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Coping with distance: An empirical study of communication on the Jazz platform

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Abstract

Global software development - which is characterized by teams separated by physical distance and/or time-zone differences - has traditionally posed significant communication challenges. Often these have caused delays in completing tasks, or created misalignment across sites leading to rework. In recent years, however, a new breed of development environments with rich collaboration features have emerged to facilitate cross-site work in distributed projects. In this paper we revisit the question "does distance matter?" in the context of IBM Jazz Platform – a state-of-the-art collaborative development environment. We study the ecosystem of a large distributed team of around 300 members across 35 physical locations, which uses the Jazz platform for agile development. Our results indicate that while there is a delay in communication due to geographic separation, teams try to reduce the impact of delays by having a large percentage of work distributed within same/few time zones and working beyond regular office hours to interact with distributed teams. We observe different communication patterns depending on the roles of the team members, with component leads and project managers having a significantly higher overhead than development team members. We discuss the practical implications of our findings in terms of some best practices that can help lessen the impact of distance.

Categories and Subject Descriptors D.2.7 [**Software Engineering**]: Distribution, Maintenance and Enhancement.

General Terms Measurement, Human Factors.

Keywords *Communication,Distributed Development,Delay*

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1. Introduction

Distribution of team members across several locations is now common in software development projects. Indeed, many of the benefits of global software development – such as availability of a large skill pool, access to emerging markets, cost arbitrage etc. - are leveraged out of this very distribution. But along with these benefits, distributed development also brings several challenges [11]. Many of the difficulties that arise in practice can be traced to inadequate communication and lack of awareness between team-members, separated by distance and time-zone differences. Early evidence had shown that these communication gaps frequently lead to inefficient information flows, delays in completing tasks, misalignment and rework [5, 12].

These challenges were an important trigger for a new breed of Collaborative Development Environments (CDEs) that have emerged in the last few years. CDEs are meant to provide a "virtual space wherein all the stakeholders of the project – even if distributed by time or distance – may negotiate, brainstorm, discuss, share knowledge, and generally labor together to carry out some task, most often to create an executable deliverable and its supporting artifacts" [13]. For example, the IBM Jazz platform1 facilitates distributed development in significant ways; it offers mechanisms to discuss and track units of work as they are acted upon by developers who may not have any face-to-face contact. The IBM Rational Team Concert2 based on the Jazz platform, is now widely used by distributed teams to coordinate development work. The success of CDEs have led some to pose the question: "Does Distance Still Matter?" [8]. Indeed, how the distributed development teams of today use CDEs to communicate across sites and

[1] http://www-01.ibm.com/software/rational/jazz/

[2] http://www-01.ibm.com/software/awdtools/rtc/

time-zones, is an interesting topic of research, which has motivated us to undertake the study reported in this paper.

The "distributed" in distributed software development has several dimensions. As Gumm [1] has pointed out, physical distribution, organizational distribution, temporal distribution, and distribution among stakeholder groups all play significant roles in a distributed development project. Physical distribution is a characteristic of distributed people across different offices, cities or countries. Temporal distribution refers to work-hour synchronicity or the time during which team members are available for real-time interactions. Different types of stakeholders groups exist in each project – managers, testers, developers, etc., each with different perceptions and responsibilities about a project. Organizational distribution refers to distribution of the team across organizations. Out of these dimensions, physical and temporal distribution are closely linked to one another, and by far the most ubiquitous in global software development. In this paper we focus on the interplay of these dimensions as they introduce delays in project communication and require teams to devise mechanisms to cope with such delay. We also explore the relation between the roles of developers and their position in the network of interactions. As the subject of our study, we have selected a large, globally distributed project in IBM that has been developing a product on the IBM Jazz platform for a number of years. The contributions of our work can be summarized as:

- We explore the origins of delay in project communication in terms of lack of work-hour synchronicity across different locations.
- We examine how teams try to minimize the effects of delay through pragmatic distribution of work and flexible working hours.
- We use constructs from social network analysis to understand how developer roles relate to interaction.

Our study was guided by a series of questions related to communication patterns in global software development, which we introduce next in Section 2. The following section describes the project under study and the key terms associated with it. Section 4 provides a detailed report on the findings from our study in relation to the questions. In Section 5, we discuss the practical implications of our findings in terms of best practices that can help lessen the impact of distance. Related work is described in Section 6, while Section 7 concludes the paper.

2. Study Questions

Our study questions center on three of the four key dimensions of distribution [1] – physical, temporal, stakeholder groups. As the development was done within IBM, we did not look into the fourth dimension of distribution that occurs across organizations. These questions are introduced below.

Q1: Does lack of work-hour synchronicity across different sites introduce delay in project communication?
Previous studies indicate that the distribution of work across multiple-sites hinders informal communication among developers who need to work together [5]. Synchronous communication becomes less common due to time zone and language barriers. We evaluate the extent of delay in communication caused due to distribution across geographic locations. This question relates to the temporal dimension of distribution.

Q2: How do distributed teams cope with communication delays?
Synchronous communication is hindered by physical location of teams. Assigning work to different work sites in a manner that minimizes the need for multi-site communication has been recommended by earlier studies [4]. We examine the distribution of work and communication (occurring in the context of work) across teams. This question relates to physical dimension of distribution.

Q3: Do the roles of team members' influence their communication behavior and their social networks?
Stakeholder groups play a key role in project communication. Team leads, testers, developers have different responsibilities and perceptions about the software being developed [2]. This question relates to the impact of distribution on different stakeholders.

3. Project Background

This section introduces the project under study, describes the collaborative development environment used in the project and explains the key terms associated with the study.

3.1 Project and Environment Overiew

The project under study has been developing a software product on the Jazz platform for more than 3 years using Java and JavaScript programming languages. The project team comprises close to 300 developers and component leads, spread over 35 locations and 19 time zones. The team members belong to multiple functional areas of the product being developed.

The project uses IBM Rational Team Concert (RTC) as the development platform. IBM RTC provides mechanisms for creating and managing a Scrum-based project. In IBM RTC, a project area that refers to a project can be created. Users and their specific roles can be defined. Sprints with their time lines can be recorded. A product backlog is associated to a project area and further a sprint backlog for each sprint can defined. The sprint or product backlog is a set of work items. A work item is a unit of work. Work

items can be of different types – plan, user story, task, defect, enhancement, test case, etc.

Each work item consists of a set of basic attributes that are useful for tracking it; these include, name, unique identifier (ID), description, iteration it has been planned for, creator (name of the team member who created the work item), owner (name of the team member who is responsible for successfully completing the work item), creation date, closure date and priority. The code changes made against each work item can be committed into the version repository as change sets.

Discussions between team members are recorded into the tool and associated with the work item as comments. Each team has daily meetings within the site. There is a weekly team meeting that includes multiple sites for each functional area. While team members may use face to face (when possible) and telephonic meetings to coordinate work, they generally record most of the important communication along with the work item to enable other team members from different sites in understanding the context of the work item.

3.2 Key Terms and Definitions

This section briefly explains all the terms used in the context of the project and our study.

Team Area: The project consists of 35 functional areas called team area. Each team area primarily represents a component or a module of the system. There are a few team areas representing project management based activities such as build and release of the system, user documentation and testing

Work Item: A work item represents a single unit of work. There can be different types of work items. In the context of our study, we focus on task, defect and enhancement work items which represent the development or build activities. A work item is associated to a team area.

Comments/Discussion: All interactions in the project are in the context of the development activities or work items. Hence, any team member can add comments to the work item. Each comment has the discussion text, the name of the team member and the date and time of its creation stored along with the work item.

Site (City, Country, and Time Zone): Site represents the physical location of the work place of team members. The city, country and time zone of each site are identified for each team member. This information is available in the people management system within IBM.

Overlap Time: Overlap time represents the time period when team members are available in the context of their working hours. In our study, 9 AM – 6 PM is considered as the regular work hour window. Hence, two team members working in the same time zone have a 9 hour overlap time as they are available for synchronous communication for all the 9 hours of work hour window.

Comment Response time: We use the assumption as conceptualized by Wolf et al [8]. Considering that a comment thread on a work item represents a conversation about the work item, a comment is assumed to be a reply to the previously created comment. We measure the intervals between the creation times of successive comments, and consider this as the Response Time of the second comment with respect to the first.

Work Item Response Time: The Response time for a work item is the time interval between the first and the last created comments for a work item.

Team Roles: Team members play different roles in project development. A ***contributor*** to a team area owns work items and develops the system. A ***component lead*** is a scrum master responsible for defining the sprint back log, reviewing the architecture of the component and assigning the work items to the contributors of the team area (which may include the lead herself). The ***project management committee*** is responsible for the project-wide coordination that includes iteration planning and release of the entire system.

4. Data Analysis and Results

In this section we describe the data analysis methods and findings in relation to each of our questions. For our study, we evaluate the release of the software system spanning over 16 months with 10,967 work items. There were 4311 work items having *at least* two distinct users making comments, and these are the work items we selected for studying communication patterns. Of the 300 team members,

Table 1 Comment Response Time based on the Overlap Working hours of the team members in discussion

Maximum Response time of 5 days						
Overlap working hours across time zones	# of conversations (pairs of comments)	% of conversations	25 PERCENTILE (HRS)	MEDIAN (HRS)	MEAN (HRS)	75 PERCENTILE (HRS)
0-1 hrs	2354	14.54%	2.23	8.18	14.75	16.70
2-3 hrs	1772	10.95%	0.50	3.44	10.37	12.69
5-6 hrs	1275	7.88%	0.67	2.76	11.69	14.82
7-8 hrs	1454	8.98%	0.40	1.37	9.11	9.13
9 hrs	9334	57.66%	0.43	1.73	10.20	12.18

there were 200 developers who had contributed to source code changes for the release under study. The remaining team members were testers, system administrators, user assistance experts and the project management team or developers contributed to a different release of the system. Note that there are over 6000 work items that either had no discussions, or had comments from only one user. This is not surprising since many work items may not require coordination across multiple developers (for example, a work item may only depend on other work items owned by the same developer.) Also, several defect work items are related, or are duplicates, and only one may be taken up for discussion.

We now discuss our findings for the first question.

Q1. Does lack of work-hour synchronicity across different sites introduce delay in project communication?

To examine the impact of time synchronicity - or the lack of it - on communication delays, we compute the response times for pairs of sequential comments that have been exchanged between any two team members in the context of a work item. We categorize the response times by time synchronicity of the team members – the overlap work time of the team members. Table 1 shows the mean, median, lower and upper quartile measures of the response time. On manual analysis of comments on work items and their responses, we realized that there are mainly two types of exchanges that occur. The first type is ad-hoc communication that occurs to clarify the details of work, handle exceptions, correct mistakes etc. where typically synchronous response is expected. It is here that the time-zone differences have the potential to cause significant delays. We limit the maximum response time for ad-hoc communication to 5 days considering the possibility of holidays and weekends. The second type is planned communication, where a longer timeframe (e.g. several days to few weeks) is needed to provide a response, often on the completion of work or update of status. For such exchanges, time-zone differences are unlikely to make any significant difference.

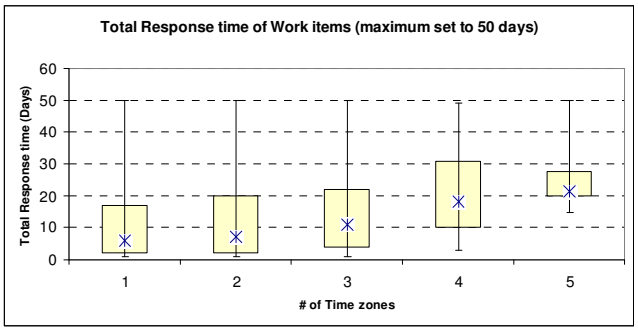


Figure 1 Box plot of the work item response times categorized by the number of sites involved in the work item communication

Hence, we focused primarily on the analysis of ad-hoc communication. With reference to Table 1, the median response times vary from 1-2 hours (when there is significant overlap in working hours) to over 8 hours, when the overlap is minimal (0-1 hour). We also notice that with a small increase in overlap (2-3 hours), the delay in response comes down appreciably. Finally, it is interesting to note that the response times for cases where there is full synchronicity (9 hours overlap), is higher than that for 7-8 hours overlap. We hypothesize that this may be due to the fact that people in the same time-zone are more likely to have other means of communication (e.g. face-to-face, telephone etc), through which an initial response may be provided before formally updating the discussion thread to inform other team members.

We also compute the total response time for each work item. We limit the maximum response time to 50 days as the largest iteration during our study was 50 days long, and we wanted to focus on communication that is relevant for a specific iteration. Figure 1 shows the box plots of the total response time of all work items categorized by number of time zones. The horizontal cross in the middle shows the median value. The bottom/top line of the box shows the 25th/75th percentile. The box shows where 50% of the data lie. The whiskers show the minimum and maximum response time values. We see that with an increase in the number of time-zones from where users communicate on a work item, there is a steady increase in the total response time.

To address Q1 in summary, we may say that response times are impacted by geographic distance, measured in terms of the time synchronicity of the interacting team members. The response time to work item comments is high when the work hours between the team members do not overlap. Even a small window of overlap time reduces the response times considerably. Finally, more is the number of time-zones that need to be involved in discussing a work item, the higher is the total response time.

Q2. How do distributed teams cope with communication delays?

Given that time-zone differences can cause significant delays, a natural question to ask is how distributed teams cope with the challenge. From Table 1, we see that ~58% of comments/responses happen within the same time-zone. This suggests that the distribution of work may have been done in a manner that localizes dependencies to the extent possible, and this is what we decided to explore in more depth. At the same time, ~25% of communication exchanges happen between time-zones with little overlap in working hours (0-3 hours). Given this, we wanted to explore if global development calls for "stretchable" working hours, where team members frequently communicate beyond regular hours to stay in sync with remote colleagues.

To examine the extent of distribution of interactions across sites, we identify the city, country and the time zone of the team members involved in the communication. Figure 2(a) shows the box plots containing the number of work items with discussions spanning across cities, countries and time zones. As the plots indicate, 75% of the work items have communication spanning within 2 cities, countries and time zones. We also found that 99% of the work items have discussions restricted to within 3 time-zones. Thus, localization of dependencies seems to have been a guiding principle in work allocation. The maximum number of distributed team members involved in discussions is in 9 cities across 6 time zones.

As discussions on a work item are primarily by team members belonging to the team area of the work item, we also evaluate the distribution of team areas across sites. The box plots in Figure 2(b) shows that 75% of teams lie within 4 cities and 3 countries or time zones. We found a team having maximum distribution of developers across 10 cities. The team was dealing with user documentation of the software being developed hence was divided across all the major cities where the software was being developed.

However, even the distribution of a team area across 3 time-zones seemed to be on the high side, as far as localization of work is considered. Hence, for each team, we next reviewed the relative percentage of team members across the different time-zones. This is shown in Figure 3, for some of the largest team areas. It is clearly evident that while a team may span several time-zones, the large majority of the team members reside in the same time-zone or at most in two time-zones. For example, while team area 1 is distributed over 4 time-zones, 75% of the team is in the same time-zone, and a similar trend is observed for the other team areas as well. Hence, there seems to have been a conscious effort towards localizing teams, so that most of the team-members who need to work together may enjoy the benefits of time synchronicity.

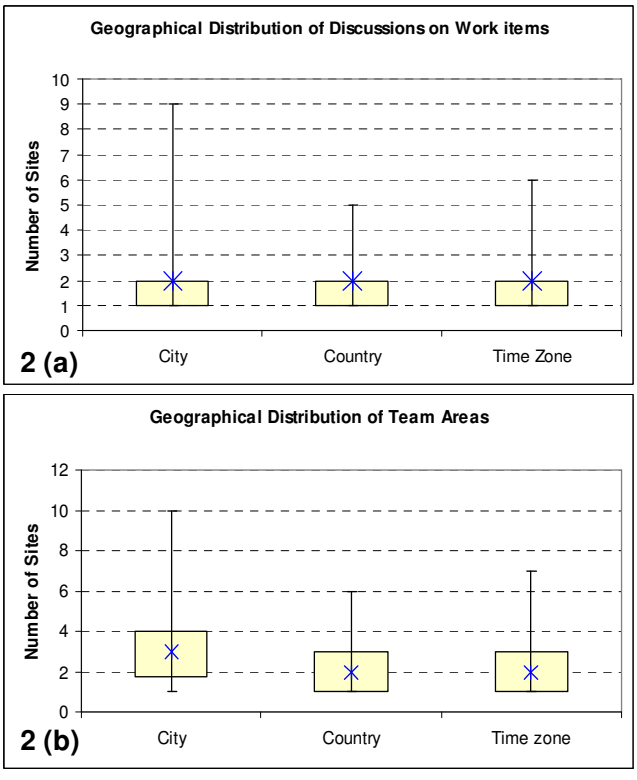


Figure 2 Box plot of (a) geographical distribution of users discussing on work items (b) geographical distribution of team areas

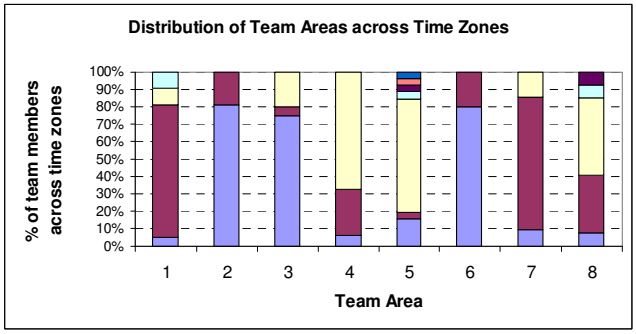


Figure 3 Percentage of team members across time zones for large team areas

Finally, we report on the other mechanism used to deal with the lack of time synchronicity – increasing "virtual" synchronicity by communicating with remote colleagues outside of regular office hours. For each team member, we identify when the comment was made by him/her (the local time based on the time zone of the team member's work location). Figure 4 shows the percentage of discussions that occur through the day aggregated for all the discussions in the release. As we can see, the number of discussions increases sharply with the start of regular working hours in the morning; it then reduces around lunch time, before increasing again in the afternoon, peaking close to the end of regular office hours (probably to sync up with colleagues before closure) and then trails off.

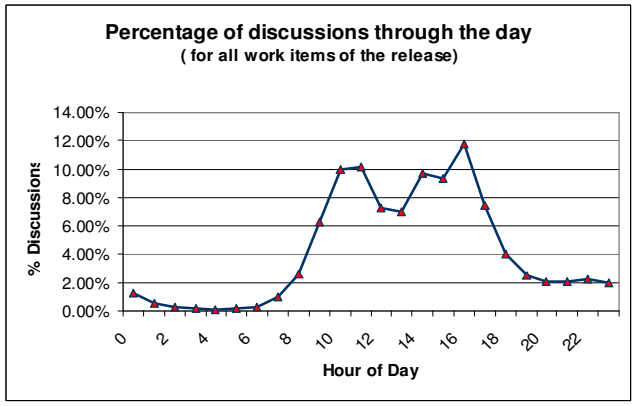


Figure 4. Percentage of Discussion through the day

Table 2 Percentage of discussions made by members with different roles

Role	Members	Comments	Median (# of comments per member)	Mean (# of comments per member)
Contributor	174 (68%)	15462 (42%)	28	88.86
Component Lead	62 (24%)	16115 (44%)	96.5	259.92
Project Management Committee	20 (7%)	5323 (14%)	146	266.15

However, a steady stream of discussions is sustained through the evening extending till almost midnight or even beyond, as team members seek to stretch the time synchronicity with remote sites. Overall around 20% of the discussions happen out of work-hours (6 PM to 9 AM),

Thus the second question can be answered as: A distributed project can cope with distance by restricting its functional teams within a few sites/time-zones, with a large majority of team members residing in the same time-zone. The team members also spend a considerable amount of time out of office hours to co-ordinate with team members across time zones.

Q3. Do the roles of team members influence their communication behavior and their social network?

Our final question seeks to explore the impact of team roles on communication. First, we look at the distribution of discussions against work items across each of the roles contributor, component lead and project manager. We considered only roles related to the development of the system – we have not considered tester, administrators, etc. Table 2 shows the percentage of team members belonging to different roles and the percentage of discussions they have contributed. It is clear that component leads have a significantly higher communication overhead compared to contributors, and project managers need to communicate even more. A component lead contributes to a large number of discussions as (s)he is responsible for several coordination activities – reviewing architecture of the component, defining sprint backlog, reviewing the work items and assigning them to the team. Project managers have an even wider span of responsibility, as they need to ensure project wide coordination, as well as engage in iteration planning and project releases on a large scale. We also discovered that higher coordination responsibilities also lead to a higher percentage of communication beyond office hours. For example, component leads have 25% of their communication beyond office hours, compared to 17% for contributors.

To understand the impact of roles on the collaboration structures in a project, we constructed a communication-based social network that includes all team members and their communication. We create a network of developers who have commented on work items. With reference to Figure 5, each vertex of talk network is a developer and an edge exists between two developers if both of them have commented on at least one work item. In the rare instance of the owner of a work item has not having commented on the work item, (s)he is also connected by edges to all others who have commented on the work item. Talk network

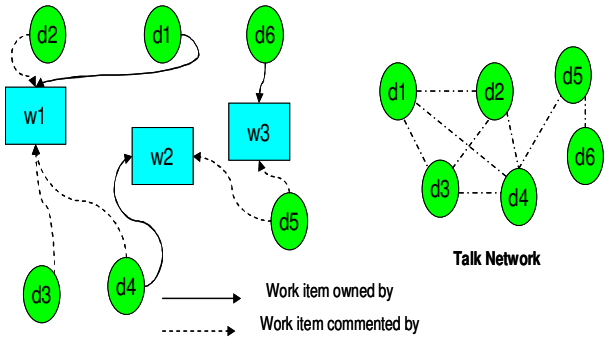
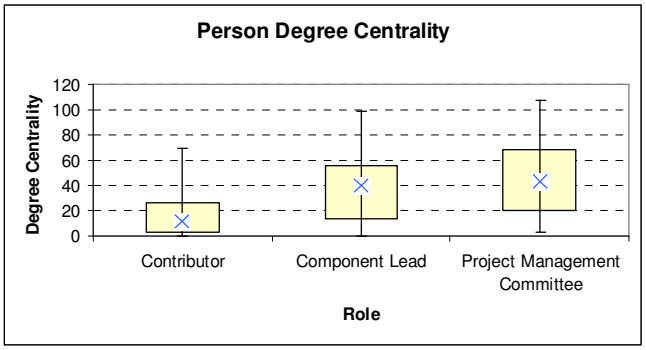


Figure 5 Communication based Talk Network



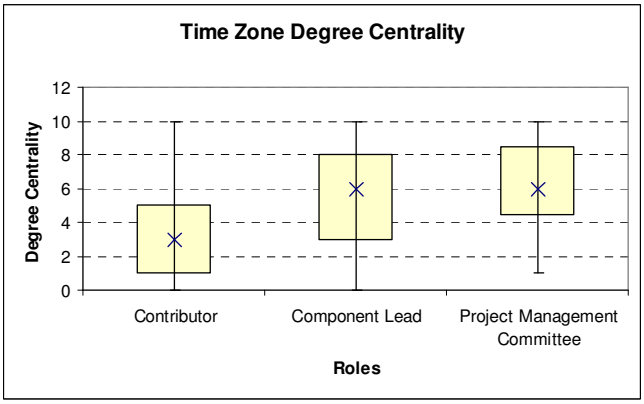


Figure 6 Person degree centrality, Time zone degree centrality of team members with different roles

is generated for the set of developers who own at least one work item. In Figure 5 edges exist between d1, d2, d3 and d4 as d1 is the owner of work item w1 and d2, d3, and d4 have commented on w1; similarly for edges between d4 and d5 as well as d5 and d6. We have made the links between vertices non-directional. We investigate a key measures used to understand the communication structures across roles.

Degree centrality: In a network, degree centrality of a vertex is its degree, sometimes expressed as a ratio with the highest possible degree in the network [10]. In our context, degree centrality of a developer indicates the number of other developers (s)he is collaborating with.

The box plot of Person degree centrality of different roles in Figure 6 shows a high median (40) for Component Leads and Project Management Committee (PMC) as compared to Contributors (12). A component lead interacts with several people for all the coordination activities related to his/her team area. We compute the degree centrality index based on the time zone of team members in the network to identify the communication needs of different roles across time zone. With reference to figure 6, 75% of contributors have communication spanning within 3 time zones, while for component leads and project management committee members, this can go up to 8 time zones.

We conclude that the role of a team member has a significant influence on his/her collaboration patterns.

5. Discussions

While quantitative analysis of communication data (as reported above) has helped provide clear answers to our study questions, it is pertinent to ask what implications all of this has for the successful governance of a globally distributed project. Below, we summarize some of the key insights that can be gleaned from the results of our study.

- Communication delays due to distance are a reality – hence this needs to be accounted for during estimation, project planning and work distribution in global projects.
- Even a 2-3 hour overlap in working hours can significantly reduce delays between dependent sites. Without this, however, the response time grows sharply and can extend over working days.
- In general, more the number of sites (time-zones) that need to collaborate on a task, larger will be the delays. Hence, it is advisable to localize component ownership as far as practicable.
- Team members on global projects are likely to spend a significant amount of time beyond regular office hours communicating with remote colleagues. This calls for providing more flexibility in their working environment.
- The coordination responsibilities of component leads (and management staff) make them the focal point of many communication links, generally extending across a number of sites and time-zones (thereby, also cultures). Thus, together with technical acumen, component leads need to possess strong social skills to ensure smooth collaboration across sites.

6. Related Work

As mentioned, a significant body of research has been reported around the general theme of distributed software development. In a pioneering study Herbsleb and Grinter highlighted the “extraordinary communication and coordination problems" faced by distributed development teams [4]. They advocated modular design to address some of these problems, but pointed out that modular design by itself may not be sufficient to avoid the ill-effects of distance. In a subsequent paper, Herbsleb and Mockus analyze information from source code change management and survey of development team members to report a key finding: distributed work items take more than twice the amount to time to be completed vis-a-vis similar items with entirely collocated work [5]. The detrimental effect of distance on work completion time has also been corroborated in other studies [3]. Taweel et al. identify the factors of better management of communication, knowledge and co-ordination across distributed teams for leveraging the full potential of distributed software development [7]. Hinds and McGrath report results from the correlation study of 33 research and development teams to conclude that an informal hierarchical structure facilitated coordination in distributed teams, even as collocated teams communicate more smoothly in flatter organizational structure [6].

Collaboration in Jazz development using constructs of social network analysis have been studied at depth in [8] and [9] . In [8], the Wolf et al. examine the communication structure of a distributed, project-wide Jazz team – in the context of their larger research question, “does distance still matter?” – and conclude that redundant communication ties exist across project participants located in different geographies; and barring the measures group degree centralization and group betweenness centralization, significant differences do not exist in other measures between communication structures of co-located and multi-site Jazz teams. The authors consider the response time of a work item as the average of time interval between each pair of comment in the comment thread. Considering the average of time intervals between pairs of comments for a work item obscures the impact of physical and temporal distance as a there could be a high proportion of comments in a comment thread for a work item occurring within the same time zone or the same site. In [9] the authors report results

at predicting build failures using a Bayesian classifier model trained by social network metrics from the respective communication network of developers around successful and failed build in the past.

7. Conclusions

In this paper, we have reported on a study of communication characteristics of team members in a large, globally distributed software development project that uses the IBM Jazz platform. Our results indicate that while there is a delay in communication due to geographic separation, teams try to reduce the impact of delays by having a large percentage of work distributed within same/few time zones and stretching beyond regular work hours to interact with distributed teams. In general, component leads and project managers were found to have a significantly higher communication overhead than development team members. We discuss the practical implications of our findings in terms of some best practices that can help lessen the impact of distance. In future, we would like to leverage our findings to develop quantitative models of communication and delays in a distributed project that can aid project planning and estimation.

References

[1] D. C. Gumm. Distribution dimensions in software development projects: a taxonomy. IEEE Software, 23(5):45–51, 2006.

[2] J.R. Evaristo and R. Scudder, Geographically Distributed Project Teams: A Dimensional Analysis, Proc. 33rd Hawaii Int'l Conf. System Sciences (HICSS 00), IEEE CS Press, 2000, pp. 7052–7063.

[3] Ehrlich, K., Valetto, G., and Helander, M. Seeing inside: Using social network analysis to understand patterns of collaboration and coordination in global software teams. In *Proceedings of the International Conference on Global Software Engineering* (Washington, DC, USA, 2007), ICGSE '07, IEEE Computer Society, pp. 297–298.

[4] Herbsleb, J. D., and Grinter, R. E. Architectures, coordination, and distance: Conway's law and beyond. *IEEE Softw. 16*, 5 (1999), 63–70.

[5] Herbsleb, J. D., and Mockus, A. An empirical study of speed and communication in globally distributed software development. *IEEE Trans. Softw. Eng. 29* (June 2003), 481–494.

[6] Hinds, P., and McGrath, C. Structures that work: social structure, work structure and coordination ease in geographically distributed teams. In *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work* (Banff, Alberta, Canada, 2006), ACM, pp. 343–352.

[7] Taweel, A., Delaney, B., Arvanitis, T., and Zhao, L. Communication, knowledge and co-ordination management in globally distributed software development: Informed by a scientific software engineering case study. In *Global Software Engineering, 2009. ICGSE 2009. Fourth IEEE International Conference on* (2009), pp. 370–375.

[8] Wolf, T., Nguyen, T., and Damian, D. Does distance still matter? *Softw. Process 13*, 6 (2008), 493–510.

[9] Wolf, T., Schroter, A., Damian, D., and Nguyen, T. Predicting build failures using social network analysis on developer communication. In *Proceedings of the 31st International Conference on Software Engineering* (2009), IEEE Computer Society, pp. 1–11.

[10] De Nooy, W., Mrvar, A., and Batagelj, V. Exploratory Social Network Analysis with Pajek. Cambridge University Press, Jan. 2005

[11] Sengupta, B., Chandra, S., and Sinha, V. A Research Agenda for Distributed Software Development. In Proceedings of International Conference on Software Engineering (ICSE), 2006, pp 731-740.

[12] Herbsleb, J.D. and Moitra, D. Global Software Development. IEEE Software, March-April 2001, pp 16-20

[13] Booch, G. and Brown, A. Collaborative Development Environments. Aadvances in Computers, Vol. 59, Academic Press, August 2003.

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