

Collaborative Network Organizations: New Technical, Managerial and Social Infrastructures to Capture the Value of Distributed Intelligence

William H. Dutton with the OII-MTI Team¹
Oxford Internet Institute
University of Oxford

Paper prepared for presentation at the EPSRC Workshop on 'Managing for Usability: Challenges and Opportunities for e-Science Project Management', at the Oxford e-Research Centre, University of Oxford, 10-11 April 2008.

Building Value from Distributed Networks for Collaboration: A New Management Challenge

Managers, professionals and experts across most sectors of business and industry are using digital networks not only to search for information, but also to provide information and expertise to networks of their peers stretching well beyond the boundaries of their firm or organization. The Internet, in particular, is increasingly enabling new forms of collaboration, such as in information sharing and problem-solving involving individuals and groups distributed geographically and across the organizational boundaries of firms and public agencies – reconfiguring information and communication flows within and across organizations.

A growing number of researchers view this as illustrating the value of tapping into the 'wisdom of crowds' – the idea that 'the many are smarter than the few' (Surowiecki 2004), where a large number of ordinary people can outperform a few experts by sharing information and solving problems. This has been categorized as 'peer production', 'social production', 'co-production', 'co-creation', 'mass collaboration' and by many other labels (e.g. see Surowiecki 2004; Benkler 2006; Tapscott and Williams 2006).

However, popular metaphors relating to crowds could be misleading. Individuals enabled by networking are choosing to collaborate with one another in groups that are not limited by time or space, and are doing so in ways that benefit the participants who choose to engage in such collaborations. Far from being about 'crowds', the successful initiatives are

¹ This paper is based on 'The Performance of Distributed Problem-Solving Networks' research project, anchored in collaboration between the Oxford Internet Institute and the McKinsey Technology Initiative (see: www.oii.ox.ac.uk/research/project.cfm?id=45). The lead author thanks David Bray, Wolf Richter, Matthijs den Besten, Paul David and the entire OII research team, as well as colleagues within the McKinsey Technology Initiative, particularly James Manyika, Brad Johnson, and Michael Chui. This paper is not intended to convey the consensus view of the project team, but the lead author's synthesis of the team's contributions to the project's exploratory research and collaborative workshops. Finally, the lead author thanks Malcolm Peltu for providing his editorial support on this paper. The project was supported by a grant from McKinsey & Company.

well-managed, distributed networks of individuals.² The challenge is to enable managers and professionals within more traditional firms and other place-based or virtual entities to capture the potential value of these new forms of collaboration.

This paper provides a synthesis of a study by the OII and McKinsey Technology Initiative (MTI) of such recent innovations, which embody widely used Internet, Web and other information and communication technology (ICT) advances. These networks are diffusing as rapidly as the Web, and our investigations identified an emerging new picture of their general importance. This led us to change the way we referred to the innovations we were examining. We moved from our original conception of these being 'Distributed Problem-Solving Networks' to consider the new phenomena as being 'collaborative network organizations' (CNOs). However, while these are new, they are anchored in decades of earlier developments. Our study therefore highlights both their novel characteristics and the roots from which these have grown.

Outline of this Paper

This paper starts with a brief look at historical precedents to the new socio-technical enabled organizational forms we are calling CNOs. It then identifies the critical management issues whose exploration has driven the OII-MTI study before highlighting some main findings on the technical, managerial and social underpinnings of distributed collaboration. Background and analysis is provided on the exploratory case-study based methodology employed. Findings from the study highlighted include a typology of these networks that emerged helped to analyse and understand the factors shaping these collaborative networks and associated phenomena. The paper also outlines the cases studied. It concludes with a summary of the study's perspectives on the critical issues relating to 'managing the wisdom of networked individuals', which we argue is more significant than the notion of the wisdom of crowds.³

Historical Precedents for Collaborative Network Organizations

The emergence of CNOs represent the latest stage in a thread of initiatives stretching back over forty years, which were aimed at using computer-based systems to harness distributed expertise. For example, the development in the 1960s by the RAND Corporation of Delphi techniques in forecasting⁴ sought to reduce the bias of the social dynamics of co-located groups of experts. This often leading influential individuals to steer group outcomes, but the difficulties of soliciting thoughtful responses from experts, and many weak applications of the technique, tended to undermine its perceived value.

² I am using the concept of networked individuals to reflect a correspondence to Barry Wellman's (2001) notion of 'networked individualism', a term he uses to break old dichotomies between the individual and place-based communities.

³ Greater detail and updates on the OII-MTI case studies and findings are available through the project's Website at: <http://www.oii.ox.ac.uk/research/project.cfm?id=45>

⁴ <http://www.iit.edu/~it/delphi.html>

Since the 1960s, significant funding and notoriety has been attracted to the concept of using networks to bring geographically distributed experts together in a short span of time. An example in one of the most prominent of the areas attracting this interest was the pioneering network called the Emergency Management Information System And Reference Index (EMISARI)⁵, which was launched in 1971 by the US Office of Emergency Preparedness. While its implementation, performance, and sustainability fell short of expectations, the concept was clearly ahead of the technology of its time (Hiltz and Turoff 1978).

The potential for computer-based communication networks to enable the sharing of expertise accelerated the drive towards distributed collaboration in the 1970s, such as with computer conferencing systems, group decision-support systems (GDSS), and later initiatives around computer-supported cooperative work (CSCW). Initiatives in GDSS and CSCW evolved out of the diffusion of personal computers across organizations, leading to efforts to develop 'groupware' and other applications to reconnect individuals within and across organizations through networks.⁶

An Evolving Array of Internet-Enabled Success Stories

More recently, the application and diffusion of the Internet has greatly expanded the opportunities for collaborative distributed working and sharing of information and expertise. For instance, 'open source' software developments, where groups collaborate in software production for non-commercial or proprietary reasons, seem to defy conventional wisdom about the incentive structures required for the production of high-quality computer software. This approach has been the basis of a number of open source project successes (e.g. the Linux operating system) as well as failures (e.g. see Weber 2004; Bollier 2007). The collaborative creation of Wikipedia to a level of quality that has been compared with the *Encyclopaedia Britannica* provides another illustration of the potential of non-proprietary co-production of a new product.⁷

Likewise, the track record of 'prediction markets' (sometimes called 'information markets') has generated increasing confidence across a growing number of domains, from forecasting election outcomes to Oscar nominees (Croxson and Bray 2008). Also, the explosion of social networking through so-called 'Web 2.0'⁸ applications has generated a wide range of proposals for employing 'user-generated content' (UGC) and greater collaboration in a number of sectors, from social networking to corporate communication and scientific research.

⁵ For a background on EMISARI, see: http://www.livinginternet.com/r/ri_emisari.htm and Hiltz and Turoff (1978).

⁶ An excellent overview of groupware and other early collaborative tools is provided by Johansen (1988).

⁷ Giles (2005) at: <http://www.nature.com/nature/journal/v438/n7070/full/438900a.html>

⁸ The term Web 2.0 remains a subject of debate, but is generally used to refer to Web applications that exploit user-generated content to 'harness collective intelligence' (O'Reilly 2005). See: <http://www.oreilly.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html?page=1>

Some suggest that these developments make hoarding information for personal or organizational advantages old-fashioned, to be replaced by a new rule of thumb: to 'share information to the maximum'. Is this a naïve view that will undermine the competitive position of firms, and the individuals within them? Or a promising new approach to solving problems that will enhance the performance of managers and professionals and their firms?

This paper presents one synthesis of the results of our set of exploratory case studies of Internet-enabled distributed networks. These were conducted to empirically ground debate over the performance of CNOs and the motivations supporting participation in these networks of distributed co-production.

A Key Management Challenge: Understanding the Value of CNOs

The importance of collaborative network organizations means managers will have a growing need to understand the reasons for the success of new, largely Internet-enabled forms of distributed collaboration. These have been the focus of a wide range of researchers in management, economics, and Internet studies. Box 1 summarizes how researchers have sought to explain the value and potential of CNOs.

Box 1: The Potential for Collaborative Network Organizations

Collaborative networks could enable the many to outperform the few by:

- superiority of statistical averaging of individual judgements, when the individuals have no prejudice and a greater than even (.5) probability of being correct – the Jury Theorem (Condorcet [1785]);
- bringing the attention of more people – 'eyeballs' – to the problem;
- aggregating information, intelligence, that is geographically distributed
- enhancing diversity: bringing together more heterogeneous viewpoints, perspectives, and approaches (Page 2007);
- simultaneous review rather than sequential processing, enabling more rapid diffusion of questions and answers;
- avoidance of small group processes, such as 'groupthink' (Sunstein 2006); and
- greater independence of, and less control by, established institutions (Dutton 2007).

Adapted from: Austen-Smith and Banks (1996), Surowiecki (2004), Benkler (2006), Sunstein (2006), Page (2007), Dutton (2007).

On the other hand, many practical initiatives aimed at capturing the value of distributed collaboration have failed, including many efforts to produce open source software code or generate collaborative documents, such as via an

organizational wiki⁹. Difficulties in establishing and maintaining co-production networks pose formidable challenges for managers and professionals who seek to harness this potential for themselves, and for their own firm or organization. These difficulties mean the success of such new approaches is far from inevitable.

Key Issues Highlighted by the Case Studies

The effective development and use of CNOs is likely to remain an exception rather than the rule until both researchers and practitioners identify and manage a set of critical issues that set these networks apart from information systems in formal organizations. These issues centre on questions such as:

- How do the new approaches to co-creation or co-production heralded by CNOs measure up to the performance of more traditional approaches for creation or production? Even when these innovations work exceptionally well, are they superior to other approaches?
- Who captures the value of these new forms collaboration of information sharing – individuals, firms, or providers of CNO platforms? And how do these new forms shift traditional balances of power, influence, and authority?
- What are the technical, managerial, and social underpinnings of these initiatives, such as the motivations of individuals who participate?

To address such questions, the OII-MTI study team conducted a set of case studies in fields ranging from high-energy physics, biomedical sciences, and pharmaceuticals – to IT software, publishing, entertainment, and e-mail use. Some of the most significant issues that emerged from these case studies are summarized in the following sections. The key effort involved in grouping the cases into categories that could create a useful analytical framework is discussed later.

Reconfiguring Access

The potential of CNOs to create new socio-technical organization forms over networks stems from the role that the Internet and related ICTs can play in ‘reconfiguring access’¹⁰ – to people, information, services, and other resources. The Internet, for example, can reconfigure access in two fundamental ways.

First, it can change the way we do things, such as how we get information, how we communicate with people, and how we obtain services and access technologies. Secondly, and perhaps more fundamentally, the use of the Internet can alter the outcomes of these activities. It changes what we know, whom we know, and with whom we keep in close touch. We are also using

⁹ Lee Lefever has produced a short video to describe ‘Wikis in Plain English’, arguing that the idea of a wiki is hard to explain – but easy to show (see: <http://www.commoncraft.com/video-wikis-plain-english>) .

¹⁰ This concept is developed in Dutton (1999b), and Dutton (2005). It is reinforced by other syntheses of the role of ICTs, such as Cukier (2006).

the Internet to change what services we obtain, what technologies we use, and what know-how we require to use them.

ICTs – from the printed book to the Web – reconfigure access by changing cost structures, by expanding or contracting the geography of access¹¹, and by eliminating or introducing new gatekeepers. New information technologies can reconfigure access by giving greater or lesser control to users, viewers or readers.¹²

The Wisdom of Managing Access over Collaborative Networks

One of the most interesting overall findings from the OII-MTI research questions the notion that the cases we studied were tapping ‘the wisdom of crowds’. Instead, the wisdom of these networks lay primarily in the intelligence behind the management of these collective networks, with the contributions of individuals and expertise channelled towards either predetermined specific goals or wider meta-goals. A variety of network management levers that can yield more useful outcomes were identified. These include, as discussed below, the CNO’s architecture design, its degree of openness, the controls employed, and the approaches to the management and modularization of tasks. This indicates that the types of management issues raised by these studies need to be addressed by individuals and their organizations if collaborative network innovations are to fully capture their potential value.

Top-Down Goals and Bottom-Up Choices of Participants

While the diversity of the cases was in itself of significance as an indication of the range of networks being developed and used, so were a number of commonalities which characterize CNOs. For instance, the decision to join these highly adaptable networks is generally not a top-down process, with individuals tending to have the key choice, often against their organization’s stated policy and without their colleagues explicit approval, knowledge, or direction. Just as informal networks within an organization are often quite different from the formal organizational chart, so distributed collaboration networks are often dramatically different from the boundaries of the firm or organization. Most often, they network individuals across multiple organizations, and change over time. This contributes to a move away from static networks within, or defined by, the lines of formal organizations. Instead, there is a tendency towards CNOs as emergent networks of peers (defined broadly as including a wide range of individuals, from those who write code in the case of open software to physicians in the case of medical practice).

Networks and Organizations

¹¹ This does not make geography irrelevant. To the contrary, it makes geography more important as the Internet could enable you to be where you need to be in order to have face-to-face communication, say by enabling you to be at this EPSRC workshop because you can stay within the electronic reach of colleagues or family members.

¹² Dutton (1999b; 2005).

Organizations seek to define networks through such devices as organizational charts and management structures. The Internet is a network of networks that enables organizations and individuals to reconfigure the links between information and individuals across time and space. For these reasons, the concept of ‘network organization’ is useful because of it helps distinguish this organizational form from more placed-based or formal organizations. It could be argued that all networks are organizations.¹³ However, the concept of a collaborative network organization is used here to distinguish the degree to which these are dynamic and, most often, inter-organizational configurations of individuals – as opposed to more institutionalized organizational entities, such as a firm or agency. This does not exclude the potential for CNOs to be created by formal organizations, such as a firm, whether real or virtual. However, in such instances the networking of individuals achieved is likely to vary significantly from the formal organization.

Who Captures the Benefits?

There is a complex distribution of costs and benefits involved in CNO development and use. As individuals join and choose to contribute to various distributed problem-solving networks, they could perceive some benefit in two main ways: by gaining some reduction in their costs through participation; or from their act of participation, even in something as intangible as entertaining themselves or boosting their reputation. While the benefits of participating can accrue to individuals or the providers of platforms, additional costs can be borne by their formal organizations. Moreover, CNOs may either introduce fundamentally new participation benefits or reduced costs, or alter how individuals assess these benefits and costs. Successful CNOs seem to encourage a strong sense of group identity (Bray et al. 2008a).

Measuring Performance in Producing Intangible Digital Goods and Services

Geographically-dispersed teams that use CNOs tend to work and interact asynchronously on ‘intangible’ informational goods and services. Table 1 lists some of the performance and evaluation indicators cited in different cases, which can be difficult to formulate because of the products’ intangible nature. The diversity of types of distributed problem-solving networks, identified also means different performance criteria need to be developed for different types of CNO.

Table 1. A Multiplicity of Intangible Performance Indicators

Performance being monitored	Illustrative alternative outcomes
Susceptibility to threats, error or related risks	Trusted outcomes or evidence of the gaming of systems, susceptibility to preconceived, prejudiced views, openness to mob rule

¹³ Paul David (2007b: 1-2) provides a useful discussion the distinctions among these terms, but prefers to use the concept of ‘network organization’ in the way I am using the concept of network. I use network to signify the break from formal organizations.

Speed	Faster, or hastier with less speed
Quality of information	Improving accuracy, or dumbing down
Information sharing, transfer	Enabling pieces of an information puzzle to be put together in ways that reveal patterns or foster new insights, or overload and distract participants
Control over Information	Security or loss of sensitive or proprietary information (Croxon and Bray 2008)
Agenda-Setting	Responding to set agenda or reshaping what users/the public focus on, and what shapes their attention (Bray et al. 2008b)
Independence from company, organizational, institutional bias	More independent and disinterested information or less relevant work, undermining organizational goals, and objectives

The Exploratory Case Studies

Preparing for the Case Studies

To answer questions raised about CNOs, we started by examining approaches to assessing the performance of existing networks. We accomplished this by bringing together a multidisciplinary team of practitioners and academics, ranging from students of communication and computer science to economics and management.¹⁴ The team itself became a distributed problem-solving group of 15 academics spanning three continents.

During the six months of this exploratory project, we moved beyond a review of existing literature to focus on investigating a variety of empirical studies of a selected set of real cases that employed different forms of distributed problem-solving networks. A series of collaborative workshops, with our partners from industry, examined cases with the aim of moving beyond the description of new approaches to problem-solving towards understanding of the major factors affecting CNO performance. Devising approaches to evaluate their comparative effectiveness was also an important activity.

Each case was chosen to provide original insights on different types of network. Another criterion was our ability to gain access to these networks for more in-depth analysis. We began by identifying projects that have become identified with peer-produced, distributed problem-solving, such as open source and Wikipedia. The aim was to bring new approaches to the study of each case. We then sought wholly novel cases that employed different approaches in a variety of areas of application, from scientific collaboration to film production.

¹⁴ More information about this OII project is available at: <http://www.oii.ox.ac.uk/research/project.cfm?id=45>

The Selected Cases

The research team focused on 8 CNO cases (Box 2). Each was chosen to represent a different type of network or organization for distributed problem-solving. For each study, we sought to develop an overview of developments around distributed problem-solving that was tied to the specific area in which the case is embedded, while also focusing on the specific case in order to understand possible indicators and determinants of performance outcomes. In the film production case, for example, we scanned the horizon for an overview of distributed co-creation in global media and entertainment industries, but focused on one specific example that we could explore in-depth – the Swarm of Angels (Cassarino and Geuna 2008).

Box 2. The Project Case Studies

- Sermo – a community-based knowledge ecosystem for licensed physicians in the USA;
- Seriosity – a creative use of multi-player gaming and virtual currency to regulate the use of e-mail in organizations;
- Distributed News Aggregators – such as Digg News;
- Information Markets – the dynamics and performance of prediction markets;
- CERN's ATLAS project – an e-Science collaboration;
- Bug-Patching for Mozilla's Firefox – Bugzilla;
- Wikipedia – case studies of efforts to simplify the text of selected entries;
- A Swarm of Angels – distributed film production

The OII-MTI project adopted a variety of approaches to the case studies undertaken. For example, some were focused on a single platform, such as Sermo or Seriosity, while others defined the case as a type of platform, such as news aggregation or prediction markets. All remain case studies in progress.¹⁵

Broadening the Study's Base

The scope of this project was widened by incorporating insights from additional cases, not all of which we studied directly. Two colleagues had studied the role of Bugzilla, a shared database for tracking software defects and managing repairs. Their understanding of how this shared, viewable database was used to triage, allocate resources, and otherwise manage the repair of defects (bugs) for Firefox and other Mozilla open source projects fed into our discussion of problem-solving networks (Dalle et al. 2008).

Our cases did not include an example of 'broadcast search', which has been a mainstay of collaborative networks, typified by the common question: Does

¹⁵ Working papers at varying stages of completion are posted on the project Website at: <http://www.oii.ox.ac.uk/research/project.cfm?id=45>

anybody know someone or something? This led us to rely on published work on a particularly well-examined case of broadcast search – ‘Innocentive’ (Lahkani 2008). Another was the move to enhancing the Web as a resource for linkage and search by shifting from a focus on the linkage of documents to one emphasizing the semantic data and text embedded within documents or databases. We incorporated this innovation supporting deep search by working with published material on ‘NeuroCommons’.¹⁶

Classifying types of Collaborative Networks

While each case was incorporated for its representation of a unique set of projects, we also sought to use the studies to group the cases within a more general typology. First, however, we needed to explore classification approaches.

An Initial Broad Categorization

Early scanning of projects led to an early broad categorization into two types.¹⁷ One category focused on projects that linked individuals within an existing community or organization using Internet-enabled applications to solve particularly complex and novel problems, such as addressing the ‘bugs’ in software (Dalle et al. 2008). The second type focused on problems that were pre-structured by Internet platforms that enabled new inter-organizational networks to generate or mine insights gathered from the interaction of distributed actors, such as licensed physicians on Sermo (Bray et al. 2008a).

There are other useful classifications that also focused on the nature of the problem being addressed. For example, Scott Page (2008) identifies three types of problem-solving networks: those focused on ‘information aggregation’, such as with wikis, ‘prediction model aggregation’, and ‘problem-solving’. However, the case studies underscored the degree to which any categorization system based on the function of bringing together a distributed group of people would over-simplify and restrict the goals and objectives of the actors. As discussed below, the case studies of what we originally called distributed problem-solving networks reveal multiple goals and objectives behind the often complex ecology of actors shaping their design and use. The OII-MTI case studies underlined the many different problems that are addressed by each network – some simple, others complex – making it difficult to group the cases by any specific category of problem.

However, it was clear that the choice of networks was not rationally driven by solving a pre-defined problem. Often, the networks became solution spaces, looking for emergent problems to solve. In contrast to rational problem-solving models, we more often saw ‘solutions’ using network approaches looking for

¹⁶ John Wilbanks, Executive Director of Science Commons, and key to the development of NeuroCommons, was able to participate in our final project forum on 14 December 2007 and discuss its use and impact.

¹⁷ The definition and rationale for this early classification is provided and elaborated by David (2007a; 2007b).

problems to solve. This is similar to Cohen, March and Olsen's (1972) 'garbage can' model of organizational decision-making, in which people in organizations have solutions looking for problems to which they can be applied, such as outsourcing a problem.

Moving away from an attempt to characterize the underlying purpose of complex sets of technologies and activities, it might be more useful to identify the types of ICT that underpin the potential of these networks being applied to problem-solving. This categorization was also complicated by the degree to which each network exhibited multiple and overlapping design features, and that many designs could be applied across a wide array of industries. Across and within each of the cases, the platforms provided a wide range of design options. They varied across a number of important dimensions, each of which enables the creators of distributed problem-solving platforms to tailor networks for specific communities and problems.

However, it was clear from the cases that the most central design features of each were aimed at reconfiguring who communicated what, to whom, and when within the network. These are not crowds, but regulated interactions among networked individuals – regulated in part through the architecture of the network. Moreover, it was clear that in most of these networks it was a small minority of 'core participants' who represented a majority of the contributions made within the network (Bray et al. 2008a; Richter et al. 2008). It is therefore more reliable to characterize these networks by the activities they support rather than the purposes they serve. That is why this paper refers to them as 'collaborative network organizations', instead of our original view that they should be conceived of as 'distributed problem-solving networks'.

CNO Architectures: A Classification Framework

One of the primary design features of a CNO is its architecture. From this basis, our case studies surfaced a technologically and socially relevant typology that is simple but analytically powerful. Our categorization system is close to the evolving nomenclature surrounding different generations of Web technologies, specifically the so-called Web 1.0, 2.0 and 3.0. These typological terms have been used to characterize the exploitation of different capabilities of the Internet.

Definitions of these terms vary widely but we found three main characteristics in their use of Internet technologies that were most valuable for our studies: Web 1.0 – sharing hypertext documents and other digital objects; Web 2.0 – deploying social networking tools to support collaboration and generate user-content; and Web 3.0 – applying collaborative software to support cooperative co-creation (Hofkirchner et al. 2007).

From these definitions we were able to identify three types of CNO, which focus on supporting collaboration through:

- 1.0. *Sharing*: The ability to create linked documents and objects within a distributed network, thereby reconfiguring how and what information is shared with whom. This is exemplified by Tim Berners-Lee's inventing the Web to share documents at CERN. This has been moved forward by his later articulation of the idea of a 'semantic Web' to support more intelligent search, linkage and retrieval of information.¹⁸
- 2.0. *Contributing*: The ability to employ social networking applications of the Web to facilitate group communication, thereby reshaping who contributes information to the collective group.
- 3.0. *Co-creating*: The ability to collaborate through networks that facilitate cooperative work toward shared goals (e.g. joint writing and editing of Wikipedia), thereby reconfiguring the sequencing, composition, and role of contributors.

Table 2 illustrates the key features of different types of collaboration networks. This table suggests that networks enabling user-generated content also exploit the hypertext linkages so valuable in finding and sharing documents. Likewise, cooperative joint collaboration, enabled by collaboration 3.0, exploits the potential for user-generated content, and hypertext links, but also focuses on the collaborative production of documents or other information products. While CNOs are often regarded as being peer produced (Benkler 2006), it is worth noting that they are seldom anchored in peer-to-peer networks. Many Web 1.0 applications are one-to-a-few or one-to-many and are oriented to broadcasting or narrowcasting information. However, these applications do not incorporate user interaction as a central component of their operation.

Table 2. Communication Network Features that Support Collaboration

Collaboration	Hypertextual	User-Generated	Cooperative Work
3.0. Co-creating			
2.0 Contributing			
1.0 Sharing			

The Range of CNO Types Encompassed by the Case Studies

Networks for orchestrating distributed intelligence tend to focus on one of these fundamental strategies for reconfiguring access. However, while networks are key enablers, they do not determine the process or outcomes of distributed collaboration. These are shaped also by management strategies and the decisions and choices of users.

We chose our cases carefully to reflect a unique class of similar projects as well as covering a wide spectrum of types according to the classification dimension in Table 1. For instance, we looked at 'Simple Wikipedia' to reflect a wide range of wiki projects (Table 3).

¹⁸ An excellent overview of the semantic Web has been provided by Yorick Wilks (2006), available at: <http://www.oii.ox.ac.uk/research/publications/RR12.pdf>

Table 3. Types of Distributed Collaborative Networks.

Type	Case	Focus
1.0 Sharing	Atlas – joint creation of a blueprint for a high energy physics (HEP) experiment	Internet and Web-based documents supporting collaboration among 1900 physicists in 37 countries
	Shared, viewable database for coordinating distributed collaboration (e.g., Bugzilla)	Database for tracking software defects (bugs) and managing repairs (bugs) for Firefox and other Mozilla open source projects
	Broadcast Search (e.g. Who knows?; InnoCentive), networking problem holders and solvers through awards, prizes, and other incentives	Solution ‘seekers’ post problems and rewards challenging network of ‘solvers’ through ‘broadcast search’ processes
	Deep search, enabling data, not only documents, to be linked and searched (e.g. Neurocommons)	Text mining and natural language processing of open abstracts and datasets
2.0 Contributing	Digg and related news aggregation projects	News aggregator finds, rates, and prioritizes news available online
	Sermo	Enabling licensed physicians to share information with one another and sponsoring organizations
	Prediction (Information) Markets	Aggregating judgements to predict public and private events
	Seriosity	Use of massive multiplayer online game (MMOG) features to help prioritize and manage e-mail
3.0 Co-creating	Atlas shared data centres	Sharing hardware and software services through CERN’s Grid of shared computing services
	Firefox, an open source Internet browser	Prioritization of features to produce a more user friendly version of the Mozilla open-source development of the Netscape Mosaic browser
	Wikipedia, an open content encyclopaedia	Writing, simplifying complex text entries
	A Swarm of Angels – Brighton-based experiment with open creator-led film production	Collaborative authorship, development of characters, plot and script, and remixing of footage and music

The Cases Classified by Collaboration Typology

Our typology illustrated in Tables 2 and 3 can be concretely understood by a brief outline of each of our case studies, showing how these features of the collaboration networks are utilized. Each case is discussed within the context of the classification we have used to define its central architecture.

Collaboration 1.0 Cases: Hypertextually Shared Documents, Data and Objects

1. Designing and Managing the Atlas Project

Much scientific collaboration is increasingly distributed, but we chose to focus on an extreme case of collaboration with Atlas¹⁹: a project launched in 1992 that engages nearly 2,000 scientists in the design of a large-scale high-energy physics (HEP) detector facility (Tuertscher 2008). Scientists travel to CERN frequently for face-to-face meetings, but core aspects of distributed collaboration have been managed for over a decade through the use of e-mail, attachments, listservs, and shared Web-based documents among 165 working groups distributed across the world. CERN was where the World Wide Web was invented, and this platform has become a central infrastructure for sharing documents among its distributed teams of scientists. That said, there are other major applications of advanced Internet technologies, primarily the CERN Grid, that are designed to support shared computing facilities for Atlas researchers to analyze the huge quantities of data generated as part of their HEP experiments, which are more characteristic of what we have called Collaboration 3.0.²⁰

2. Managing the Repair of Software Bugs through Bugzilla

A study of Bugzilla²¹ enabled the project to look at open source software development. In particular, we focused on the performance of Bugzilla in supporting the identification and management of the repair of software bugs in Firefox, one of the principle software projects within Mozilla, which represents a collection of open source software projects (Dalle et al. 2008). At the core of Bugzilla is a shared database that enables the tracking of software defects, and the management of repairs. Our case focused on the use of Bugzilla for triage and management of the repairing of defects in Firefox. However, the value of Bugzilla was anchored in a shared document system. The database helped to coordinate the work of a distributed array of individuals who wished to contribute to the software by either notifying Mozilla of the defects, or contributing to their repair.

3. Competing for Prizes and Generating User's Solutions on InnoCentive

Some platforms offer a prize as an incentive for individuals or groups to solve problems, which is a way of linking problem-holders and problem-solvers.

¹⁹ <http://atlas.ch/>

²⁰ For example, see: <http://www.usatlas.bnl.gov/computing/grid/#gs>

²¹ <http://www.mozilla.org/bugs/>

InnoCentive²² is one of the more successful of such networks. It matches researchers (called the ‘problem-solvers’ by platform providers) to companies with problems (the ‘problem-seekers’). We incorporated this as a case because it had been studied by others (Lakhani et al. 2007; Lakhani 2008) and it represented a different approach to incentivizing participation. InnoCentive has been used primarily to broadcast problems as a means to find problem-solvers, which Lakhani calls ‘broadcast search’, rather than as a medium for collaborative work. It also employs the full potential of the Internet to find and match solvers with seekers.

4. Opening Access to a Biomedical Information Commons: NeuroCommons

A priority within the open source movement has been to open to search engines the content of databases, not simply the title of scientific articles. The aim of such efforts is to employ new technologies, such as the semantic Web, to enable scientific access to specific information that might otherwise be invisible on the Web. NeuroCommons²³, which is part of the Science Commons, is one such project in the medical and pharmaceutical area. This is another case incorporated on the basis of its contrast to other cases and the opportunity to work with one of the project’s executives, John Wilbanks. With NeuroCommons, users can access multiple datasets to address a diverse set of problems. In many respects, NeuroCommons represents an evolution towards a semantic Web in which machines will be able to distinguish content based on its meaning in different contexts.

Collaboration 2.0 Cases: Communicating User-Generated Content

5. Aggregating News Content via Digg and other News Platforms

Originating as a study of a site that aggregated the ratings of online news stories, called Digg²⁴, this study evolved into a more comparative survey of news aggregator platforms (Richter et al. 2008). The study emphasizes user-generated and user-contributed content. The value of Digg and many other news aggregator platforms is based on the ratings of stories identified by users of the Internet. The way users rate, tag, recommend, view, and comment on news stories is central to Digg’s performance. Most news aggregation sites are open – although they normally require individuals to register before participating in an active way, such as by rating a story or to provide their own story. Anyone reading a news story on one of many news sites, such as BBC Online, can refer a story to a news aggregator site, such as del.icio.us, Digg, reddit, Facebook, or StumbleUpon. If a reader ‘digg’ a Web story or news posting, it will be listed on Digg. If another user had already dug the story, then the user can ‘digg it’, giving it a positive vote. Stories can also receive negative votes. In such ways, stories are selected, aggregated and rated by users, helping other users to find stories of interest to the larger community of news readers.

²² <http://www.innocentive.com/>

²³ <http://sciencecommons.org/projects/data/background-briefing/>

²⁴ <http://digg.com/about>

6. Sharing Medical Insights, Information, and Opinions via Sermo

Sermo²⁵ is also exemplary of Web 2.0 developments, as it too is anchored in user-generated content. Sermo is a community-based system where licensed physicians in the USA ask questions of one another and post replies (Bray et al. 2008a). Physicians can both answer questions and surveys as well as asking questions and creating survey questions for other doctors. In addition, pharmaceutical firms, insurance companies, government agencies, or other potential problem-holders can pay to see the answers to questions. Third-parties can also post questions for the physicians within the Sermo community to answer. Physicians remain anonymous, but their answers can be rated, creating a reputation assessment for each participant.

7. Predicting Outcomes: Information Markets

The performance of prediction markets has been one driving force behind the renewed attention on distributed collaboration. This case reviewed the performance of such prediction or information markets (Croxson and Bray 2008). In these, individuals are asked to rate the likelihood or probability of different events or outcomes. The aggregation of such individual judgements yields a group opinion that can be more trusted than a single expert under the right conditions, such as when the experts are not prejudice and trying to sway the outcome. One case study of an information market (focused on predicting the outcome of local elections) appeared weak, possibly since it lacked disinterested, non-prejudiced experts – or because an insufficient diversity of views were present in the market.

8. Multi-Player Games for Multi-Player Collaboration over Seriosity

A final case of user-generated content focused on an example of the use of massive multiplayer online games as a way of creating an incentive for individuals to pay closer attention to their use of e-mail and solve their problems with information overload. Seriosity²⁶ is developing a platform to enable individuals to simulate the redistribution of resources in sending and receiving e-mail in ways that will lead them to be more strategic about the mail they send and open (Bray et al. 2008b). However, there is no group-shared product, only the potential for individuals, and therefore the organization as a whole, to better allocate their attention to different e-mail messages. There are as many problem-holders as there are e-mail users, each contributing to solving others' problems.

Collaboration 3.0 Cases: Co-creating Information through Collaborative Work

9. Open Source Software Development – Firefox

Firefox is an open source Internet browser that evolved from Mosaic, developed at the University of Illinois and later commercialized by Marc Andreessen and Jim Clark as Netscape Mosaic, then Netscape Navigator. The availability of this and subsequent Web browsers has been comparable to the development of the hypertext markup language in fostering the diffusion

²⁵ <http://www.sermo.com/>

²⁶ <http://www.seriosity.com/>

of Web technologies. When Netscape was eclipsed by Microsoft's Internet Explorer, a foundation called Mozilla was created to support continued development of the Netscape browser code as an open source software project (Dalle et al. 2008). Since then, Firefox has become a popular browser, competing successfully with many proprietary browsers. It continues to be refined through collaborative contributions from a distributed network of coders. Open software production is a key example of co-creation.

10. Simplifying Text on Wikipedia

Wikipedia²⁷ is an open content encyclopaedia that is among the most well-known and debated products of distributed collaboration, with a global array of contributors co-creating a resource that has been compared favourably to any leading encyclopaedia. One of our case studies focused on efforts by the Wikipedia team to simplify the text of selected Wikipedia entries (den Besten and Loubser 2008). Readability scores were used to automatically identify 'unsimple' entries. Entries are marked if they are viewed as too complex and in need of simplification. These markings direct individuals within the Wikipedia community to help re-write and simplify the text. The collaboration of individuals in the construction of these entries is a prime example of collaboration 3.0, even though everyday use of Wikipedia by Internet users relies primarily on simple access to shared hypertext documents – collaboration 1.0.

11. Creating a Film: A Swarm of Angels

A Swarm of Angels²⁸ was selected as a case study of open content film production. The project is based in the UK but extended its open source model to movie making in ways that could bring distributed collaborators into the film project from anywhere in the world (Cassarino and Geuna 2008). Launched in 2006 by a pioneering director from Brighton, the project seeks to create a feature film by pulling together contributors from around the world who make a small donation (£25) in order to join the production. The director assumes the role of a 'benevolent dictator' but enables the community to be polled on controversial issues. Shared information is central, as are discussion groups, and polling, but all is geared to co-production of an information product.

Commonalities Across the Networks

The diversity of these cases is one of the major observations gained from our studies. Moreover, even within each type of case, such as prediction markets, or news aggregators, we found wide variation. Before focusing on these variations in design, the next section suggests several commonalities across the cases. What is central to all of these distributed collaboration networks?

Networks Amid a Multiplicity of Communication Channels

²⁷ <http://en.wikipedia.org/wiki/Wikipedia:About>

²⁸ <http://aswarmofangels.com/>

Our classification of three types of collaboration networks should not mask the degree to which each type is embedded within a broader array of communication networks and channels. For example, the use of the Internet to support collaboration on the Atlas project must recognize that frequent travel for face-to-face meetings also is central to the conduct of the project. Similarly, Wikipedia is co-produced online, but members of the Wikipedia community get together, such as at their International Wikimedia Conference, called Wikimania²⁹. This helps to foster the extraordinary contributions of this community in many ways analogous to a social movement.

Individuals, Organizations and Networks: The Locus of Adoption Decisions

Across many of the most successful CNOs, the decision to participate in collaboration networks is not a top-down process. Individuals tend to have the key choice. In this respect, the diffusion of CNOs in organizations in the early 21st Century might be comparable to the diffusion across organizations in the early 1980s of personal computers, such as the Apple and IBM PC. Just as individual managers and professionals decided to bring their own PC into the office, often against their organization's stated policy, individuals are deciding to join CNOs, often without their colleagues' knowledge or direction. For example, licensed physicians often join Sermo unbeknown to their medical practice, as they view it as a personal productivity tool, or something a colleague recommended – but not because their parent organization or practice mandated its use. Thus, individual performance is often more salient than organizational or institutional performance.

As discussed above, this is one reason why we use the CNO label to highlight their role as 'networks' rather than 'organizations'. Just as informal networks within an organization are often quite different from the formal organizational chart, so to are distributed collaboration networks often dramatically different from the boundaries of the firm or organization. Most often, CNOs network individuals across multiple organizations.

There are exceptions, as companies (including Google and HP) have sought to create CNOs within their organizations, for example to address prediction markets. Similarly, many projects employ a wiki and other collaboration tools in order to support teams and co-production. However, even in these cases, initiatives succeed or fail on the basis of individual choices. This includes the ability of individuals participating in these corporate, or project-focused, networks to choose to use the Internet to join many other networks within and outside their organizations' boundaries. In many respects, corporate and other organizational efforts to exploit CNOs will compete with a wider population of networks for the attention of individual managers, professionals and technical staff.

Complex Ecologies of Actors, Goals and Objectives

²⁹ http://wikimania2007.wikimedia.org/wiki/Main_Page

The bottom-up process described here contributes to the tendency for CNOs to be networks of peers versus networks within or of existing organizations. This leads to a second commonality: the absence of an overriding motivation. Instead, participation in networks tends to be driven by ecologies of actors with a multitude of often highly individualistic motivations. Across the case studies, we found distinctions among actors such as:

- Insiders vs. Outsiders
- Contributors vs. Lurkers
- Registered (Angels) vs. Non-Registered
- Platform Providers vs. Users
- Sponsors vs. Users

Likewise, the individual benefits vary greatly. For example, we found:

- token or symbolic winnings (e.g. Seriosity) as potentially effective as real prizes and payoffs (e.g. InnoCentive or Sermo);
- market structures created for some networks (e.g. prediction markets) but not for others (e.g. Atlas);
- simulations and games central to some (e.g. Seriosity) but not to others; and
- widely varied personal motivations, ranging from 'Zealots' to 'Good Samaritans' (e.g. Digg or Sermo)

The Blurring of Problem Holders and Problem Solvers

We also found a blurring of traditional distinctions between problem-holders and problem-solvers, reflecting both the diversity of actors and the degree that all forms of the new CNOs enable users to be producers themselves. InnoCentive makes an explicit distinction between the researchers as problem-solvers and the companies with problems as problem-holders. Yet this rational distinction breaks down in practice across most of the cases, as the Internet enables individuals to move seamlessly from one role to the other. For instance, physicians involved with Sermo can both answer questions as problem-solvers as well as asking questions as problem-holders. Readers of Wikipedia, as problem-holders, can become problem-solvers when they decide to correct or add to an entry. Newsreaders, as problem-holders, become problem-solvers as they comment on or rate a story, or refer it to a news aggregator.

The Adaptability and Institutionalization of Networks

The case studies demonstrated the continuous evolution of CNOs. As the platform developers and users experienced problems over time, it was possible to introduce new forms of moderation, new points of control, and complementary media to resolve issues and maintain the network. Of course, all organizations can evolve new management mechanisms, but some information technologies are viewed as 'electronic concrete' given the difficulty of change (Quintas 1996: 85-9). In the case of CNOs, their Web-based platforms have developed over time, and continue to introduce

emergent refinements. While capable of adapting over time, they are likely to face greater problems in sustaining their form as they compete with more institutional actors, such as the firm.

A Focus on Asynchronous Production of Intangible Goods and Services

The Internet enables people distributed across the world to collaborate with others to communicate, find information, obtain services and solve problems through these mechanisms. Thus, in a broad sense as illustrated by the 1.0 cases above, among other things the Internet is a distributed collaboration network. For instance, the Atlas project and Bugzilla case found that simple e-mail along with attachments and Web pages can play a major role in distributed collaboration. There are some applications of the Internet built specifically to solve particular problems, such as the platforms created by Sermo or Seriosity. At the same time, common problems exist that all these networks address.

First, illustrations and debate about the use of distributed collaboration tends to focus on the production or creation through asynchronous production of intangible information products and services, rather than tangible material goods and services (Table 4). Web 1.0, 2.0 and 3.0 are ICTs. Distributed groups provide information – tips, bets, votes, opinions, ratings, answers, text, designs, programs, formulas, and other symbolic goods and services – rather than material input. It is true that a motorcycle, or particle accelerator, can be designed by distributed teams, but it would be more challenging to construct one remotely.

Table 4. The Focus of Distributed Collaboration Networks.

Producing:	Synchronous	Asynchronous
Intangible Information (designs, code, text, digital content, ...)	Face-to-face meetings; Audio or Video conferencing; Internet chat rooms; Access Grid for multimedia, multimode conferencing	Focus of Collaboration Network Organization; Knowledge Ecosystems; Software; Text as in an Encyclopaedia; Film Production
Tangible Material (physical goods and services)	Computer-aided Manufacturing; Real time Multiple Operator Single Robot (MOSR) systems; Controlling an Actor; Digital Companions and Assistants	MOSR systems, and Internet-based Online Robots; Planting and Nurturing a 'Telegarden'

Of course, a distributed team of volunteers could remotely control a robotic arm on a space vehicle, or fly a plane, but few would recommend it. The production of intangible information goods and services is also increasingly central to the economies of advanced industrial societies – as well as to the performance of other industries, such as in the extraction of raw materials for manufacturing industries (Bell 1980). Distributed collaboration networks increasingly contribute to advanced economies.

Secondly, geographically distributed teams tend to work best asynchronously, and most discussion of distributed collaboration is about asynchronous communication and asynchronous contributions to solutions. A great virtue of asynchronous working is the ability for individuals to choose their own time and place for communicating and contributing to collaborative efforts. Global teams can work around the clock by harnessing asynchronous communication and contributions.

As Table 4 suggests, most examples of distributed collaboration networks entail asynchronous contributions to information-centric problems, such as writing software or editing an entry in an encyclopaedia. CNOs are not mainly focused on synchronous group communication. Problems like bargaining or negotiating, which require real time information sharing or communication among a geographically distributed group, can best be addressed by virtual meetings – to include video conferencing or real-time chat on the Internet. Generally, however, conferencing and other support for meetings is not the focus of developments around distributed collaboration. This is because such conferencing efforts are in real time and involve far smaller groups (smaller than a 'crowd').

Distributed groups can remotely control material production processes, but some famous examples have had problematic outcomes. For example, Internet-based online robots or Multiple Operator Single Robot (MOSR) systems have been devised for groups to remotely control a human 'Tele-Actor' (Edgar 2002).³⁰ Emerging developments of 'digital companions' (Wilks and Peltu 2008)³¹ might be classified in this category as they provide information to users in real time that can enable them to change their behaviour, such as by taking medication or calling home. Local and distributed sources of information are guiding human behaviour.

Larger groups working together in a more asynchronous mode have been part of the Telegarden³² project, which enabled a virtual community to help cultivate a garden. People who provided their e-mail address to the virtual community could plant a seed or water a plant by controlling a robotic arm. It was through participation in the virtual community that individuals were given the right to water their plant and place more seeds. The creativity and degree of success of the Telegarden led it to become a focus of discussion and

³⁰ See also the more technical report by Goldberg et al. (2002) .

³¹ See also: <http://www.companions-project.org> .

³² See McLaughlin et al. (1997) for an empirical study of Telegarden, as well as details of this project on the Web at: <http://www.ieor.berkeley.edu/~goldberg/garden/Ars/> and a video presentation at: <http://www.medienkunstnetz.de/works/telegarden/video/1/>

eventually a museum piece. However, many plants died for lack of water and care.

There are aspects of the Telegarden project and remote control over material processes that could contribute to an understanding for distributed collaboration. For example, the Telegarden lacked the incentive structures to keep many people involved or some plants alive. However, most projects focused on co-constructing material products tend to be focused on creating demonstrators (e.g. Telegarden and Tele-Actor) rather than on serious collaboration activities.

The Wisdom of Controlling Crowds

The central focus of distributed collaboration is on the asynchronous creation of information-centric products by geographically distributed groups. How is this done?

Managing Collaborative Network Organizations

The case studies show that CNOs identified in Tables 2 and 3 are not tapping the wisdom of crowds. Instead, each CNO platform manages the contributions of individuals – and expertise – in ways that contribute to pre-determined designs, be they specific goals or more loosely defined meta-goals. The wisdom of these networks is in the intelligence behind the management of these collective networks. The providers of CNO platforms can shape the patterns of behaviours and norms of use associated with these networks in ways that yield useful outcomes through a variety of management levers. Table 5 suggests some of the key ways in which CNO platforms can manage the contributions in ways that enable constructive contributions. Moreover, as noted before, in most of the CNOs the ‘crowd’ involved was actually a small minority of ‘core participants’ that represented a majority of the contributions made within the network. Several lurkers benefited from the CNO, but it was this small minority of core participants who kept different CNOs vibrant and successful.

Table 5. Linking Management Strategies to Collaboration.

Mechanism	1.0 Sharing	2.0 Contributing	3.0 Co-creating
Architecture	One-Many	Many-to-Many	Many-to-One
Openness	Open	Networked	Managed
Control	Low	Moderate (Reputation)	High
Modularization	Low	Moderate (Simple Tasks)	High

Determining the Architecture of the Network

The three types of CNOs define one set of critical features of the architecture of collaborative networks which control patterns of communication and information access. Of the different vertical categories, collaboration 1.0 is focused on open sharing of documents (one-to-many), while 2.0 seeks to enable user-generated content (many-to-many), and collaboration 3.0 seeks

to support collaboration on joint products (many-to-one). Our interviews with CNO platform providers revealed details on the various design features built into these networks.

Opening, Closing, and Tiering Communities

Another key point of control is over who participates in the network. Some CNOs enable wide-open access, such as in simply reading Wikipedia. Others are closed, such as Sermo which currently limits registration to authenticated physicians in the USA (though there are plans to expand). A Swarm of Angels is open to contributors willing to pay a modest fee. However, this is not a dichotomous choice, as it is possible to have tiered levels of access to different elements of the application. For example, Wikipedia managers can: close an entry, thereby closing off editing completely; allow trusted members of the community to resolve editorial issues, limiting access; and can give some trusted contributors the permission to delete the work of others. Most networks create a hierarchy of rights and privileges that determine who can do what within the network, enabling them to configure access to key resources in numerous ways. The need for this control over access and tiering is greater in the 3.0 networks than the 1.0 networks.

Control Structures

The management structures of the various networks vary, but several have more hierarchical than egalitarian arrangements for handling peer production (Loubser 2008). Some, like The Swarm of Angels, have a self-announced 'benevolent dictator'. Others, such as Atlas, have strived to support peer review and consensual decision-making, but permit leadership to evolve within teams and workgroups. In contrast, even in the several CNOs representing bottom-up communities (e.g. Sermo or Seriosity), there is usually a core authority responsible either for membership into the community or a core principle governing how the community 'plays the game' or interacts.

Modularization and Other Tools for Managing the Complexity of Tasks

Finally, all of the CNO platforms researched employ mechanisms to simplify tasks in ways that make them manageable to the individual problem-solvers and problem-holders. One of the major strategies in this area is to modularize the product in ways that do not overwhelm contributors. In fact, modularization can be used to keep the cost of participation low, enabling volunteers to contribute to large projects. Wikipedia can ask contributors to edit single entries, enabling them to make incremental changes and additions. Bugzilla modularizes the repair of defects into precise software projects. Sermo provides numerous mechanisms to simplify the contributions of physicians, such as encouraging their input to be provided in the form of answers to multiple choice questions. Given the complex array of often personal motives behind individual participation in these networks, the cost of participation must be kept low for problem-solvers and problem-holders.

The Complexity of Assessing the Performance of Intangible Tasks

Differences across the case studies highlighted many issues of performance surrounding CNOs. The debate over Wikipedia reached a wide public audience with respect to its comparative quality (Giles 2005). Debate also surrounds other 2.0 and 3.0 networks, such as Sermo and Firefox. However, once it is understood that there are major differences across CNOs, it is important to distinguish the critical points of performance tied to each type of network (Table 6).

Table 6. Differential Foci of Performance Across Type of CNOs.

Network Type:	Audiences	Contributors	Producers
3.0 Collaboration			Does the CNO engage targeted group of experts or producers?
2.0 Contributing		Does the CNO draw actors to contribute answers, ratings, votes?	
1.0 Sharing	Does the hypertexted object yield readers, viewers, in and out links?		

For collaboration 1.0, focused on sharing of information, performance is most critically tied to whether information is read, cited, and rated highly. Who finds it helpful? This can be assessed to a degree by log files identifying those who go to a Web page. However, most log files of sites are confidential and not publicly accessible. That said, a provider of Web-based information can assess the level and range of interest in their information and make over-time and comparative judgments of its value. Log files can lead to follow-on qualitative interviews with, or surveys of, users.

Webmetrics could be suited to examining the centrality of information within particular networks (Ackland 2008), and could represent a useful approach to gaining a first approximation of the performance of contributions to some collaboration networks. However, there are major limitations on Webmetrics, including access to linking and log data within the platform, such as within the Sermo site, and the relatively small size of many collaboration networks. For example, a small number of high-quality contributions can be valuable to a 3.0 network, such as A Swarm of Angels. The growing prominence of Wikipedia entries on the Web as reflected in search engine results is one reflection of the performance of this network, but the study of joint co-production of particular pages would require more qualitative study.

The performance of collaboration 2.0 networks would also be judged by whether they are successful in generating user content, such as comments,

ratings, tags, answers to questions etc. The ratings of books on Amazon.com are claimed to be evidence of the site's success because many books are rated by multiple individuals. Sermo appears to be relatively successful because many (over 50,000) licensed physicians register to use the system. A sizeable proportion of these regularly contributes content, either by asking questions of their fellow physicians or by answering the questions they are posed. Sponsors also contribute questions.

However, for the project's case studies, Webmetrics of publicly accessible data proved useful only in the case of assessing our news aggregators (Ackland 2008). Here, the analysis indicated that prominent platforms, such as Digg, were prominent sites among other news sites, including traditional news outlets, and tended to occupy a location between traditional news sites and online actors, such as bloggers. This suggests that they might play a 'brokering' or 'bridging' role in the online information environment (Ackland 2008: 8).

Finally, in the case of collaboration 3.0 networks, the proof of performance is in the ability of a network to attract and sustain relevant contributors to the production of information products or services, such as software code, or encyclopedia entries. Wikipedia entries are rated highly not simply because they are written well, but because they attract experts in the respective topics.

These criteria of viewing, contributing, and collaborating are necessary but not sufficient conditions of performance. However, they do present a focal point, and one that can help concentrate attention on those networks that are the most credible sites of high performance.

Comparative Indicators of Performance

One difficulty of assessing most applications of ICTs is that new applications often do new things but seldom the same thing that would be done through other means. For example, prediction markets could be considered as substitutes for expert opinion or survey research (Croxson and Bray 2008), but they are very different from both alternatives. In this respect, they are more likely to be used as a complement than a substitute for other sources of information. If these alternative sources of information differ, neither is necessarily better or worse. Instead, these differences themselves can be valuable for strategic decision-making.

Likewise, comparison over time is not necessarily an evaluative criterion. Before and after the New Hampshire US Presidential Primary elections in January 2008, prediction markets varied widely day by day on the fate of the Democratic Party candidates. This variance spoke volumes in conveying the uncertainty of the outcomes, and therefore the predictions could be useful even if at variance one day to the next.

The Distribution of the Costs and Benefits of Collaborative Networks

Our studies found that the physical and organizational geography of

distributed collaborative networks leads to uncertainties over who pays and who benefits. Individuals often make the critical decision on whether or not to contribute to these networks. The benefits to individuals, the larger network of participants, and any sponsors are therefore the least problematic for those networks that are successful. However, if these same actors do not perceive a specific collaborative network to be of value, their participation declines and the network fails. This is one reason why others have observed that networks must be seen as a 'two-sided', meaning that the developers need to 'think about what value the contributors is getting' (Donald Procter quoted by Bollier 2007: 8).

The speed with which these networks can be launched and either succeed or fail is one critical aspect of their evolution. However, even successful networks could raise reasonable questions about the payoffs to the organizations that employ the participants in these boundary-spanning networks. Why pay the salaries of individuals spending their time on another organization's project?

One rationale is that if the project supports the performance of individuals within the organization, then the organization as a whole might well capture the benefits. Another is the value of expanding the networks of organizations beyond their boundaries. James March (1991) argued that organizations face a trade-off between focusing on the search for new ideas through learning and experimentation, versus focusing on the exploitation and refinement of the existing knowledge of an organization. March (1991: 71) described exploration as engaged in 'search, variation, risk taking, experimentation, play, flexibility, discovery, innovation', which he characterized exploitation as involving 'refinement, choice, production, efficiency, selection, implementation, execution'. An over-emphasis on experimentation can undermine 'competence', where an overemphasis on exploitation can undermine innovation and leave the organization in a rut.³³

Distributed collaborative networks can enhance both, but the inter-organizational dimension of most of the networks we studied suggests that they are a particularly useful source of new ideas from outside their existing organizational context. Some degree of the participation in collaborative networks that reaches beyond the formal boundaries of any organization could support efforts to encourage additional exploration and thus provide organizational benefits.

Finally, the distribution of costs associated with collaborative networks are such that individual contributions are often incremental and therefore easily absorbed by their home organizations. The design of networks, particularly the modularization of tasks, helps to minimize the costs for any participant. Minimizing the cost of participation represents one strong reason why several individuals do opt to participate in collaborative networks. Moreover, some of the most substantial costs are in setting up the networks rather than in their day-to-day use.

³³ My thanks to David Bray (2008) for pointing out this role of collaborative networks.

This leads to another question: Why do individuals pay the more substantial costs in setting up a network? In this case, it is important to look at the nature of intellectual property (IP) created and who pays and benefits (Table 7). These vary across the range of collaboration network types. For example, the major IP created by Type 3.0 Collaboration is in the co-produced product, involving multiple, distributed authors or co-creators. The value of Type 2.0 networks is more centred on the platform itself, as the platform generates and aggregates the contributions of users. In such ways, the IP issues vary widely across the cases (Richter 2008).

Table 7. Differential Criteria of Performance Across Type of CNOs.

Network Type:	Locus of IPR	Central Cost	Capture Benefits
3.0 Collaboration	The co-created product.	Creation, implementation, and management of the co-created product, to include software, films, other content.	Licensing, or sale of information product; non-monetary benefits, such as training, status, notoriety.
2.0 Contributing	The platform for soliciting and processing contributions.	Creation, implementation, and management of the community platform for generating and managing community input.	Licensing or sale of the platform, or the network, such as for advertising or third-party access to the network.
1.0 Sharing	The information being shared, sold, or advertised.	Creation of the information product.	Authors, creators, and aggregators in terms of reputation, influence, or fees.

Technical, Managerial, and Social Dimensions of Distributed Collaborative Networks

It is clear that the potential for distributed collaboration networks is substantial, but these networks do not represent an information Utopia. Many fail, and the best networks face major management challenges. There are critical issues to be faced by those who manage these new networks as well as by the managers of organizations who might wish to capture the value of these networks while avoiding unwarranted risks to their organizations. Overall, these issues fall into three broad categories: technical, managerial and social.

Technical Underpinnings

1. Technology Matters

Differences in the underlying technical infrastructures across collaborative networks are important. They reconfigure access to information and people in collaboration by supporting: sharing; contributing; and co-producing information within networks. Therefore, technical designs and architectures are of major significance in constructing distributive collaborative networks. Network types 1.0, 2.0 and 3.0 identified in this synthesis are overlapping and general, but illustrate some of the fundamental differences in design that have shaped how these collaborations work – how they reconfigure information flows within and across organizations.

2. Solutions Looking for Appropriate Problems

It is important that managers realize that networks do not simply follow once there is a recognition of a problem. The Internet and the many platforms that Internet technologies enable represent solutions that can be tapped to address a growing range of problems; however, not all problems appropriately align with such technologies.

One issue is the legitimacy of a problem. For example, Croxson and Bray's (2008) study of prediction markets identified a set of potential applications that have been judged as inappropriate (e.g. asking people to predict a human tragedy, such as an assassination). Likewise, the need to simplify tasks in order to foster participation – such as in creating multiple choice questions that are easily answered – can place practical limits on the quality of information obtained on a specific prediction model. It remains unclear whether some collaborative networks, such as Type 2.0, can handle complicated, interdependent tasks.

Managerial Underpinnings

3. The Centrality of Managing Networked Individuals

The rhetoric of the 'wisdom of crowds' can deflect attention from the degree to which successful CNOs are actually managed networks of individuals. These individuals choose to enter or exit a network, but leadership and management structures play a role in recruiting participants, maintaining their involvement, and managing their contributions. All our case studies have shown the central importance of clear management structures in coping with the challenges of distributed collaboration (Loubser 2008). The leaders of some open source projects have been compared to benevolent dictators. The Firefox managers have gained a strong reputation of being focused directors.

The significance of managing participation emerges from the cases in a variety of ways. For instance, an important factor identified is the need to create a critical mass of users to sustain the network. If successful, this translates into effective management of levels and types of participation, including the rights and privileges of participants. Type 1.0 networks can be open to the world, but many type 2.0 and 3.0 networks need to restrict participation (e.g. Sermo limits access to licensed physicians in order to gain

the trust of participants; Atlanta, limits access to ensure that scientific teams compose its research networks). Platform managers regulate participation in a variety of ways, such as in freezing membership or bringing in a new cohort of participants, and in such ways they restrict or enlarge the size of the network.

There was also evidence across the cases that managers of CNOs need to structure tasks, just as individuals might structure their 'to do list'. Structuring tasks translates in most of our case studies to the modularization of problem solving. Incentive structures and information systems need to address issues surrounding the competition for the attention of their users, which is related to a more general 'management of attention'. Which pages need editing? Which bugs need to be fixed? Which e-mails are important to read right now? For example, Bugzilla is focused on defining and allocating the task of bug fixing. Wikipedia's managers identify sites that need to be simplified or built upon.

4. The Use of CNOs Can Support or Undermine Organizations

Donald MacKenzie (1999) has developed the concept of a 'certainty trough' to capture the degree that one's distance from a technology is not uniformly related to one's certainty over its performance. This suggests those most distant from a technology, such as CNOs, are likely to be highly uncertain of its value, whereas experience with a technology is likely to increase one's confidence and trust in its performance. However, those most proximate and knowledgeable about a technology might have somewhat less confidence because they know all the contingencies and uncertainties of its use and impact. Being too close to a technology might therefore make one overly familiar with the technology's weaknesses.

This understanding is an important underpinning to the OII-MTI's research findings, which have established a clearer recognition of both the potential benefits and risks of CNOs. The benefits of capturing the value of distributed intelligence are great. Knowledge sharing, social networking, and collaboration across time and space can be enormously valuable for organizations, such as in tracking change.³⁴ The fact that CNOs are not well aligned with the boundaries of formal organizations can be good, for example in supporting better surveillance of intra- or inter-organizational environments.

However, these networks also bring some risks, such as in the loss of control over private, proprietary, or sensitive information. Similarly, there are multiple threats arising from errors in the outcomes of CNOs, for example in prediction market cases where small markets might magnify prejudices, or where local actors try to 'game' a system. Managers and professionals need to understand the risks in order to capture the benefits and not be caught in a 'certainty trough' created by the buzz surrounding the supposed wisdom of the crowds.

³⁴ Bray (2008) develops a strong case for the value of supporting what he calls 'knowledge ecosystems' as a means for organizations to cope with turbulent environments.

Social Underpinnings

5. The Challenge of Building a Motivated Ecology of Contributors

Our exploratory case studies focused on some successful developments of CNOs. It is important to emphasize that many efforts to create networks, such as by posting a wiki, fail to attract a critical mass of contributors. The technologies for supporting these networks are becoming more accessible and powerful, but their success requires that platforms are two-sided, enabling individual participants to see benefits to themselves from their participation. For example, in the case of Sermo: contributing physicians value the community or the information they can obtain through the network; the platform provider has found a successful business model; and sponsors perceive a net gain. Envisioning and constructing such a strategy for developing an ecology within which all stakeholders have clear 'wins' represents a crucial challenge of distributed networks.

6. Individuals Can Lose or Gain by Participation in Collaborative Networks

Since individuals choose to participate in distributed collaborative networks and can enter and exit at will, it is possible to view these networks as optimal for the individual. However, like organizations, it is important for individuals to assess critically their participation in these networks. Who benefits? Who gains? Nicholas Carr (2008) puts it most graphically by arguing that users of Web 2.0 platforms are becoming a 'global pool of cut-rate labor' for the 'digital elite' in the age of the information utilities, such as Google. Rather than creating an information utopia through user-content and open source, Carr sees the Edisons of the digital age reaping large profits off the free labour of users, while at the same time reducing the ranks of paid information workers who might well have generated higher quality information (Carr 2008: 143).

The Future of Collaborative Network Organizations

Is the interest surrounding distributed collaboration simply the sign of the latest 'new thing', which will rapidly dissipate once the novelty wears off – or are these networks the beginning of a trend towards a greater reliance on capturing the value of distributed intelligence? The vitality of the networks explored in this study suggests that they will be of growing importance. There are many initiatives on the horizon, such as developments seeking to build on, or mimic, the success of collaborative network organizations (e.g. Google Knol³⁵, Wikia Search³⁶, and Bigthink.com³⁷). Clearly, some will fail, and inform us further about the dynamics of distributed collaboration. Whatever the outcomes, managers and professionals must understand the potential for an array of actors to capture the value of distributed intelligence, as well as to

³⁵ <http://googlesystem.blogspot.com/2007/12/google-knol-encyclopedia-written-by.html>

³⁶ http://search.wikia.com/wiki/Search_Wikia

³⁷

http://medgadget.com/archives/2008/01/bigthinkcom_the_closest_you_will_get_to_intellectuals_in_medicine.html

manage the wisdom of networked individuals in ways that can mitigate the risks of such collective approaches.

References

Ackland, R. (2008), 'What Can We Learn About Distributed Problem-Solving Networks through Webmetrics'. Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

Austen-Smith, D., and Banks, J. S. (1996), 'Information Aggregation, Rationality, and the Condorcet Jury Theorem', *American Political Science Review*, 90(1), March, 34–45.

Barabási, A.L. (2003), *Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life*. New York: Plume.

Bell, D. (1980), 'The Social Framework of the Information Society', in Forester (1980): 500-49.

Benkler, Y. (2006), *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. New Haven: Yale University Press.

Bollier, D. (2007) (Rapporteur), *The Rise of Collective Intelligence: Decentralized Co-Creation of Value as a New Paradigm of Commerce and Culture*. Washington DC: Communications and Society Program, The Aspen Institute.

Bray, D. (2008), *Knowledge Ecosystems: Technology, Motivations, Processes, and Performance*. Unpublished dissertation, Graduate School, Emory University.

Bray, D., Croxson, K., Dutton, W., and Konsynski, B. (2008a), 'Sermo: An Authenticated, Community-Based, Knowledge Ecosystem.' Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

Bray, D., Croxson, K., Dutton, W., and Konsynski, B. (2008b), 'Seriosity: Addressing the Challenges of Limited Attention Spans'. Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

Carr, N. (2008), *The Big Switch: Rewiring the World, From Edison to Google*. London: W. W. Norton & Company.

Cassarino, I., and Geuna, A. (2008), 'Distributed Film Production: Artistic Experimentation or Feasible Alternative? The Case of a Swarm of Angels'. Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

Condorcet, M. de ([1785] 1994), *Essai sur l'application de l'analyse a la probabilité des decisions rendues a la pluralité des voix*. Trans. Iain McLean and Fiona Hewitt. Paris: l'Imprimerie Royale.

Cohen, M. D., March, J. G., Olsen, J. P. (1972), 'A Garbage Can Model of Organizational Choice', *Administrative Science Quarterly*, 17(1), 1–25.

Croxson, K. and Bray, D. (2008), 'Information Markets: Feasibility and Performance'. Working paper in progress, Oxford Internet Institute, University of Oxford. Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

Cukier, K. (2006), *Herd with a Thousand Voices*. A Report of the 2006 Rueschlikon Conference on Information Policy. Switzerland: Swiss Re Centre for Global Dialogue.

Dalle, J.-M., den Besten, M., Masmoudi, H., and David, P. (2008), 'Bug-Patching for Mozilla's Firefox'. Working paper in progress, Oxford: Oxford Internet Institute, University of Oxford.

David, P. A. (2007a), 'Distributed Problem-Solving Organizations and the Evolution of Innovation Strategies'. Presentation to a symposium on 'Open source Corporate Strategy'. AOM Conference, Philadelphia, Pennsylvania, 6-8 August.

David, P. A. (2007b), 'Toward an Analytical Framework for the Study of Distributed problem-Solving Networks.' Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

den Besten, M and Loubser, M. (2008), 'Resolving Simple and Contested Entries on Wikipedia.' Working paper in progress. Oxford Internet Institute, University of Oxford.

Dutton, W. H. (1999a), 'The Virtual Organization: Tele-Access in Business and Industry'. In DeSanctis, G. and Fulk, J. (eds.), *Shaping Organizational Form: Communication, Connection, and Community*. Thousand Oaks, CA and London: Sage, 473–495.

Dutton, W. H. (1999b), *Society on the Line: Information Politics in the Digital Age*. Oxford: Oxford University Press.

Dutton, W. (2005), 'The Internet and Social Transformation', pp. 375-398 in Dutton, W. H., Kahin, B., O'Callaghan, R., and Wyckoff, A. W. (eds), *Transforming Enterprise: The Economic and Social Implications of Information Technology*. Cambridge, MA: MIT Press.

Dutton, W. H. (2007), 'Through the Network of Networks – The Fifth Estate', Inaugural Lecture, Examination Halls, University of Oxford. Available at: http://webcast.oii.ox.ac.uk/?view=Webcast&ID=20071015_208

Edgar, B. (2002), 'Robotic Tele-Actor: A Virtual Tour Guide with Soul', Berkeley Engineering (Berkeley: UCB College of Engineering), Fall. Available at: <http://www.coe.berkeley.edu/forefront/fall02/telerobot.html>

Forester, T. (1980) (ed.), *The Microelectronics Revolution*. Oxford: Basil Blackwell.

Giles, J. (2005), 'Internet Encyclopedias Go Head To Head', *Nature* 438, 900-901, 15 December. Available at: <http://www.nature.com/nature/journal/v438/n7070/full/438900a.html>

Goldberg, K., Song, D., Khor, Y., Pescovitz, D., Levandowski, A., Himmelstein, J., Shih, J., Ho, A., Paulos, E. and Donath, J. (2002), Collaborative Online Teleoperation with Spatial Dynamic Voting and a Human 'Tele-Actor', IEEE International Conference on Robotics and Automation, May 2002, Washington, DC. Available at: <http://goldberg.berkeley.edu/pubs/teleactor-icra02.pdf>

Hiltz, R. and Turoff, M. (1978), *The Network Nation: Human Communication via Computer*. Reading, MA: Addison-Wesley Publishing Company.

Hofkirchner, W., with Fuchs, C., Raffl, C., Schafraneck, M., Sandoval, M., and Bichler, R. (2007), 'ICTs and Society: The Salzburg Approach'. Salzburg: ICT&S Center Research Paper Series.

Huberman, B. A. (2001). *The Laws of the Web: Patterns in the Ecology of Information*. Cambridge, MA: MIT Press.

Johansen, R. (1988), *Groupware: Computer Support for Business Teams*. New York: The Free Press.

Lakhani, K. R. (2008), 'Removing "Newton's Blinkers" Through the Organization of Distributed Problem-Solving'. Text of lecture at an OII Forum. Oxford: Saïd Business School, University of Oxford, 31 January.

Lakhani, K. R., Jeppesen, L. B., Lohse, P. A., and Panetta, J. A. (2007), 'The Value of Openness in Scientific Problem-Solving'. Working paper number 07-050. Cambridge, MA: Harvard Business School.

Loubser, M. (2008), 'Governance Structures in Distributed Problem-Solving Networks', Working paper in progress, Oxford: Oxford Internet Institute, University of Oxford.

MacKenzie, D. (1999), 'The Certainty Trough'. In Dutton, W. H. (ed.), *Society on the Line*. Oxford: Oxford University Press, 43-6.

Mansell, R. and Silverstone, R. (1996) (eds), *Communication by Design*. Oxford: Oxford University Press.

March, J. G. (1991), 'Exploration and Exploitation in Organizational Learning', *Organization Science*, 2(1), 71–87.

McLaughlin, M. L., Osborne, K. K., and Ellison, N. B. (1997), 'Virtual Community in a Telepresence Environment'. In Jones, S. (Ed.), *Virtual Culture* (London: Sage Publication), 146–168.

Nuttall, C. (2007), 'Share Ideas to the Maximum', *Financial Times*, 5 December, 16.

O'Reilly, T. (2005), 'What is Web 2.0: Design Patterns and Business Models for the Next Generation of Software', 30 September. Available at: <http://www.oreilly.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html?page=1>

Page, S. E. (2007), *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies*. Princeton, NJ: Princeton University Press.

Page, S. E. (2008), 'Diversity in Distributed Problem-Solving Networks'. Text of lecture at an OII Forum, Oxford: Saïd Business School, University of Oxford, 31 January.

Quintas, P. (1996), 'Software by Design'. In Mansell and Silverstone (1996), 75-102.

Richter, W. (2008), 'Intellectual Property Law and the Performance of Distributed Problem-Solving Networks (DPSNs)'. Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

Richter, W., Escher, T., and Bray, D. (2008), 'The Performance of distributed News Aggregators'. Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

Rheingold, H. (2002), *Smart Mobs: The Next Social Revolution*. New York: Basic Books.

Sunstein, C. R. (2006), *Infotopia: How Many Minds Produce Knowledge*. New York: Oxford University Press.

Surowiecki, J. (2004), *The Wisdom of Crowds: Why the Many Are Smarter than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*. New York: Doubleday.

Tapscott, D. and Williams, A. D. (2007), *Wikinomics: How Mass Collaboration Changes Everything*. New York: Penguin.

Tuertscher, P. (2008), 'The ATLAS Collaboration: A Distributed Problem-Solving Network in Big Science.' Working paper in progress. Oxford: Oxford Internet Institute, University of Oxford.

Weber, S. (2004), *The Success of Open Source*. Cambridge. Massachusetts: Harvard University Press.

Wellman, B. (2001), 'Physical Place and Cyberplace: the Rise of Personalized Networking', *International Journal of Urban and Regional Research*, 25(2), June, 227–52.

Wilks, Y. (2006), 'What is the Semantic Web and what will it do for eScience?' OII Research Report No. 12. Oxford: Oxford Internet Institute, University of Oxford. Available at: <http://www.oii.ox.ac.uk/research/publications/RR12.pdf>

Wilks, Y. and Peltu, M. (2008), 'Close Engagements with Artificial Companions: Key Social, Psychological, Ethical and Design Issues', *OII/e-Horizons Forum Discussion Paper No. 14*. Oxford: Oxford Internet Institute, University of Oxford, January.