

2005

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COORDINATION OF FREE/LIBRE OPEN SOURCE SOFTWARE DEVELOPMENT

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Abstract

The apparent success of free/libre open source software (FLOSS) development projects such as Linux, Apache, and many others has raised the question, what lessons from FLOSS development can be transferred to mainstream software development? In this paper, we use coordination theory to analyze coordination mechanisms in FLOSS development and compare our analysis with existing literature on coordination in proprietary software development. We examined developer interaction data from three active and successful FLOSS projects and used content analysis to identify the coordination mechanisms used by the participants. We found that there were similarities between the FLOSS groups and the reported practices of the proprietary project in the coordination mechanisms used to manage task-task dependencies. However, we found clear differences in the coordination mechanisms used to manage task-actor dependencies. While published descriptions of proprietary software development involved an elaborate system to locate the developer who owned the relevant piece of code, we found that “self-assignment” was the most common mechanism across three FLOSS projects. This coordination mechanism is consistent with expectations for distributed and largely volunteer teams. We conclude by discussing whether these emergent practices can be usefully transferred to mainstream practice and indicating directions for future research.

Keywords: Free/libre open source software development, coordination theory, coordination mechanisms

Introduction

The apparent success of free/libre open source software¹ (FLOSS) development projects such as Linux, Apache, and many others has raised the question, what lessons from FLOSS development can be transferred to mainstream software development? In this paper, we address this question for one key problem in large-scale software development, namely coordination of the work of multiple developers.

Coordination is a significant concern in large software development teams. Curtis et al. (1988) found that large projects have extensive communication and coordination needs that are not mitigated by documentation. These coordination problems are exacerbated when the development team is geographically or organizationally distributed, as is increasingly common. More effort

¹The free software movement and the open source movement are distinct and have different philosophies but mostly common practices. The licenses they use allow users to obtain and distribute the software’s original source code, to redistribute the software, and to publish modified versions as source code and in executable form. While the open source movement views these freedoms pragmatically (as a development methodology), the free software movement regards them as human rights, a meaning captured by the French/Spanish word *libre* and by the saying “think of free speech, not free beer.” (See <http://www.gnu.org/philosophy/> and <http://opensource.org> for more details.) This paper focuses on the development practices of these teams, which are largely shared across both movements. However, in recognition of these two communities, we use the acronym FLOSS, standing for Free/Libre and Open Source Software, rather than the more common OSS.

1 is required for interaction when participants are distant and unfamiliar with each others' work (Ocker and Fjermestad 2000;
2 Seaman and Basili 1997). Curtis et al. noted that coordination breakdowns were likely to occur at organizational boundaries, but
3 that coordination across these boundaries was often extremely important to the success of the project. The additional effort
4 required for distributed work often translates into delays in software release compared to traditional face-to-face teams (Herbsleb
5 et al. 2001; Mockus et al. 2000). The problems facing distributed software development teams are reflected in Conway's law,
6 which states that the structure of a product mirrors the structure of the organization that creates it. Accordingly, splitting software
7 development across a distributed team will make it hard to achieve an integrated product (Herbsleb and Grinter 1999). Despite
8 these challenges, some FLOSS development teams have been quite successful in overcoming the challenges of distributed
9 software development. In this paper, we analyze the coordination mechanisms used in FLOSS development to answer our
10 research question, namely, how coordination of FLOSS differs from proprietary software development, and to explore what
11 proprietary development might learn from FLOSS about coordinating the work of distributed developers.

12
13 Coordination of developers working on proprietary software has been extensively studied. Curtis et al. studied how requirement
14 and design decisions were made, represented, and communicated, and how these decisions impacted subsequent development
15 processes for large systems. Kraut and Streeter (1995) found that the formal and informal communication mechanisms for
16 coordinating work on large-scale, complex software projects were important for sharing information and achieving coordination
17 in software development. Crowston (1997) used coordination theory to analyze coordination mechanisms in software change
18 processes, including task assignment, resource sharing, and managing dependencies between modules of source code, in order
19 to suggest alternative processes. Kraut et al. (1999) found that reliance on personal linkages rather than electronic networks
20 contributed to coordination success. Faraj and Sproull (2000) found a strong relationship between expertise coordination and team
21 performance, over and above the contribution of team input characteristics, presence of expertise, and administrative coordination.
22 Espinosa et al. (2001) tested whether implicit mechanisms such as shared mental models are used for coordination for
23 geographically distributed projects. In a later study, Espinosa et al. (2004) concluded that an effective strategy for coordination
24 success involves finding a mix of explicit and implicit coordination mechanisms appropriate for the task, which may change as
25 the task progresses across time.

26
27 However, the archetypical community-based FLOSS development process differs greatly from proprietary development in several
28 respects that may affect or depend on the coordination mechanisms used. (In focusing on community-based development, we
29 exclude projects such as MySQL that are developed by a single organization following a conventional software engineering
30 approach and only released under a FLOSS license.) A primary difference is that the community-based development process is
31 not owned by a single organization. Developers contribute from around the world, meet face-to-face infrequently if at all, and
32 coordinate their activity primarily by means of computer-mediated communications (CMC) (Raymond 1998; Wayner 2000) and
33 other software development tools (e.g., source code control systems). As noted above, the research literature emphasizes the
34 difficulties of distributed software development, but the case of FLOSS development presents an intriguing counter-example.

35
36 While distributed work is becoming more common even for proprietary software development, what is perhaps most surprising
37 about the FLOSS process is that it appears to eschew traditional project coordination mechanisms such as formal planning,
38 system-level design, schedules, and defined development processes (Herbsleb and Grinter 1999). As well, many (though by no
39 means all) programmers contribute to projects as volunteers, without working for a common organization or being paid.
40 Generally, a small core group oversees the overall design and contributes the bulk of the code, but other developers play an
41 important role by contributing bug fixes, new features, or documentation, by providing support for new users, and by filling other
42 roles in the teams. Characterized by a globally distributed developer force and a rapid and reliable software development process,
43 effective FLOSS development teams somehow profit from the advantages and overcome the challenges of distributed work (Alho
44 and Sulonen 1998), making their practices potentially of great interest to mainstream development.

45
46 In the next section, we briefly review coordination theory and show how it can guide the analysis of a process such as software
47 development. The data and method section describes the FLOSS projects we analyzed, our data elicitation and analysis approach,
48 and the rationale for their selection. The results section presents the dependencies and coordination mechanisms identified in the
49 cases. We conclude with some observations about the coordination of software development and suggestions for further research.

50 **Theory: A Coordination Theory Approach to Organizational Processes**

51
52 To analyze coordination in FLOSS development processes, we use the framework developed by Malone and Crowston (1994),
53 who define coordination as "managing dependencies between activities" (p. 90). They define coordination theory as the still
54 developing body of "theories about how coordination can occur in diverse kinds of systems" (p. 87). Coordination theory analyzes

1 group action in terms of *actors* performing *interdependent tasks* that may also require or create *resources* of various types. For
 2 example, in the case of software bug fixing, *tasks* include diagnosing the bug, writing code for a fix and integrating it with the
 3 rest of the system, as mentioned above. *Actors* include the customers and various employees of the software company. In some
 4 cases, it may be useful to analyze a group of individuals as a collective actor (Abell 1987). For example, to simplify the analysis
 5 of coordination within a particular subunit, the other subunits with which it interacts might all be represented as collective actors.
 6 Finally, *resources* include the problem reports, information about known problems, computer time, software patches, source code,
 7 and so on.

8
 9 It should be noted that in developing this framework, Malone and Crowston describe coordination mechanisms as relying on other
 10 necessary group functions, such as decision making, communications and development of shared understandings, and collective
 11 sense-making (Britton et al. 2000; Crowston and Kammerer 1998). To develop a complete model of some process would involve
 12 modeling all of these aspects: coordination, decision-making, and communications. In this paper, our analysis will focus on the
 13 coordination aspects, bracketing the other phenomenon.

14
 15 According to coordination theory, actors in organizations face *coordination problems* that arise from dependencies that constrain
 16 how tasks can be performed. These dependencies may be inherent in the structure of the problem (e.g., components of a system
 17 may interact with each other, constraining the kinds of changes that can be made to a single component without interfering with
 18 the functioning of others) or they may result from decomposition of the goal into activities or the assignment of activities to actors
 19 and resources (e.g., two engineers working on the same component face constraints on the kind of changes they can make without
 20 interfering with each other).

21
 22 To overcome these coordination problems, actors must perform additional activities, what Malone and Crowston call *coordination*
 23 *mechanisms*. For example, a software engineer planning to change one module in a computer system must first check if the
 24 changes will affect other modules and then arrange for any necessary changes to modules that will be affected; two engineers
 25 working on the same module must each be careful not to overwrite the other's changes. Coordination mechanisms may be specific
 26 to a particular setting, such as a code management system to control changes to software, or general, such as hierarchical or market
 27 mechanisms to manage assignment of activities to actors or other resources.

28
 29 There are often several coordination mechanisms that could be used to manage a dependency, as the task assignment example
 30 illustrates. Possible mechanisms to manage the dependency between an activity and an actor include manager selection of a
 31 subordinate, first-come-first-served allocation and various kinds of markets. Again, coordination theory suggests that these
 32 mechanisms may be useful in a wide variety of organizational settings. Organizations with similar activities to achieve similar
 33 goals will have to manage the same dependencies, but may choose different coordination mechanisms, thus resulting in different
 34 processes. In this paper, we will consider if the coordination mechanisms used in FLOSS development differ from those described
 35 in the literature for proprietary software development, and if so, what mechanisms might be transferred.

36
 37 As a guide to applying coordination theory, Crowston (2003) presents a typology of dependencies and associated coordination
 38 mechanisms. The main dimension of the typology involves the types of objects involved in the dependency. To simplify the
 39 typology, we compress the elements of Malone and Crowston's framework into two groups: tasks and resources used or created
 40 by tasks (which here includes the effort of the actors). Logically, there are three kinds of dependencies between tasks and
 41 resources: those between two tasks, those between two resources, and those between a task and a resource. Each of these
 42 dependencies has an associated set of appropriate coordination mechanisms.

43 **Methods: Inductive Coding of FLOSS Developer E-Mail Interactions**

44
 45 In this paper, we use coordination theory to analyze FLOSS software development processes in order to compare the mechanisms
 46 used in FLOSS to those described in the literature for proprietary development. Because the coordination mechanisms used by
 47 these teams have not yet been described, we adopted an inductive multiple case study approach to the research, which involves
 48 carefully analyzing real FLOSS developers' interactions for evidence of the coordination mechanisms in use. An inductive
 49 approach was indicated by our desire to extend theory for this new phenomenon. The rationale for the use of a case study
 50 approach was that case studies provide rich empirical data from a real setting, necessary for theory generation. In particular, Yin
 51 (1984) notes that case studies are particularly appropriate for answering *how* or *why* questions about current events in situations
 52 where the researcher has no control over the circumstances of the study.

Table 1. Projects Selected for Analysis.

	EGroupWare	GAIM	Compiere
Development Status	5 – Production/Stable	5 – Production/Stable	5 – Production/Stable
Programming language	PHP	C	Java
License	GNU General Public License (GPL)	GNU General Public License (GPL)	Mozilla Public License 1.1 (MPL)
Developer count	42	12	44

8 *Sample Selection*

10 Because the process of manually reading, rereading, coding, and recoding messages is extremely labor-intensive, we had to focus
11 our attention on a small number of projects. We analyzed coordination mechanisms used among developers of three successful
12 FLOSS projects, namely GAIM, eGroupWare, and Compiere ERP.

- 14 • GAIM is an instant messenger application that supports multiple platforms and protocols
15 (<http://sourceforge.net/projects/GAIM/>).
- 17 • eGroupWare is a multiuser, web-based groupware suite with modules such as e-mail, address book, calendar,
18 content management, forum, wiki, and so on (<http://sourceforge.net/projects/egroupware/>).
- 20 • Compiere is an ERP+CRM solution for small-medium enterprises covering areas such as order and customer/
21 supplier management, supply chain, and accounting (<http://sourceforge.net/projects/compiere/> and
22 <http://www.compiere.org/>).

24 The development status of the three projects is shown in Table 1.

26 The rationale for the selection of these three specific projects was that they all seemed to be successful at managing the
27 contributions of multiple developers (the core developers noted in Table 1 plus many more peripheral contributors), thus providing
28 relevant data for insight into coordination mechanisms for FLOSS development. We assessed success according to the criteria
29 suggested by Crowston et al. (2003): these three projects are successful in that they have attracted numerous developers beyond
30 the initial project founders, are continuing to release software, have numerous downloads, and have an active user community
31 that provides feedback.

33 In addition, these projects differ in ways that allow for some interesting comparisons. GAIM is an end-user desktop application
34 written in C, while eGroupware in a web-based server application written in PHP. As a result, we expect GAIM mostly to be used
35 as is, but expect eGroupware to have a lower barrier to entry for developers and to be more often customized, potentially
36 increasing problems in integrating these contributions. Compiere was originally a commercially developed product that later
37 moved to open source development. Its history allows us to examine coordination problems that arise as a new set of developers
38 begin working with an established code base and developer community. As well, one of the authors had extensive experience
39 with proprietary ERP systems, providing a basis for comparison.

40 *Data*

42 The data used for the study were interactions on the main developer communication venue, either a developer mailing list or
43 online forum. We chose these interactions because they are the communications between developers used to coordinate project
44 development. To increase the comparability of our analyses, we examined messages from a similar period in the development
45 life cycle for each project. We expected that coordination-related activities would occur more frequently around (and especially
46 before) a major release, so we analyzed the period leading up to and immediately after the first open source release for each
47 project.

- 49 • For GAIM, we selected messages posted to the “GAIM-devel” mailing list during August and September 2004
50 for analysis (GAIM 1.0.0 was released on September 16, 2004). The total number of messages was 710, posted

1 by 85 individuals (11 were identified as developers according to the current developer list for GAIM, and 1 was
2 identified as a former developer).

- 3
- 4 • For eGroupWare, we selected messages posted to the “egroupware-development” mailing list during October
5 and November 2004 for analysis (version 1.0.00.006 of eGroupWare was released on November 18, 2004),
6 which resulted in 665 messages total posted by 151 individuals (20 were identified as developers according to
7 the current developer list).
- 8
- 9 • For Compiere, we selected messages posted to the Development Chat Forum from the January 1, 2001, to
10 November 20, 2002, which covers the period up to and following the September 5, 2002, release of the
11 Compiere Version 2.4.3a, the first version released after the move to SourceForge. Perhaps because this was
12 a project transitioning from in-house development, the initial traffic on the developers’ forum was sparse and
13 we had to draw from a longer time period than with the other projects to gather the 315 messages we examined.
14 The Compiere project had more defined roles: the total number of users posting was 57; project managers, 2;
15 advisor/mentor /consultants, 3; developers, 6; and translators, 3.

16
17 All three projects selected are hosted on the SourceForge system (<http://sourceforge.net/>), making data about them easily
18 accessible for analysis. Nevertheless, analysis of these data poses some ethical concerns that we had to address in gaining human
19 subjects approval for our study. On the one hand, the interactions recorded are all public and developers have no expectations
20 of privacy for their statements (indeed, the expectation is the opposite, that their comments will be widely broadcast). Consent
21 is generally not required for studies of public behavior. On the other hand, the data were not collected for research purposes but
22 rather to support the work of the teams. We have, therefore, followed the common practice of rendering all data anonymous by
23 using pseudonyms in publications.

24 *Analysis*

25
26 For this project, we carried out a coordination-theory-based analysis of the developer e-mail interactions to identify the
27 coordination mechanisms used in the process. We started by developing a coding scheme based on prior work by Crowston and
28 Osborn (2003) on coordination theory. Crowston and Osborn describe three heuristics for identifying coordination mechanisms:
29 matching activities performed against known coordination mechanisms, such as searching for duplicate tasks or task assignment;
30 identifying possible dependencies between activities and resources and then searching for activities that manage them; and looking
31 for problems that suggest unmanaged or incompletely managed dependencies. However, these approaches were developed for
32 use in field settings and so the scheme had to be evolved for use in coding interactions in e-mail messages. In particular, we found
33 that it was difficult to identify dependencies from the messages, so our attention focused instead on coordination problems and
34 mechanisms. The coding system was evolved through discussion of the applicability of codes to particular examples, both in
35 group meetings and as three coders worked on the same set of messages over the course of several months. The final coding
36 system has 24 categories, organized into 3 high-level codes: task-task, task-resource, and resource-resource coordination
37 mechanisms taken directly from the categories of coordination theory.² Through the process of iterating the coding system, it
38 became apparent that the most interesting and novel aspect of the FLOSS development process as revealed in our sample was the
39 approach to task assignment. Therefore, we focused our final efforts on this part of the coding system. All messages were double-
40 coded for task assignment to allow computation of inter-rater reliability. The level of inter-rater agreement for coding the
41 Compiere, eGroupWare, and GAIM projects were 0.893, 0.887, and 0.810 respectively, all above the usual rule-of-thumb
42 acceptable level of 0.80.

43 **Results: Dependencies and Coordination Mechanisms in Software Development**

44
45 In this section, we discuss coordination mechanisms identified in the software development process. We then discuss differences
46 between the FLOSS and proprietary processes as well as differences among the three FLOSS projects.

²Space does not allow complete description of the lower-level codes, but the coding system is available from the authors on request.

1 **Common Output Dependencies Are Managed in a Similar Way**

2

3 Many coordination problems and mechanisms appear to be broadly similar between proprietary and FLOSS development
4 processes. For example, one common dependency is a *common output* dependency, meaning that two tasks create the same
5 output. Avoiding such duplicate tasks is difficult if there are numerous workers who could be working on the same task,
6 especially if they are distributed and have restricted opportunities to interact. For example, many users may report the same bug,
7 but managers of a development group would likely prefer not to waste resources diagnosing and solving the same problem
8 repeatedly. Crowston (1997) described how marketing engineers in a proprietary development organization would search a bug
9 report database for each bug report to identify possible existing solutions or duplicate reports. *Looking for duplicate tasks* is a
10 coordination mechanism for managing a dependency between two tasks that have duplicate outcomes. In the FLOSS process,
11 users are encouraged to search the bug tracker database for duplicate problem reports before filing a new one. Nevertheless, there
12 is no guarantee that users will search or that they will find a duplicate even if it exists, so duplicate bugs are reported and have
13 to be identified and marked as such by developers. For example, an e-mail from GAIM developers pointed out that a problem
14 report duplicated a known bug:

15

16 I suspect that this is the common "cygwin/bin in your path" issue. If you
17 do have cygwin's bin directory in your path, it causes these symptoms as
18 GAIM tries to load cygwin's tcl84.dll for the tcl plugin loader. You can
19 read more about it at <http://GAIM.sf.net/win32> and in various threads on
20 the forum.

21

22

23 Another noted with regard to a patch:

24

25 Looks like this takes care of bugs #993985 and #1001031.

26

27 In FLOSS development, many developers might be working on the same part of the code, so this coordination mechanism can
28 be applied more generally. For example, one developer on eGroupWare asked:

29

30 Is there someone who has any experience with including the app. OWL
31 (owl.sourceforge.net) in eGW ? I'm playing with the code right now, but
32 this wouldn't be necessary if someone did it before.

33

34

35 In a few cases, this kind of coordination was done ahead of time, as shown in these quotations:

36

37 Patches to update the svn tree can be submitted to me, please update this
38 thread with any work you are starting so we can avoid duplication.

39

40 I don't know how assignments work, but can I can dibs on this? I don't
41 want to have any of your work duplicated, so I want to make sure that I
42 don't infringe on what someone is already working on.

43

44

45 In the Compiere project, many user questions come from the new users who are trying to install and use the software, so the
46 project managers' and other senior developers' roles have evolved to include pointing people in the right direction to avoid
47 duplication of efforts. In Compiere, we coded these kinds of references 29 times:

48

49 Yes .. see doc <http://www.compiere.org/support/install>

50

51 There are also "hacker fixes" for the problem you mentioned.

52

53 Here are the links: [http://cvs.sourceforge.net/cgi-bin/viewcvs.cgi/
54 compiere/lib/postgresql.jar](http://cvs.sourceforge.net/cgi-bin/viewcvs.cgi/compiere/lib/postgresql.jar)

55

56 [http://cvs.sourceforge.net/cgi-bin/viewcvs.cgi/compiere/tools/
ib/ocrs12.jar](http://cvs.sourceforge.net/cgi-bin/viewcvs.cgi/compiere/tools/lib/ocrs12.jar)

1 ***Some Usability Dependencies Are Managed Similarly, and Some Differently***

2
3 A second similarity is the management of flow dependencies, which arise when one task creates a resource that another task
4 requires as an input. While in general a flow dependency implies the need for three different kinds of coordination mechanisms,
5 usability is often the most significant issue in the software development processes studied. Usability means that there must be
6 some mechanism in place to ensure that the output of the first task is usable by the second task. An interesting usability constraint,
7 common to both cases, arises from the flow dependency between the steps of finding a bug and fixing a bug. The output from
8 the first step, bug reports from the general public, are often not detailed enough to be useful for developers performing the second
9 step (Glance 2004). The low quality of bug reports discourages developers from relying on a bug reporting system, thus further
10 decreasing the quality of the bugs. In response, some developers may take on the role of filtering or improving reports. In the
11 proprietary process, marketing engineers check that problem reports are detailed enough to be used by the developers fixing the
12 bugs (Crowston 1997). In the FLOSS process, developers might post follow-up messages to a report (either on the e-mail list or
13 in the bug tracker database) requesting additional information. For example, one developer in eGroupWare asked a user to clarify
14 a problem:

15
16 Does Outlook send some sort of error message? What do you mean by crash--
17 does it stop responding, or close? What version of Windows are you
18 running? I'll try to figure this out asap.

19
20 Again, coordination mechanisms for ensuring usability can be applied generally. For example, a key problem in software
21 development is requirements analysis, that is, ensuring that the software being developed meets the needs of the users. In most
22 software development projects, requirements work is done by a dedicated team. In contrast, FLOSS development generally
23 assumes that developers are users themselves and thus able to understand user requirements. Users may also read the developer
24 lists and offer suggestions that way, as this quotation suggests:

25
26 I have read through this entire thread and seen a lot of suggestions for
27 how to implement this, and as an extensive `_user_` of GAIM, let me say that
28 the best one that I have heard so far is the idea of tabbing the buddy
29 list interface.

30
31 In Compiere, we furthermore see that companies that use the software also use the company resources (time and people) to make
32 the software fit their company or to enhance the software's functionality. The developers of the company introduce the idea to
33 the FLOSS team and coordinate efforts for that development:

34
35 Our company planned to work on a payroll and fixed asset module for the
36 Compiere. I wanted to know if anybody is interested in it?

37
38 The following conversation between an end user from a company and the project manager also shows how involvement of the
39 companies as end users might change the coordination of the teams by bringing extra resources:

40
41 - Hello, I saw on the page "product status" that serial numbers... are
42 planned for the future. Because we really need these functions, I
43 would like to know when it will be implemented.
44
45 - No plan yet. Are you willing to sponsor it?
46
47 - We are still in the evaluation period, but if we choose Compiere, why
48 not...

49 ***Task Assignment Is Handled Differently***

50
51 We next consider the coordination mechanisms that manage the assignment of tasks to actors. *Task assignment* is a coordination
52 mechanism for managing the dependency between a task and an actor (a special case of a resource) by finding the appropriate
53 actor to perform the task. There are numerous places where actors perform part of a task assignment process. For example, in
54 the proprietary process described by Crowston (1997), customers give problem reports to the service center, which in turn assigns
55 the problems to product engineers, who then assign them to software engineers. In addition, software engineers may assign

1 reports or subtasks to each other. Interestingly, there appear to be significant differences in this area between proprietary and
 2 FLOSS development.

3
 4 A key problem in task assignment is the basis for choosing the actor to whom to assign a task. For the proprietary process, the
 5 choice is often made by a project manager based on the specializations of the individual developers (Crowston 1997).
 6 Specialization allows developers to develop expertise in a few modules, which is particularly important when the engineers are
 7 also developing new versions of the system, and allows a single person to manage all changes to particular modules, thus
 8 minimizing the cost of integrating changes. However, the cost of such a system is the need for an elaborate process for assigning
 9 tasks to the appropriate developer.

10
 11 In order to identify the key coordination mechanism used for managing task assignment in FLOSS projects, we coded task
 12 assignment in terms of who was assigned the task and by whom. Five task assignment mechanisms are identified, as shown in
 13 Table 2. A striking feature of FLOSS development is how often developers introduce a task and offer to work on it, in effect
 14 assigning the task to themselves. For all three projects, self-assignment is the most frequent form of assignment. The following
 15 is an example of a poster self-assigning a task:

16
 17 Thanx for the wonderfull help ... Maybe an idea to make a 'hello world'
 18 package for on the website ... this kind of standard app .. would be
 19 verry Helpful for starting eGW developers (like me ;-)) If you'd like,
 20 I'll make the package.

21
 22 In a few cases, the offer to help is not connected to a particular task, but rather to claim responsibility for a general class of
 23 problems or just to announce availability:

24
 25 Hi, developers, If you find any PHP5 related problems, please open a bug
 26 report and assign it to me.

27
 28 Well I just started 14 days of vocation in front of the telly and
 29 computer. So I guess I will do some coding these days. =)

30
 31 As well as volunteering, developers often propose tasks and ask for volunteers, explicitly or implicitly. For eGroupWare and
 32 Compiere, asking a certain person was the second most frequent mode of task assignment, followed by asking an unspecified
 33 person. For GAIM, asking an unspecified person is the second most frequent mode of task assignment, followed by asking a
 34 certain person. For example:

35
 36 Can someone please do a brief test, replacing config.php with
 37 newconfig.php? If it works for a few people without causing problems, it
 38 will help us in the long run.

39
 40 Sometimes asking for volunteers is coupled with volunteering:

44 **Table 2. Frequency of Destinations of Task Assignment by Project**

Task Assignment Mechanisms	Frequency		
	EGW (%)	GAIM (%)	Compiere (%)
Self assignment	37 (52.9)	60 (59.4)	16 (57.1)
Ask a certain person	15 (21.4)	18 (17.8)	9 (32.1)
Ask an unspecified person	12 (17.1)	22 (21.8)	1 (3.6)
Ask an outsider (not in the project development team)	0	1 (1.0)	0
Suggest consulting with others	6 (8.6)	0	2 (7.2)
Total of Task Assignment Messages	70 (100)	101 (100)	28 (100)

1 Our own project repository would require maintenance, bandwidth, and drive
 2 space. I've volunteered to do everything to get us started. Volunteers
 3 to help maintain would be appreciated.

4
 5 I'm currently working through a port of my Bugzilla data into TTS, so feel
 6 free to ask me for any more tips, suggestions, etc. I'm happy to help, as
 7 I'm going through the process myself!

8
 9 Another interesting finding from the table is that sometimes team members are suggested to consult with others before they do
 10 a certain task, especially for eGroupWare. For example:

11
 12 I only ask you to consult with the maintainer of the concerned app before
 13 you commit something. If you need to change something radical in the API
 14 please talk it through Lars or me before (e.g., Mail it as proposal to the
 15 developers list).

16
 17 Sorry for that. Have you talked to Bill about the patches? I can't image
 18 he's not willing to accept them.

19
 20 Sometimes people don't directly ask others to do a task, but discuss who among several candidates can do it. For example:

21
 22 Miguel our translation coordinator or I will get the translation via your
 23 link and will commit them / include them in the distribution. Ronald

24
 25 Amir: are you going to commit the translations and add Thai to
 26 setup/lang/languages.php to enable Thai or should I take care of that?

27
 28 Since self-assignment depends on the ability of an individual to contribute to the group, we investigated differences between
 29 developers and users in the type of assignment used, as shown in Table 3. The distinction between user and developer was
 30 assigned by comparing the poster of the message to the project's published list of developers.

31
 32 **Table 3. Comparison of Destination of Task Assignment by Developers and Users**

	EGW		GAIM		Compiere	
	Developers (%)	Users (%)	Developers (%)	Users (%)	Developers (%)	Users (%)
Self assignment	25 (51.0)	12 (57.1)	28 (51.9)	32 (68.1)	8 (44.4)	8 (80.0)
Assign to a specified developer	1 (2.05)	2 (9.5)	3 (5.6)	5 (10.6)	3 (16.7)	1 (10.0)
Assign to a specified user	12 (24.5)	0 (0.0)	8 (14.8)	2 (4.3)	5 (27.7)	0
Assign to an unspecified person	7 (14.3)	5 (23.8)	15 (27.7)	7 (14.9)	0	1 (10.0)
Ask an outsider	0	0	0	1 (2.1)	0	0
Suggest consulting with other developer	3 (6.1)	2 (9.5)	0	0	0	0
Suggest consulting with another user	1 (2.05)	0	0	0	1 (5.6)	0
Suggest consulting with others	0	0	0	0	1 (5.6)	0
Total of Task Assignment Messages	49 (100)	21 (100)	54 (100)	47 (100)	18 (100)	10 (100)

1 The table shows that for all three teams, users rarely assign work to other users, but still often self-assign tasks. Especially for
2 GAIM, the percentage of users is very high in self-assignment and some users offer to contribute several times. For example,
3 one user in eGroupWare committed himself to helping implement features:

4
5 I am willing to help implement this feature, and have sometime :-)) to give
6 away, so I started looking through the code.
7

8 In contrast to the separation of roles in the proprietary process, many users who post to the developer e-mail list prefer to solve
9 the problem by themselves when they identify a task, instead of reporting it directly and just waiting for the responses. In other
10 words, the formal division of users and developers does not necessarily constrain their behavior.

11 Discussion

12
13 Several points strike us as particularly interesting about these findings. A first observation is that FLOSS development shares
14 a number of coordination mechanisms in common with proprietary development, such as those for managing common output
15 dependencies or the usability of bug reports (alough there may be some differences in who performs these functions). This
16 similarity is to be expected. Althg the makeup of the teams and their approach differs, there is still significant commonality
17 determined simply by the fact that both are undertaking software development.
18

19 The most striking difference is that community-based FLOSS development does in fact seem to rely less on explicit assignments
20 of work, as has been suggested in the anecdotal literature on FLOSS development. First, we did not observe evidence of a
21 hierarchy in assigning tasks in FLOSS. By lack of hierarchy, we mean that individuals do not command or direct others to work
22 on a task as might a project manager. Instead, they use phrases such as “would you please,” “if you have time, can you...,” or
23 even discuss how to assign a task instead of assigning it directly. Even assignment to a specific person is qualified: “If you’re
24 interested you can ...” or “feel free to figure out why and fix it if you like.”
25

26 Second, we observed broader participation in the work on tasks. Due to the openness of the FLOSS teams, active users can take
27 on development tasks rather than the process being restricted to the official development team. Indeed, for all three teams, the
28 most common form of task assignment was self-assignment, that is, volunteering to work on a particular task. These user-
29 developers do not wait to be given something to do, but rather step forward to work on tasks that catch their interest. This form
30 of self-assignment may be an emergent phenomenon. A participant in GAIM had this to say, “I don’t know how
31 assignments work, but can I can dibs on this?” In the absence of guidelines or rules, self-assignment may
32 emerge to fill the need for a coordination mechanism to manage this part of the collaboration.
33

34 One likely explanation for these differences is that FLOSS development teams are substantially composed of volunteers. As a
35 result, task assignment in FLOSS needs to be based primarily on personal interest, not specialization or ownership. Self-
36 assignment appears to play a role in bolstering the legitimacy of the action suggested by the poster, making it more likely that
37 the group will consent to the poster’s preferences. Legitimacy is the right of a participant to be heard and respected in a forum
38 and a source of influence on the forum’s decisions. Formal groups with predefined memberships assess legitimacy up-front. In
39 proprietary software development, the right to make suggestions for features is often reserved for the specification writers or
40 customer facing marketing engineers. On the other hand, for informal groups seeking new contributors, it is not possible, nor
41 desirable, to make such prequalifications. The prevalence of self-assignment supports the anecdotal suggestion that in FLOSS
42 projects in general, legitimacy is linked to action, the value that “code speaks louder than words.” After all, if someone is willing
43 to use their own time to implement a feature or fix a bug (or even better, if they have actually already done so), it is more difficult
44 for other members of the team to deny them that opportunity.
45

46 The FLOSS approach results in a task assignment process similar to the market approach suggested by Crowston (1997). In a
47 market form of task assignment, a description of each task is sent to all available agents. Each evaluates the task and, if interested
48 in working on it, submits a bid to work on the task and the task is then assigned to the best bidder. However, the FLOSS process
49 differs in that there may not be an explicit assignment of the task; rather, a developer can choose autonomously whether to work
50 on a bug. The use of this task assignment mechanism in the FLOSS development process is consistent with predictions of the
51 effect of information and communications technologies (ICT). ICT makes it easier to gather information about available resources
52 and to decide which resources to use for a particular task, thus favoring coordination mechanisms that are more information-inten-
53 sive. At a macro level, Malone et al. (1987) suggest that decreased coordination costs favor more extensive use of markets, which
54 usually have lower costs but require more coordination activities, over vertical integration, which makes the opposite trade-off.

1 Of course, reliance on this kind of assignment does have several drawbacks. First, anyone can choose to contribute to the project,
 2 even if they are not good at it or have no relevant experience. As a result, the quality of team member output often needs further
 3 investigation by developers and other users. In some projects, developers chose to forego these contributions rather than spend
 4 the time evaluating the output. Second, because multiple developers may be working on the same parts of the project, projects
 5 must develop code management practices that allow multiple changes to be integrated. Many projects rely on code management
 6 systems such as CVS, and the design of these tools has become a pressing topic in FLOSS discussions (see the recent discussion
 7 of source code control tools for Linux).

8
 9 Finally, proprietary task assignment and resource planning relies on the participants being reliable; the employment relationship,
 10 with its clear penalties for nonperformance gives managers a reliable expectation that the work assigned will be carried out. By
 11 contrast, it has been suggested that FLOSS participants are relatively unreliable (Michlmayr 2004). The data in this study provide
 12 some support for this idea, although we did not directly measure the motivations or volunteer status of the participants so this
 13 cannot be fully confirmed. Much of the self-assignment is qualified with phrases like “if I have time,” “if I get some free time,”
 14 or, citing real-world time constraints, “I will submit this in a couple of day (have to finish some professional work first ... :/).”
 15 This uncertainty can create problems in the usability of output and timeliness of schedules. People finish their tasks according
 16 to time and interest, which may affect the effectiveness of the project. Because of uncertainty of code ownership, and the
 17 distributed nature of the participants, it is hard to track the status of developers’ work, especially when it is self-assigned. These
 18 trade-offs make sense in a volunteer activity where the service of individuals is on their own terms.

19 Conclusion

20
 21 Software development involves many dependencies and a variety of mechanisms are used to manage them. For example, the
 22 possibility of duplicate tasks may be ignored or may be investigated before engineers attempt to solve the problem. Dependencies
 23 between tasks and the resources needed to perform them are managed by a variety of task assignment mechanisms, such as
 24 managerial decision-making based on expertise, workload in proprietary development organizations, or volunteering in FLOSS.
 25 The choice of coordination mechanisms to manage these dependencies results in a variety of possible organizational forms, some
 26 already known (such as change ownership) and some novel (such as voluntary selection of work by developers). Understanding
 27 the roles and tradeoffs of these mechanisms will help guide managers interested in transferring practices from FLOSS
 28 development into their own organizations and this paper provides the first empirical investigation of these practices in FLOSS
 29 development.

30
 31 Our results suggest several avenues for future research. First, our results are based on just three projects. Studies of other projects
 32 are needed to confirm the pattern of coordination mechanisms reported here and to identify factors affecting the choice of
 33 mechanisms. For example, we expect that task assignment in company-sponsored projects works differently than in community-
 34 based projects. Further studies could examine the role of project culture, leadership, or power. As well, future studies should
 35 seek to identify FLOSS-specific coordination mechanisms used to manage other dependencies. For example, there has been some
 36 discussion of how FLOSS manages the usability dependency between system development and use that is usually managed by
 37 a formal requirements process (Scacchi 2002). Our study has only scratched the surface of this aspect.

38
 39 Finally, future studies could examine the link between coordination and other group processes. For example, task assignment
 40 appears to play a role in the development of shared mental models for the project teams. “Assignment to unspecified person”
 41 provides a discursive and informal but continuous source of to-do items and the desired future of the project (e.g., “I’d really
 42 appreciate it if maybe someone could write the list suggesting the use of ‘sound themes’” or “I think it’d be cool if someone
 43 modified the image”). Yamauchi et al. (2000) identified the practice of maintaining to-dos at various levels of specificity as a
 44 feature of FLOSS development. Similarly, assignment to a specific person also communicates the assigner’s understanding of
 45 the other participants’ skills and areas of knowledge. “Sarah, can you please clarify for me a few things about this design?” or
 46 “BTW, have you talked with Alvin at all? I think he has something like your global status drop-down somewhat implemented
 47 too” not only creates a task for Sarah or the question asker, but announces to the rest of the community that Sarah probably knows
 48 something about that design and that Alvin has experience with status drop-downs. In this way, practices that build shared mental
 49 models are embedded in coordination mechanisms and as such do not require explicit additional work for participants, minimizing
 50 the effort required to collaborate.

51
 52 For managers of traditional software groups, perhaps the most interesting result is use of volunteering as an assignment
 53 mechanism. On their face, the concerns noted above about the problems with voluntary assignment suggest that the task
 54 assignment practices of FLOSS developers would be hard or undesirable to transfer to mainstream software development.

1 However, these coordination mechanisms may not be limited to volunteer projects only. Knorr-Cetina (1999) identified similar
2 “gentle management” in the high energy physics (HEP) experiments at CERN. She writes of “a marked self-organization of the
3 experiments observed, a form of voluntarism” and relates a coordinator using a gentle approach in which he hopefully finds
4 volunteers—somebody willing because they have a particular interest, something which happens whenever new tasks require
5 attention (p. 179). She continues, “it is not ‘morale’ per se that is [the origin of self-organization or volunteerism], but the
6 discourse that expresses necessities and interdependencies and allows for groups ‘freely’ (with a little nudging on the part of
7 conveners and spokespersons) to respond to demands.” Self-assignment and gentle assignment to others, then, is also found
8 within mission-critical work involving the spending of substantial financial and scientific resources.

9
10 Another example of the use of these techniques within a nonvoluntary environment is the practice reported at Google where
11 engineers are allowed one day a week to work on whatever they want to work on, as did 3M (see, for example,
12 http://www.oreillynet.com/pub/a/network/2005/03/16/etech_2.html). The innovations in the Google Labs (labs.google.com)
13 are said to be the result of these self-assigned activities. There is scope for the emergent practices identified in this study to be
14 imaginatively applied in other contexts.

15 **Acknowledgments**

16
17 This research was partially supported by NSF Grants 03-41475 and 04-4468. Any opinions, findings, conclusions, or
18 recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National
19 Science Foundation. This paper has benefitted from suggestions from Kathy Chudoba. The authors also thank the FLOSS
20 developers who contributed to the research.

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