demand for next generation high bandwidth networks, it is essential for artistic and educational groups to be able to play, tinker, and experiment on a large scale. Technical innovations in the multicast platform and software applications would benefit collaborative cross-disciplinary projects, but such advances are not the only requirement. Taking the next steps requires changes in cultures of creative production and educational practice as well. This, in turn, requires multidisciplinary collaboration which is always 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 – a case study

MARCEL - Multimedia Art Research Centres and Electronic Laboratories - has some 300 member organizations including universities and creative arts organizations in Europe, North America and elsewhere. It has been trying to mobilize investment in multidisciplinary innovation and learning to make better use of high bandwidth networks for artistic and educational purposes. Its International Coordinator, Don Foresta, has been working 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 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 organizations with technical support, maintenance, resources, networks' [7, p. 228].

Foresta realized early on that when artists and educationalists seek new ways of engaging with digital networks the way they plan and execute their work often changes. These changes may challenge deeply rooted cultural and organizational conventions about how art or educational courses 'should' be produced [8. 9]. Some artists and educationalists become leaders and others followers as they learn how to appropriate novel virtual spaces. Participants need to gain experience of collaborating across disciplinary and practice divides. They need to tinker. They need to rethink how to express creative works and educational content in novel and often unfamiliar ways. Foresta's MARCEL network participants consistently emphasized that access to 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 enable a growing presence of artistic experimentation. Funding was needed to support technical developments, but also to support the coordination of many actors across physical distance and to ensure that all actors would be able to negotiate their integration into a multicasting environment [8]. Many attempts were made to stimulate interest. Considerable interest was expressed among potential users, but the significant funding that is needed to support experimentation did not follow. Occasional projects backed by universities and some private sector funding were not big enough or sustained over time to demonstrate the full potential of multicasting. The reasons included the perception that neither the creative arts nor the educational sector need an alternative to currently available proprietary platforms, that demand is insubstantial, and that multicasting is not required because web-based virtual environments and commercial videoconferencing already achieve sufficiently high quality standards.

MARCEL's efforts persisted and by 2014 a consortium was 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 and software and network engineering communities, higher education institutions (science and social science), and the performance and exhibition arts; communities that typically do not collaborate. All the participants were committed to overcoming barriers to the full exploitation of the e-infrastructure as an educational and cultural space. The aim was to experiment using real-time educational and artistic events, engaging with peers, and, ultimately, once demand could be demonstrated, the public. Multicasting was to be integrated within Europe's e-infrastructure to enable the best of human endeavour in a way that was responsive to society's cultural needs and would empower researchers to respond to societal challenges in the digital era.

At this time the European network GÉANT had become available to provide an infrastructure for scientific research collaboration, offering high bandwidth and a high-capacity 50,000 km network connecting National Research and Education Networks across Europe. The availability of this network for research offered the basis for promoting a significant leap forward in digital, truly interactive, online experiences. Through applied research, technology development, and validation of pilot projects, the consortium would be well placed to show the technical feasibility of addressing quality issues and provide a platform for multidisciplinary learning and GÉANT supported 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 would be designed as open source applications that could be modified as bespoke modules depending on a user's specific needs. A substantial number of use cases would emerge to demonstrate demand and stimulate investment, creating a virtuous circle of supply-demand interaction. Access Grid would provide the multicasting platform and a programming language, PureData, would be used 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 and a network of 2,000 developers with 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 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 and flexible platform would give users the possibility to adjust it to their specific needs. The creation of virtual environments would also demonstrate the functionality and capacity of the platform, inspiring innovative applications of high bandwidth networks. Additionally, there was a plan to develop a mobile app for using the 4G network to access to platform from standard (current and future) mobile devices, thereby broadening the potential user base. To enhance the attractiveness of these developments to smaller private sector firms, the consortium planned to devise a tailored license for industry which would pay a license fee, resulting in a mixed open source/commercial business model. This would contribute to advancing sustainable models for content ownership, rights and compensation for artists and scholars by addressing legal and economic issues and conflicts.

Crucial to this initiative would be capacity building in a multidisciplinary environment. Not only would user needs require identification but the platform environment would need to enable a variety of non-technical participants to learn how to devise new content production practices. Experimentation with high bandwidth networks has been shown to fail because of the limitations of available tools, limited access, the 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 the MARCEL network, social scientists with experience of socio-technical development and an understanding of the need for inclusivity had been involved from the earliest days of the network, as were creative artists and university lecturers. Coordinator, Foresta worked with all members of the new consortium to support them in formulating pilot projects, building trust among all the participants at each stage of the Horizon 2020 bid preparation process.

Pilot projects emerged from both the creative arts and higher education participants. In the creative arts, theatrical performances are arguably the most demanding uses of distributed networking activities. One pilot project was to analyse the requirements of real-life theatrical performance using workshops 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, audio and video resolution, would be crucial. So too would be the need to examine 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. Learning and experimentation would involve working closely with production, performance and technical experts on the structure and content, the use of external performers and more. Facilitators for simulations between three rooms on one site, later tested on the multicast platform itself, plus rehearsals using new or existing texts, and innovating performance practices, were just some of the issues that would need to be tackled. Many of these would require dramaturgical and organizational solutions, in some instances, even the re-conception of performance and integration with existing conventions and practices. All this falls within the social and cultural domains of innovative learning. Only by coupling this learning dimension with the technical

innovations would the MARCEL project have a chance of succeeding. Success would yield use cases demonstrating strong potential demand for investment in the multicasting environment that would become accessible to a wide range of users.

In the case of the higher education sector, one proposed pilot would implement the multicasting platform to support international components 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 would support a semester-long seminar course on cinema and interactivity at a leading university in France that is dedicated to building the digital literacies and capabilities of students interested in the creative arts. Yet another pilot would develop a course on anti-matter linking science and educational institutions in Western and Eastern Europe. For the higher education institutions, the incentive to participate was partly a reflection of pressures to develop online and distance learning models for vocational and higher education that support improved interactivity between learners and teachers so as to enhance learning, especially through 'blended learning' strategies integrating face-to-face and online contact [12]. In the United Kingdom alone it is estimated that in 2011-12, non-EU students generated some £3.5b for the university sector and throughout the European Union there is increasingly strong competition in the overseas student market. Stimulating demand for digital applications in this area was expected to underpin cost-effective delivery methods.

Technical and sector-oriented pilots would not be sufficient to facilitate multidisciplinary learning. In addition, it would be necessary to closely follow the experiences of both the participants and their innovative uses of the objects – network hardware and software application. Social scientists with expertise in studying socio-technical developments in digital technologies would be needed to analyse existing work and to examine the processes through which the subjects (persons) and the objects (multicast platform) would engage with each other over the life of the initiative. Social science research would attend to how decision-making can be structured and organized to enable inclusive participation. It would attend to processes of learning among participants with diverse disciplinary expertise.

This research would involve a mixed-method approach using qualitative and quantitative approaches. The former would involve the use of off and online methods including participant observation and interviews with participants and relevant others (e.g. artists, computer scientists, software and hardware developers). The multicast platform would be used for observing the innovation process in real time, with researchers following all the activities. Discourse analysis and visual analysis would be used to examine communication among the participants and the emergence of new conventions of practices. This approach is atypical of many e-infrastructure projects. Quantitative methods using computational tools for 'big data' analysis would enable data to be collected and analysed relating to all elements of the performances and educational offerings using the new virtual space. A common spatial and temporal frame would be used to ensure data compatibility for statistical testing of relationships between events, movements and interactions in the virtual space and of how emotions and responses of participants (learners or audiences) are influenced by online performance and interactive online courses. Crucial to the success of this methodology would be continuous reporting of the results and interactions with all members of the consortium. Learning thrives best in an environment where misunderstandings of terminology, intentions, and imaginaries of how digital spaces might be experienced are discussed and reflected upon by all the participants, reducing tensions and potential conflicts. Timely feedback would encourage an inclusive learning process for those with technical expertise and the performers, choreographers and lecturers.

Although this consortium bid to the European Commission was unsuccessful, MARCEL continues to seek financing. Without funding the consortium partners are unlikely to be able to fulfil their ambitions. It is likely, paradoxically, that this consortium was perceived as being too innovative, too multidisciplinary, and perhaps even threatening to the interests of developers of technologies for videoconferencing and web-based performance in the commercial marketplace. If it had succeeded, however, it would have stimulated demand for traffic on high bandwidth networks which clearly is in the interests of investors in the underlying telecommunication infrastructure. Despite the hybrid open source/commercial business model the MARCEL consortium proposed, commercial-only developers of internet apps that fall short of meeting the aspirations of creative artists and educationalists are resistant to initiatives that risk eroding what they regard as 'their' market domain.

5. Conclusion

Research on the development and use of digital networks has demonstrated time and again that potential users do not lack imaginaries of what could be accomplished to bring the development of high bandwidth

networks into socially and economically rewarding uses that are responsive to demanding quality standards and available to the public [13, 14]. Network developers in the commercial sector are seeking justifications for investment and commercial developers of applications – whether Google, Facebook or Twitter – are innovating. The world's population is increasingly connected. The creative arts and higher education, unfortunately, remain relatively neglected areas of investment aimed at experimentation in the ways depicted here despite their potential to generate network traffic. These sectors are economically productive and they are socially and culturally valued. Multicasting provides a means of enhancing the online experiences for citizens globally, citizens who could experience cultural activities and learn in truly virtual spaces. An improved open multicasting platform would offer new sites for building capabilities and strengthening digital literacies.

E-commerce, gaming and social networking are producing a growing share of network traffic, representing a market of around 3 trillion euro worldwide and more than 10 per cent of the world's GDP is estimated to depend on the information and communication technology sector [15]. Limited multidisciplinary experience and domain specific capabilities in key sectors such as the creative arts and education, combined with weaknesses in basic digital literacies, unaffordable access and a perceived lack of relevance of high bandwidth networks, means that barriers to greater network use in some sectors and regions of the world will persist [16]. To overcome these barriers in Europe the 2020 Strategy and the Digital Agenda set out economic, social and cultural goals. The aim is to strengthen the cultural industries and the learning of new skills and competencies compatible with a very intensely digitally mediated society. In this context the development of diverse robust use cases for high bandwidth investment would be consistent with renewed efforts to meet these goals through innovative projects that emphasize partnerships. Multidisciplinary research consortia offer an approach that can begin to bridge between engineering, computing science, the social sciences, the humanities and practitioners. This would maximize opportunities for dialogue, creative experimentation and learning. Only in this way are we likely to see the full cultural and social benefits of digital technology innovation building on high bandwidth networks alongside economic benefits.

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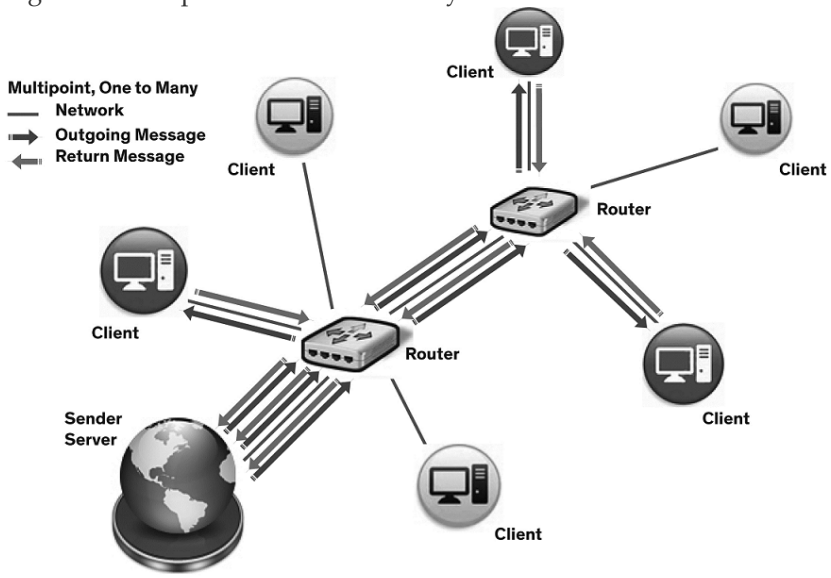
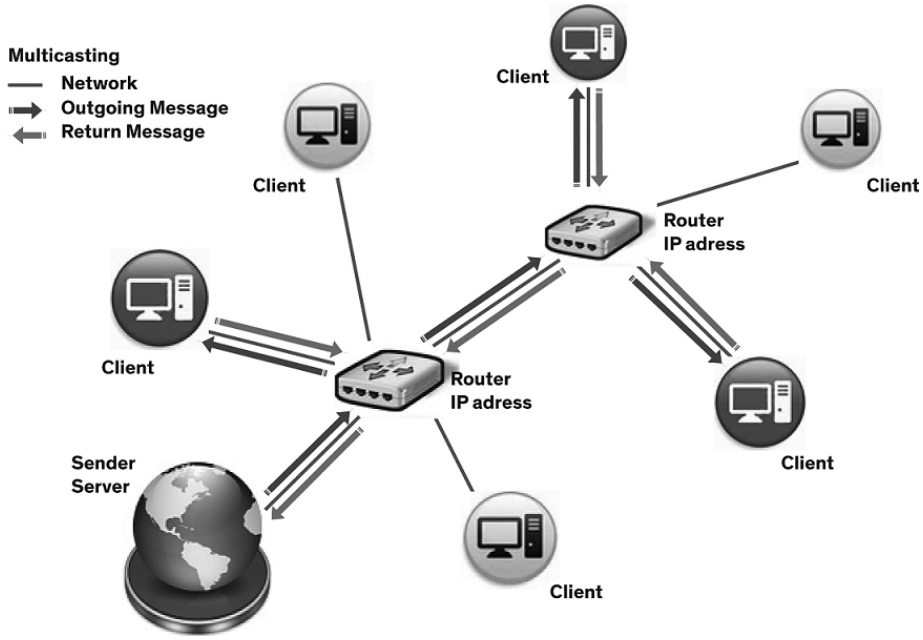
Figure 1: Multipoint and One-to-Many Network



Source: authors

Figure 2: Multicasting Network



Source: authors