Communication in Distributed Software Development: An exploratory study of Hybrid and Remote Teams

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Abstract. *In Distributed Software Development (DSD) projects, communication is essential for collaboration among geographically dispersed members. Tools such as Slack support communication flows and activity coordination, helping teams overcome challenges imposed by distance. The growing adoption of distributed models has generated new team arrangements and reconfigured communication dynamics, highlighting the need for empirical studies on these contexts. This study aimed to understand communication dynamics in different DSD team arrangements, hybrid and remote. An exploratory multiple case study was conducted over 13 months, analyzing Slack data from two projects within the same institutional context in Brazil, complemented by participant observation and document analysis. The results show that both teams predominantly use private channels, suggesting this is a structural characteristic of communication via Slack, and that communication is shaped mainly by the structures established in collaboration tools, being more influenced by factors such as team size, role diversity, project domain, and management practices than by the team arrangement itself.*

1. Introduction

The COVID-19 pandemic accelerated the adoption of distributed work models in software development, forcing organizations to rapidly shift to remote environments [Ford et al. 2022]. Although distributed work is not a recent phenomenon [Herbsleb and Moitra 2001], the pandemic intensified its adoption, leading many companies to experiment with remote and hybrid configurations [Šmite and Moe 2023, Šmite et al. 2023b]. Moreover, an increasing number of organizations have continued to pursue distributed arrangements even after the pandemic period [Quadros et al. 2022].

Distributed Software Development (DSD) results from the geographical dispersion of specialized labor, reduced costs, and increased client interaction [Garro-Abarca et al. 2021]. DSD can occur at different levels of dispersion, giving rise to various team arrangements [Audy and Prikladnicki 2007, Santos and Ralph 2022].

This study focuses on two: *hybrid*, where some members are co-located while others work remotely, and *remote*, where all members work from individual workspaces [Santos and Ralph 2022]. Properly characterizing these arrangements helps identify potential challenges and their implications for communication and coordination [Santos and Ralph 2022].

Despite its advantages, DSD teams face challenges such as cultural differences, time zones, and language barriers [Bogolii 2023], which directly impact communication [Garro-Abarca et al. 2021]. While communication in DSD has been widely discussed [Licorish and MacDonell 2015, Leitão Júnior 2021, Thanthony et al. 2022, Silva et al. 2022], many studies address these topics without detailing the team arrangement in which challenges are identified [Šmite et al. 2010]. Furthermore, there remains a lack of empirical studies examining communication dynamics in collaborative tools at the team level [Stray et al. 2019, Stray and Moe 2020], particularly in the post-pandemic context where hybrid and remote models coexist [Šmite et al. 2023a].

This study focuses on *Slack*, a Team Communication Platform (TCP) widely adopted by software development teams [Stray et al. 2019], and the subject of multiple empirical studies on communication patterns [Stray et al. 2019, Stray and Barbala 2024], coordination mechanisms [Berntzen et al. 2022, Stray and Moe 2020], and tool impact on team dynamics [Mezouar et al. 2022]. Its channel-based architecture and available analytics make it a suitable data source for examining communication in DSD, providing a comparable lens for examining computer-mediated communication across different team arrangements. Accordingly, this study seeks to answer the following research questions: **RQ1:** What are the characteristics of communication volume and visibility on Slack in hybrid and remote teams in DSD projects? **RQ2:** How are communication channel structures organized in each team arrangement? **RQ3:** What communication themes emerge in each team arrangement?

2. Background and Related Work

2.1. Communication in DSD

Communication serves as a central axis in DSD, determining the success or failure of projects [Herbsleb and Moitra 2001]. The distance in distributed settings creates obstacles [Audy and Prikladnicki 2007], requiring teams to implement formal and informal channels to facilitate information sharing and work coordination [Stray and Moe 2020]. Although communication tools facilitate interaction [Herbsleb and Mockus 2003], the absence of face-to-face communication often makes teams dependent on asynchronous modes, leading to misunderstandings and delays in feedback [Herbsleb and Moitra 2001, Leitão Júnior 2021]. Virtual teams communicate primarily through computer-mediated communication (CMC), such as email, chat, and videoconferencing [Webster and Wong 2008]. However, CMC is often perceived as less effective than face-to-face interaction due to the absence of nonverbal cues [Lin et al. 2008].

Two complementary lenses from Computer Supported Cooperative Work (CSCW) help frame communication in DSD. *Social Presence Theory* (SPT) states that media vary in the amount of nonverbal communication they can convey, and that users tend to favor media that offer greater interpersonal presence when high levels of interactivity and

reciprocity are required [Lowry et al. 2006]. The *Distance Matters* conceptual model [Olson and Olson 2000] argues that effective distributed work depends on four sociotechnical conditions: common ground, coupling of work, collaboration readiness, and collaboration technology readiness. Together, SPT helps explain *why* certain communication channels are preferred, while Distance Matters conceptual model helps explain *how* team structure and task interdependence shape communication patterns.

2.2. Team Arrangements

Team arrangements refer to how members organize where and when they work, balancing office presence and remote flexibility [Šmite et al. 2023a]. Team distribution can be classified into four types: co-located, distributed, remote, and hybrid. In *Remote* arrangements, each member works from their own workspace without a centralized meeting place. *Hybrid* arrangements combine co-located and remote members [Santos and Ralph 2022], ranging from mostly on-site to predominantly remote configurations [Šmite et al. 2023a].

Research on hybrid collaboration has grown, though unified terminology and frameworks are still lacking [Neumayr et al. 2021]. While the pandemic's effects on productivity [Ford et al. 2022, Ralph et al. 2020] and the shift to voluntary remote work [Šmite et al. 2023b] have been studied, few studies have empirically examined how communication dynamics manifest in hybrid and remote arrangements in DSD.

2.3. Related Studies

Online communication platforms play a fundamental role in software development collaboration [Mezouar et al. 2022], and several studies have explored historical communication data to analyze interaction patterns [Licorish and MacDonell 2015, Stray et al. 2019, Stray and Barbala 2024]. Regarding *Slack*, research has addressed methods for collecting and analyzing communication data [Vilaça 2023], mapping discussion topics [Silva et al. 2022], and using communication patterns to understand social behaviors and communication styles [Kumar and Wallace 2013, Licorish and MacDonell 2015, Shi et al. 2021].

Studies using thematic analysis on Slack logs found that team members constantly communicate and coordinate through the platform [Stray et al. 2019], and that message count analysis can help identify disengaged members [Noroozi 2018]. In large-scale agile contexts, Slack supports alignment through transparency and structured channels [Stray and Barbala 2024]. Complementary findings indicate that formalized usage procedures and shared understanding of tool features are important for effective use [Stray and Moe 2020, Berntzen et al. 2022]. The latter study also introduced a taxonomy of coordination mechanisms in DSD organized into three categories: meetings, roles, and tools and artifacts.

3. Method

This study follows a multiple-case study design with an exploratory and quantitative approach to investigate communication dynamics in two DSD projects with different team arrangements through Slack data analysis. The multiple-case design enables cross-case

exploration between hybrid and remote arrangements, following the replication logic recommended by [Yin 2018] and the guidelines for case study research in software engineering proposed by [Runeson and Höst 2009].

3.1. Cases

The two selected cases, referred to as Alpha and Beta, are DSD projects linked to a Technology Institute within a federal higher education institution in Brazil. Both projects are part of the Institute's research, development, and innovation (RDI) initiatives conducted in partnership with IT companies, and are composed of geographically distributed virtual teams that collaborate predominantly through Slack. Each project is led by a Coordinator and managed day-to-day by a Project Manager, with technical direction assigned to a Tech Lead. Alpha operates as a single cross-functional team under Scrum, with bi-weekly sprints and shared product backlog across all roles. Beta operates with squads, each responsible for a specific data product, with lightweight cross-squad coordination led by the Project Manager. Case selection was purposeful, based on their contrasting team arrangements within the same institutional context, enabling a structured exploration of communication dynamics. Table 1 presents a comparative overview of the two projects.

Table 1. Comparative overview of Projects Alpha and Beta

Characteristic	Alpha	Beta
Domain	Web Development	Data Products
Team size	24 members	17 members
Key roles	Back-end, Front-end, DevOps, QA, UX/UI, Tech Lead, Project Manager, Coordinator	Data Engineer, DevOps, Product Owner, Tech Lead, Project Manager, Coordinator
Dev. methodology	Scrum	Sub-projects (Squads)
Team arrangement	Hybrid	Remote
Geographic location	Brazil	Brazil
Analysis period	May 2023–May 2024	May 2023–May 2024

3.2. Data Collection

Data collection followed a cross-sectional approach, covering the period from May 1, 2023, to May 31, 2024 [Bryman 2016]. Three types of data were collected.

Slack platform data. Two categories were gathered: (a) communication indicators extracted through Slack's Analytics functionality, which provides exportable metrics on member activity and channel usage; and (b) public channel chat history, consisting of message exchanges in spaces accessible to all project members.

Participant observation. The researcher acted as a participant observer in agile ceremonies within both projects throughout the analysis period. Field notes were taken during and after ceremonies to record observations about communication dynamics, decision-making, and coordination mechanisms beyond what is captured in Slack [Runeson and Höst 2009].

Document analysis. Project documentation, including process guidelines, channel naming conventions, and project management artifacts, was analyzed to support triangulation of findings [Bowen 2009] and provide contextual information about channel structure and organizational processes.

3.3. Communication Metrics

To address the research questions, the following communication metrics were defined: **Message volume** (RQ1), capturing total messages per member, channel, and period; **Communication visibility** (RQ1), measuring the proportion of public versus private messages to indicate how accessible communication is to the broader team; **Channel activity** (RQ2), tracking messages, views, reactions, and threads per channel to reflect engagement and relevance of each communication structure; and **Communication themes** (RQ3), identifying predominant subjects discussed by each team through topic extraction from public channel messages via Latent Dirichlet Allocation (LDA).

3.4. Data Analysis

Three types of data were collected from *Slack* for both projects: Channel Activity, User Activity, and Public Chat Logs. All data underwent a processing stage including anonymization, cleaning, removal of stopwords and URLs, and translation of Portuguese terms to English for consistent representation in visualizations. Using RStudio and R, data in `.csv` and `.json` formats were extracted, transformed, and loaded into dataframes. Three dataframes were created per project: `slack-messages`, `slack-user-metrics`, and `slack-channel-metrics`.

Two analytical approaches were applied. The first employed *descriptive statistical techniques* to obtain indicators related to the volume, visibility, and dynamics of communication. The second applied *text mining operations* to understand communication style and thematic topics in public channels [Silge and Robinson 2017]. Two text mining techniques were used: (a) *Occurrence Analysis*, to identify word frequency within the text corpus; and (b) *Topic Modeling*, using the Latent Dirichlet Allocation (LDA) algorithm [Blei et al. 2003] to identify predominant topics in messages.

The LDA algorithm was applied with K=5 topics per project, selected through iterative experimentation evaluating topic coherence and interpretability via manual inspection. The analysis pipeline used the following R packages: `tm` for corpus construction and document-term matrix generation, `topicmodels` for LDA estimation, `tidytext` for tokenization and tidy extraction of model parameters, `SnowballC` and `stopwords` for stopword lists, and `stringr` for text cleaning. Using the `tidy` function from `tidytext`, the probability β of each term belonging to a topic was extracted, and the 10 highest β words were selected to define each topic. The resulting topics were then manually labeled by the researcher.

Field notes from participant observation and document analysis were used to contextualize and validate the quantitative findings, particularly for interpreting channel purposes, communication patterns associated with specific roles, and the organizational rationale behind observed structures.

4. Results

4.1. Communication Volume and Visibility

Throughout the analyzed period (Figure 1), Alpha maintained on average 23 active members on Slack, while Beta had approximately 14. Alpha exhibited a more heterogeneous composition, whereas Beta was composed predominantly of Data Engineers. Both projects maintained a stable role distribution over time.

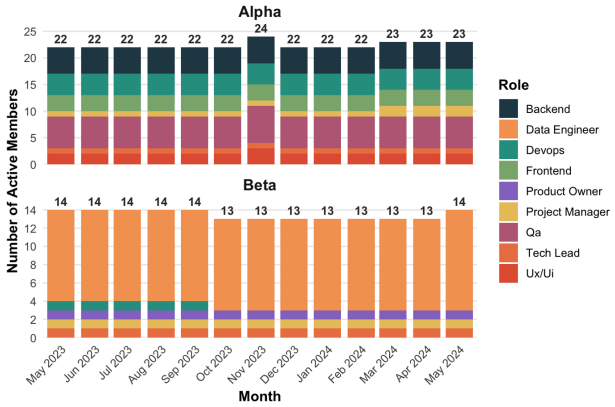

Figure 1. Active members by role per month

Concerning total message volume, approximately 211,000 messages were recorded for Alpha and 49,000 for Beta. As shown in Table 2, communication in both projects is predominantly private, with 75% to 87% of interactions occurring through private group channels or direct messages. This finding is consistent with studies which reported a similar pattern and noted its challenge for information sharing [Stray et al. 2019], reinforcing the interpretation that private-channel predominance is a structural property of Slack-based DSD communication rather than an effect of co-location level.

Table 2. Messages by visibility and project

Category	Alpha (Hybrid)	Beta (Remote)
User Private	159,891	42,613
User Public	18,447	5,201
Bot Public	33,413	1,446
Public Messages	51,860 (24.5%)	6,647 (13.5%)
Private Messages	159,891 (75.5%)	42,613 (86.5%)
Total Messages	211,751	49,260

Regarding average messages per member, Alpha showed approximately 583 messages per month, while Beta reached 249. As shown in Figure 2, public communication volume remained relatively stable over time, with more noticeable fluctuations in private communication. Total Slack traffic in both projects was mainly driven by private message volume.

Through participant observation, it was identified that Alpha's communication is more open, with higher message volume and greater public channel presence. This is associated with a collaborative, multidisciplinary management approach, evidenced by

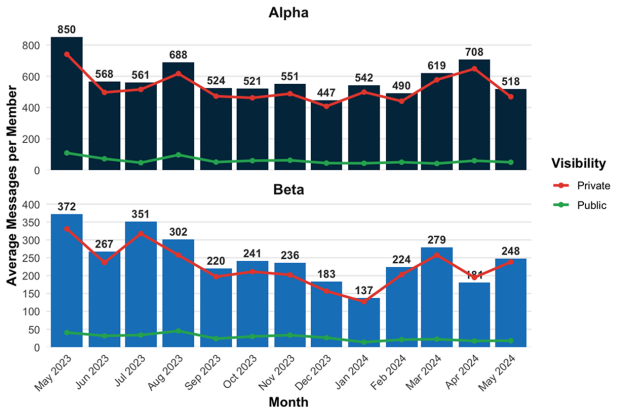

Figure 2. Average messages by member per month and visibility

daily stand-ups involving all areas and a shared general channel used for team-wide coordination. In contrast, Beta exhibits a more compartmentalized pattern focused on technical aspects within specific squads, with private messages predominating. This reflects a structure organized around independent sub-projects, each led by a Data Engineer squad with limited cross-squad coordination needs.

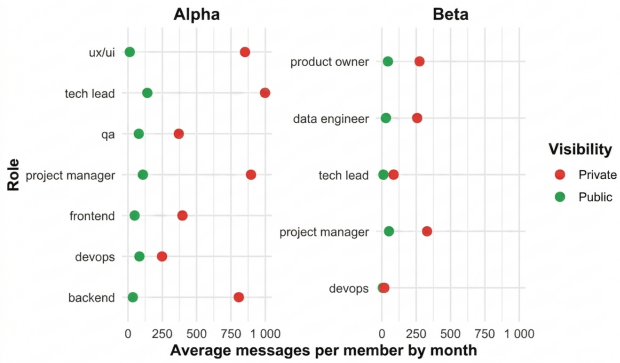

Figure 3. Average message volume by visibility per role

Regarding the distribution between public and private messages across roles (Figure 3), heterogeneous behavior was observed. In Alpha, UX/UI and Backend roles communicate primarily through private channels, while QA, DevOps, and Frontend roles showed a more balanced pattern. Leadership roles in Alpha exhibit high private communication volumes but are also among the most active in public channels. In Beta, with the exception of the Tech Lead and DevOps, most roles display similar patterns. This variation in message volume is consistent with studies which reported that more experienced members tend to communicate in open channels, whereas less experienced members prefer direct communication [Stray et al. 2019].

4.2. Communication Channels

Public Slack channels serve as the medium through which members send, view, and react to messages. In Alpha, public channels account for approximately 25% of all communication, compared to around 14% in Beta. Throughout the analyzed period, Alpha maintained between 16 and 25 active channels, while Beta had between 23 and 49 (Figure 4).

Alpha increased its channel count from 16 to 24 within four months and remained stable thereafter, whereas Beta exhibited continuous growth over time.

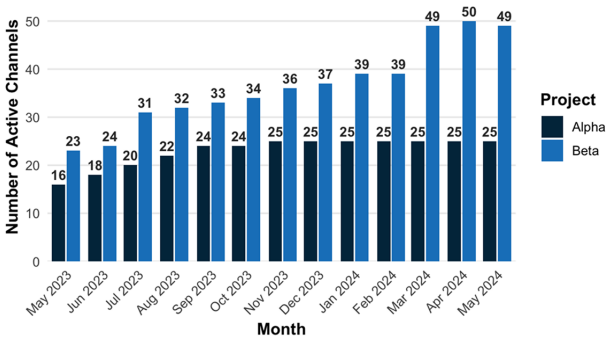

Figure 4. Active channels by month

The channel structure in each project exhibits distinct characteristics, as corroborated by document analysis. In Alpha, channels generally have a permanent nature, they are created with a well-defined purpose and remain active without the need for new channel creation. In Beta, while some channels share these characteristics, the majority are created for the execution of sub-projects. As new sub-projects are initiated, new channels are created, explaining the continuous increase in channel count.

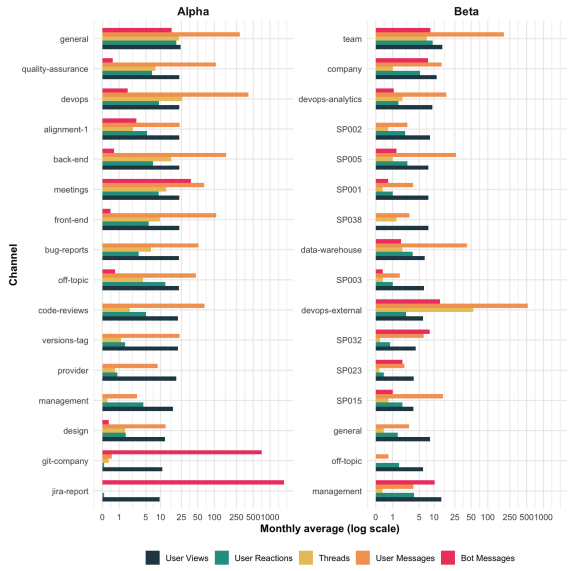

Figure 5. Channel relevance

Examining channel relevance through total messages, message views, reactions, and threads (Figure 5), channels with the highest message volume are not necessarily the most relevant to team members. In Alpha, the majority of channels exhibit high message views across all members, indicating a behavior in which members follow messages across multiple channels. As noted in another study, this requires additional effort to balance attention when processing messages, particularly in projects with high communication volume [Jackson et al. 2022].

Both projects use bots in public channels, which can facilitate communication and coordination. However, in Alpha, bot-heavy channels such as *git-company* and *jira-report* show low view counts, suggesting they are potentially muted by members. In the remaining channels of both projects, the volume of messages, reactions, and threads suggests that these structures foster information sharing, coordination, and alignment, consistent with findings that dedicated channels support knowledge sharing and inter-team communication [Berntzen et al. 2022].

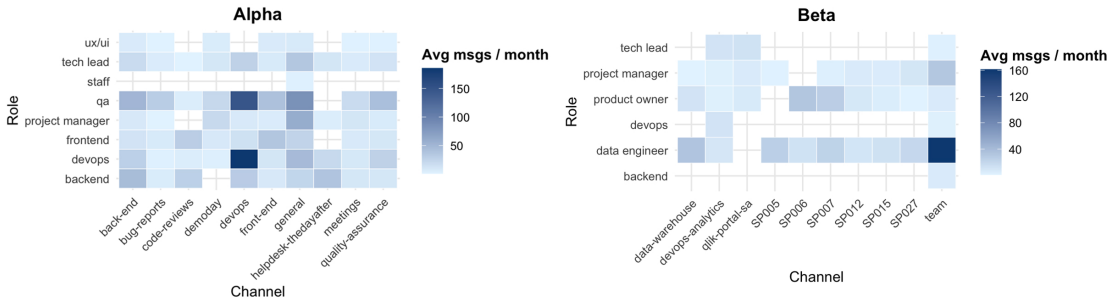

Figure 6. Role participation in channels

Regarding role participation across public channels (Figure 6), in Alpha, QA members show significant participation in technically oriented channels, particularly *devops*, alongside DevOps members, suggesting this channel is dedicated to coordinating system availability activities. Nearly all roles demonstrate considerable engagement in the *general* channel, which functions as the team's asynchronous meeting space. In Beta, all roles treat the *team* channel as their primary asynchronous space, while other channels exhibit more niche participation patterns among Data Engineers, the Project Manager, and the Product Owner.

4.3. Communication Themes

The most recurrent words in Alpha indicate a multidisciplinary technical focus spanning web application development, device integration, troubleshooting, and network infrastructure, whereas Beta's vocabulary concentrates on backend development, authentication, Python frameworks, and data-driven systems. Terms such as *environment*, *python*, *problem*, *error*, *lib*, and *local* appear across both projects, indicating shared concerns around environment setup, technology stack configuration, and fault detection.

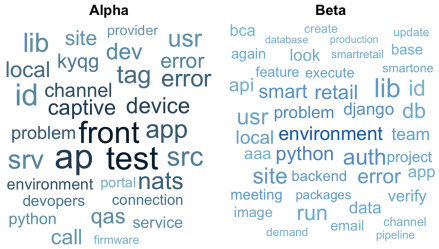

Figure 7. Word cloud

Regarding the Topic Modeling, the LDA algorithm was applied to identify five thematic topics in each project. Figures 8 and 9 present the top terms by topic.

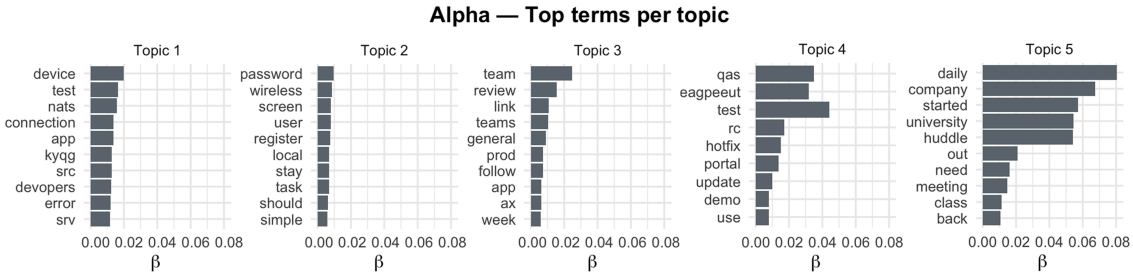

Figure 8. Top terms by thematic topic in Project Alpha

The five topics identified in Project Alpha were: (1) **Development**, related to devices, testing, and system integration; (2) **Troubleshooting**, covering authentication and user interface issues; (3) **Ceremonies and Coordination**, encompassing agile ceremonies and management alignments; (4) **Delivery and Quality**, addressing deployments, releases, and QA testing; and (5) **Organizational Communication**, involving stakeholder communication, meetings, and routines.

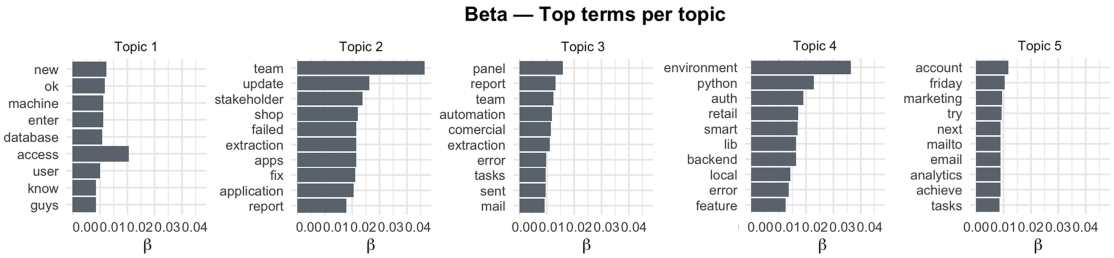

Figure 9. Top terms by thematic topic in Project Beta

The five topics identified in Project Beta were: (1) **Access**, related to authentication, databases, and permissions; (2) **Support and Maintenance**, covering system updates, data extraction, and fixes; (3) **Commercial Data Products**, encompassing panel development, extraction, and reports; (4) **Development**, addressing environment configuration, libraries, and Python frameworks; and (5) **Marketing Data Products**, involving marketing-related data analysis and deliverables. Public channels were then classified based on topic predominance, as shown in Figure 10.

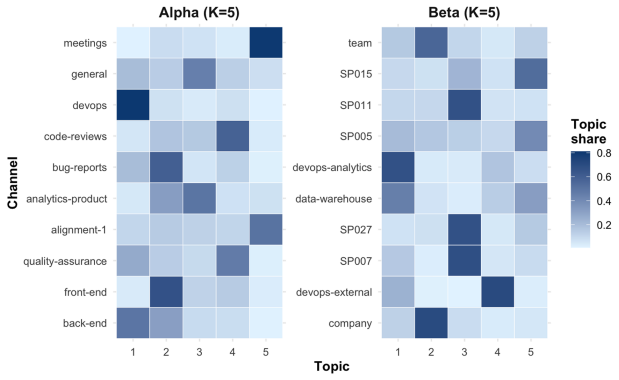

Figure 10. Thematic topic distribution across channels

In Alpha, Topics 1 and 5 showed the strongest association with specific channels: *Development* was linked to the *devops* and *backend* channels, while *Organizational Communication* was more prevalent in *meetings* and *alignment-1*. The remaining topics encompassed themes common to multiple channels such as *bug-reports*, *code-reviews*, *general*, and *quality-assurance*, indicating multidisciplinary communication focused on problem-solving, releases, and coordination. In Beta, three channels focused primarily on data product development themes (Topics 1, 3, and 5), with Topics 3 and 5 appearing more frequently in sub-project channels. Topics 2 and 4 were more prevalent in channels related to the partner company and internal team, with *Support and Maintenance* prominent in *team* and *company* channels, and *Development* in the *devops-external* channel.

Based on the thematic analysis and participant observation, communication in Alpha seems to be more collaborative and multidisciplinary, with channels facilitating coordination across all team areas. In Beta, topics are more strongly correlated with specific sub-project contexts, indicating a communication structure oriented toward guiding data product development within squads rather than fostering cross-team collaboration.

5. Discussion

The analysis revealed more similarities than differences between the hybrid and remote arrangements. The differences appear to be shaped by multiple project-level factors rather than by team arrangement. From a theoretical perspective, three main topics emerge:

The private-channel pattern as a structural characteristic. Both projects exhibit a strong predominance of private communication (75–87% of all messages). This converges with [Stray et al. 2019] and [Stray and Moe 2020], suggesting that the preference for private channels is a structural characteristic of Slack-mediated DSD communication rather than a consequence of team arrangement. This can be interpreted through *Social Presence Theory* [Lowry et al. 2006], as private channels may offer greater interpersonal presence, which is particularly relevant in DSD contexts where physical colocation is absent. The trade-off, however, is a reduction of *common ground* at the team level [Olson and Olson 2000], with conversations relevant to broader coordination being invisible to non-participants, which can erode shared awareness of ongoing work.

Message volume as a correlate of team size and role diversity. Alpha showed approximately twice the average message volume per member as Beta (583 vs. 249 messages/month). This difference appears to be more related to team size and role composition than to the team arrangement itself. The number of potential communication paths increases rapidly as team size grows [Brooks 1995], which, combined with role diversity, implies a substantially higher coordination demand in Alpha (24 members, 8 roles) than in Beta (17 members, 6 roles). Moreover, a higher message volume should not be interpreted as evidence of more effective coordination. Previous studies have associated intensive Slack-mediated communication with unbalanced participation and heavy reliance on direct messaging [Stray et al. 2019], as well as with the attentional cost imposed on members in high-traffic workspaces [Jackson et al. 2022]. Communication intensity, therefore, cannot be attributed to team arrangement in isolation, it reflects the combined effect of team size, role heterogeneity, project domain, and management practices.

Channel structure reflects the coupling of work. The distinct channel dynamics observed across projects Alpha with persistent channels and Beta with more ephemeral

ones, align with Olson and Olson's notion of *coupling of work* [Olson and Olson 2000]. Alpha operates through cross-functional work centered on a single integrated product, which benefits from persistent, shared spaces that accumulate common ground over time. In contrast, Beta organizes work as parallel sub-projects, each owned by a squad with limited cross-squad dependencies. This channel structure entails costs for knowledge continuity and makes cross-squad learning more difficult. These findings suggest that channel design is not a neutral decision, it reflects how work is decomposed within teams.

From a practical standpoint, the findings yield three implications. First, teams should monitor the balance between public and private communication, since the predominance of private channels can erode shared awareness beyond immediate participants. Second, channels should be designed with well-defined scopes, as the most relevant ones are those with clear purposes rather than the highest message volume. Finally, channel permanence should match the coupling of work: ephemeral structures suit squads working on independent sub-projects, while permanent, cross-functional channels better support teams engaged in integrated multidisciplinary collaboration.

6. Conclusions

This study investigated communication dynamics on Slack between a hybrid and a remote team in DSD projects through an exploratory multiple-case study combining descriptive statistics, text mining, participant observation, and document analysis.

Regarding volume and visibility (RQ1), both projects predominantly rely on private channels, with public communication representing only 13–25% of all messages. The hybrid team showed nearly twice the average message volume per member, though this difference appears more closely associated with team size, role diversity, and management practices than with team arrangement itself. Regarding channel structures (RQ2), the hybrid team maintains stable, permanent channels with high cross-role engagement, while the remote team creates ephemeral channels tied to sub-projects. In both projects, the most relevant channels are those with clearly defined purposes rather than highest message volume. Regarding communication themes (RQ3), the hybrid team demonstrates more diverse, multidisciplinary themes spanning development, coordination, troubleshooting, and quality assurance, while the remote team exhibits themes tightly coupled to specific sub-project contexts. Both teams share common concerns related to environment configuration, development issues, and error resolution.

This study also makes three contributions: (1) an empirical exploration of communication patterns in hybrid and remote DSD teams based on 13 months of Slack data; (2) the identification that project-level factors (team size, role diversity, management model, and coupling of work) may be stronger determinants of communication dynamics than team arrangement type; and (3) a replicable analytical approach combining descriptive statistics and topic modeling applicable to other communication platforms. This study has limitations related to multiple differences between the cases which do not allow for generalizations or direct comparisons. Future studies should extend this research by incorporating qualitative methods such as interviews and surveys, analyzing multiple communication tools beyond Slack to capture the full spectrum of team interaction, expanding the sample across different organizations and cultural contexts, and investigating the relationship between communication patterns and project outcomes.

A. AI Usage

During the preparation of this manuscript, the authors used *Claude Opus 4.6* (Anthropic) as a generative AI tool to assist with text and code revision, including improving clarity, conciseness, and English language editing of the written content. No generative AI tool was used in the data collection, analysis, or interpretation of results.

B. R Scripts

https://github.com/dsdanondev/slack

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