

Multi-Dimensional Communication Model for Collaborative Group Activity

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Abstract

Background/Objectives: To investigate the communication pattern factors in relation to multi-dimensional group communication based on communication channel, user to user and user to group relationship in collaborative group activity. **Methods/Statistical Analysis:** A multi-dimensional group communication model was formulated, along with the communication channel and collaborative relations mapping specifications. The model is based on the analyzation of a series working scenario for multi-disciplinary groups' interactions and complex sharing information in a Disaster Recovery Process of one company. Such scenarios are used as running examples with the objective to understand the risk posted by the lack of communication dimension support in group activity. **Findings:** The proposed multi-dimensional group communication model, dynamically facilitate user preference of communication media in which users at one period of time can involve with more than one formal and informal group communication activities in a collaborative working environment. The communication media act as group task governance, where users can control the communication flow within the defined communication dimension. **Application/Improvements:** The results from this study are significant to support the flexibility of controlling and coordinating multitask group activities in multi-dimensional communication platform for future research.

Keywords: Collaborative Group Activity, Collaborative Workspace, Communication Model, Media Sharing, Multi-Dimensional Communication.

1. Introduction

Collaborative Workspace (CW) consists of dynamic assemble groups from various professional skills that work together within shared Collaborative Workspace Environment (CWE). In CWE, workgroup can be classified into ten categories (refer to Table 1). Each of this group has its purpose and main activity. The group formation is mainly through formal network connections that members of groups have clearly defined their roles and responsibilities through group member hierarchy. Group activity demonstrates four types of talks by their group members. The talks are a problem-solving talk, role talk, consciousness talk and encounter talk¹.

During a group activity, all types of talks may occur at one group communication session. For example, groups of committee for system disaster-recovery-activation plan facing a server technical issue, which affect mainly

on the business department. Hence, solutions of such disaster need critical information from IT and Business department. While the entire key person in an affected department is discussing and communicating the problem, another secondary group from each department is also concurrently collaborating, contacting and sharing information about the issues. The primary group needs well-thought-idea from the secondary group in making their decision. Hence, user needs to be allowed to contact and interact with any members of the same group, members of other groups, individual or experts. Such communication should be allowed to occur at the same time but in different sessions to get solutions for the unpredictable and complex issues.

Though most of the communications focused on the work-related activity, the relational aspects of group interaction provide an underlying support for the group members is also vital. The support for various kinds

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of user-to-user interactions, while they are engaged in another group activity, is important to support interpersonal connections. Such kinds of interaction are focused more on quality communication and contribute to a better solution and enhanced group work spirit¹.

Table 1. Types of work group¹

Type	Purpose
Executive	Plan and Direct
Command	Coordinate
Negotiation	Deal and Persuade
Commission	Investigate
Design	Create and Develop
Advisory	Suggest and Diagnose
Performance	Enact
Production	Assemble and Build

Currently, CWE has fueled with various collaborative applications. These applications emphasize the new possibilities and solutions offered by the system. However, the realities of group communication in distributed collaborative groups are often painted a different picture. Most of the applications only support users with one dimension communication². This dimension allows users to be active and communicate with only one collaborative group in one application at a time. In this dimension, communication media work as basic utility tools with predefined functions and fixed parameters. Thus, the important of the communication task as a central activity of group projects and as a core element in creating a collaborative culture has been ignored³.

The remaining content of this paper is organized as follows. Section 2 presents the user-to-user multidimensional communication requirements and patterns. Section 3 describes our multidimensional communication model and Section 4 presents a discussion on handling dynamic information sharing via multidimensional group formation. Section 5 describes the background study and related works. Finally, in Section 6, we draw our conclusion and future works.

2. Communication Dimension in Group Activity: Requirements and Pattern

In this section, discussions are performed on typical

information disseminating process and sharing patterns of group communication scenario in the Disaster Recovery Activation (DRA) process. The DRA is activated due to the server malfunction that affects the business process in Unit Trust Operation department (UTO) of one leading investment company in Malaysia. The company itself has more than 200 workers and earned more than 2 billion ringgit profit a year. This unit is chosen due to its challenging working scenario and activities that involve multi-disciplinary groups' interactions and complex sharing information which involve various types of documents. Such scenarios are used as running examples with the objective to understand the risk posted by the lack of communication dimension support in CWE for group activity.

Based on this information the requirement analysis of the multi-dimensional communication is carried out that focusing on user-to-user and user-to-group relationship. Additionally, from the scenarios; three main group communication patterns are identified and labeled as sub-group, intra-group and inter-group patterns. The relationship network of this pattern is a directed graph, where each node denotes a user and an edge represents the relationship between the three main elements: User, objects and channel. The label associated in each edge indicates the type of relationship. The edge direction signifies that the originator node initiates the relationship and accepted by the target node. Interactions and communication activities are performed based on the established relationship.

2.1 Sub-Group Communication Pattern

Once the disaster has been confirmed, the Disaster Recovery Group (DRG) is created according to Disaster Recovery (DR) procedure. The group members are from various units such as Business Operation Manager, Head of Business Operation, Head of Information Technology Department and other key management personnel. During the meeting, the Group Owner (GO) will present the information and highlight the key issues and business impact. All group members will be provided a status update on the current situation. The GO who has exclusive authorization on the important document (user-to-object relationship) will use suitable communication channel for sharing it to all the group members. Figure 1 demonstrates the communication and sharing the pattern for normal group activity.

After evaluating the entire business operation, the GO might need to communicate with two different people or groups at the same time with different sources of information. In the event of dealing with confidential data, users need to have their space with another user in the same group. As an example, head of IT need to discuss with Business Operation about the wrong printed data on the day end report. Both department key person needs to exchange information related to staff's job scope, procedure and technical issues and at the same time both of them are active members of the company disaster committee. They might find a space that allows them to communicate and shared the confidential data discretely. Mobile phone messaging and social media applications are alternatives channel for such sharing and disseminating information. Such activity needs two different communication dimensions to control the data flow and sharing process in the same dimension. In this case, communication channel act as a dimension controller that ensure only target user is connected and allow participate in the activity. As depicted in Figure 2, two sub-groups are created and using its' channel to communicate with each other which consequently form the sub-group communication pattern. This sub-group is specially formed by a unique relationship between group members. Furthermore, the main work-related dimension may need more than one non-related work communication dimension in order to serve the basic social needs of the group members.

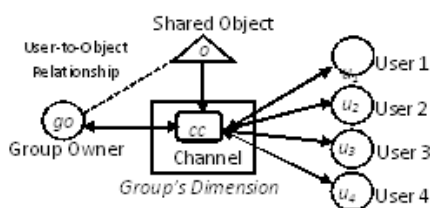


Figure 1. Information dissemination and communication pattern in group activity.

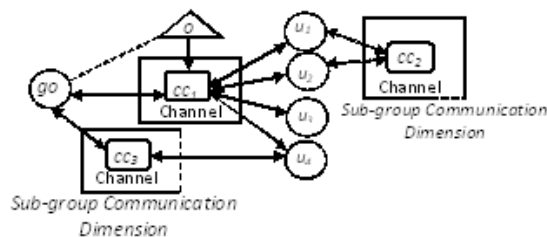


Figure 2. Group with multi sub-group communication dimension.

2.2 Inter-Group Communication Pattern

In finding fast and solid solutions, accurate information from various departments is crucial. Each department needs to form ad-hoc groups for each of the division to compile and analyze data. These groups need to communicate and share their data in order to produce solid information and evidence needed by their superior in the DRG meeting. For the case of disaster caused by mainframe malfunction, the IT department creates two groups from Technical and IT Vendors unit. The technical team needs to collaborate with IT Vendors in compiling data, evidence and propose solutions for the problem. Manager of Technical Division and Project Director of Company XYX (IT Vendor) are responsible for the technical strategy plan to activate the Disaster Recovery plan and identify the Disaster Recovery site. All information should be readily available on real-time basis to support DRG with up-to-date information. While, the application team lead by IT Application Manager will investigate the cause and do analysis on the technical aspects.

Concurrent group discussion was conducted to elevate the solution and action plan. While smaller group of a technical group is performing troubleshooting on the problems, IT Vendors group members are preparing recovery site. Each of the groups has used their communication channel in separate group spaces. In a case, when data is needed to be shared and consolidate with other group, head of both groups will communicate with each other by using appropriate communication channel that is suitable with the type of sources. Such situation demonstrates the inter-group communication pattern that shows multiple communications dimension are needed to serve multiple task and objectives at one time. This pattern is one of the complex communication paths that are currently used by face-to-face group activity. Such activity has to use various platforms of communication channels such as text messaging, phone call, video conference and group online meeting to support the nature of work activity. Figure 3 depicts the inter-group communication pattern.



It is normal practice in a group project to divide group members into a few small groups according to the objective of the activity. In this disaster scenario, Finance Department needs to reconcile information and do analysis on the impact of the disaster on the company profits. Hence, all division from Finance Department form a few small groups based on their unit operation specially to cater the disaster data analysis. Consolidated information from various unit is needed at this point to understand the repel effect of the disaster implications to the respective operations. This small group communicates and discusses to each other which in the end they have consensus in providing input on behalf of Finance Department to the DRG meeting. The communication between these units could be done in informal ways, e.g. group messaging, mobile text messaging and other available social media applications.

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The diagram illustrates a structural equation model with the following components and paths:

- Latent Variables:**
 - GO (Group's Dimension)
 - O (Group's Dimension)
 - CC_1 (Group's Dimension)
 - CC_2 (Small Group's Dimension)
 - CC_3 (Intra-group Dimension)
 - CC_4 (Small Group's Dimension)
- Observed Variables:**
 - U_{11} , U_{12} , U_{13} (Intra-group Dimension)
 - U_{21} , U_{22} , U_{23} (Intra-group Dimension)
- Path Coefficients:**
 - Significant Paths (Solid Arrows):**
 - $GO \rightarrow O$
 - $O \rightarrow CC_1$
 - $CC_1 \rightarrow U_{11}$, U_{12} , U_{13} , U_{21} , U_{22} , U_{23}
 - $CC_2 \rightarrow U_{11}$, U_{12}
 - $CC_3 \rightarrow U_{13}$
 - $CC_4 \rightarrow U_{21}$, U_{22}
 - Non-significant Paths (Dashed Arrows):**
 - $GO \rightarrow U_{11}$, U_{12} , U_{13} , U_{21} , U_{22} , U_{23}
 - $O \rightarrow U_{11}$, U_{12} , U_{13} , U_{21} , U_{22} , U_{23}
 - $CC_1 \rightarrow CC_2$, CC_3 , CC_4
 - $CC_2 \rightarrow U_{13}$
 - $CC_3 \rightarrow U_{21}$, U_{22}
 - $CC_4 \rightarrow U_{11}$, U_{12} , U_{13}

3. Multi-Dimensional Communication Model

Definition 1: (Group Activity). A group activity in collaborative working environment is modeled as a 9-tuple $GA = \langle G, K, W, O, C, U, L, TR, R \rangle$, where

- $G = \{g_1, \dots, g_n\}$ is a set of groups which users can be a member; $K = \{k_1, \dots, k_n\}$ is a set of tasks assign to a group, where $KG \subseteq K \times G$ is a set of binary tasks-to-group relationship;
- $W = \{\text{public, private, exclusive}\}$ is a set of workspace type for group activity;
- $O = \{o_1, \dots, o_n\}$ is a set of resources for group activity, where $OG \subseteq O \times G$ is a collection of binary resources-to-group relations;
- $C = \{c_1, \dots, c_n\}$ is a set of communication media available for the GA, where $c_i \subseteq M \times D$ specifies a set of $\langle \text{type of media, directional} \rangle$ and $M = \{\text{text, audio, video, whiteboard, images, services}\}$ and $D = \{\text{directional, bi-directional, multi-directional}\}$ and $CG \subseteq C \times G$ is a set of binary media-to-group relations where, $GC : G \rightarrow 2^c$ where $GC(g;G) = \{c \in C \mid (c,g) \in CG\}$, is a function mapping group to a set of communication media;

- $U = \{u_1, \dots, u_n\}$ is a set of users where $UG \subseteq U \times G$ is represents user-to-group membership and group member function $GM : G \rightarrow 2^U$ allocate group, g_i to a set of users;
- $L = \{l_1, \dots, l_n\}$ is a set of user's roles in group g_i where $UL \subseteq U \times L$ is a set of binary user-to-role relations;
- $TR = \{ME, XP, XC\}$ is a set of collaborative relationship between users defined in the system : member, expertise, exclusive;
- $R = \{r_1, \dots, r_n\}$ is a collection of user relationship sets, where $r_i = \{t_{i1}, \dots, t_{im}\}$ is a user relationship list where $i \in U$, Each relationship entry is a $\langle \text{user} : \text{relationship type} \rangle$ pairs, $t_{ij} = \langle u_j, t_j \rangle$, where $u_j \in U$, $t_j \in TR$; and UU is denotes a collection of uni-directional binary user-to-user relations where $UU \subseteq U \times U$ and $UU_{ri} = \{ \langle u_x, u_y \rangle \mid u_x, u_y \in U, u_x \neq u_y \text{ and } r_i \in R \}$;

Definition 2: (Group Communication) Let CM represents function indicating the group communication activity which can be terminated when set of condition (E) is true. The CM is formally presented as:

- $I = CM : G \times C \rightarrow D \times E \times W$ where, $CM(g_i, c) \subseteq \{g \in G \mid (g \in M(g)) - (GC(g, c))\}$ and $\forall u \in GM(g): CM(c).w = \text{public}$;

Definition 3: (Sub-group) Let S_{g_i} represent the sub-group in one group g_i activity. The subgroup of group g_i in CWE is modeled as 6-tuple $S_{g_i} = \langle U, UU, O, K, W, C \rangle$ and $g \in G$ and $i = \{1, \dots, n\}$ where,

- $U \in GM(g_i)$ is a user in a group g_i .
- UU_r is a user-to-user relationship.
- O is resources that are available to all group members, where $O \in GA$.
- K is a task where the value can be null, where $K \in KG$.
- W is a workspace value for sub-group activity that might be private or exclusive.
- C is a set of communication channel which can be use by the users where, $C \in GA$.

Definition 4: (Small group) Let H_{g_i} represents a collection of small groups in group g_i and model as 7-tuple where, $H_{g_i} = \langle P, R, L, O, K, W, C \rangle$ $g \in G$ and $i = \{1 \dots n\}$ where,

- $P = \{p_1, \dots, p_z\}$ is a set of user $p \in U$ and $P \subseteq GM(g_i)$;
- R is a set of relationship exist in g_i ;
- L is a set of role define for the small group;
- O is a resources available to all the group members,

where $O \in GA$;

- K is a task where the value can be null, where $K \in KG$
- W value for the small group is exclusive, as the small group is perform based on one-to-selected relation, where $w = \{\text{exclusive}\}$;
- C is a set of communication channel which can be use by the users where, $C \in GA$

Definition 5: (Multi-Dimensional Group Activity) Let MGA represents multi-dimensional group activity in group g_i . Group g_i at given one duration time is performing MGA when the group members successfully created one or multiple *sub-group S* or/and *small group H* where, $MGA_{g_i} = \bigcup_{i=1}^n \{s_i \cup h_i\}$

3.1 Multi-Dimensional Communication Policy Specification

To enable a multi-dimensional communication management for sub-group activities, it is essential for sub-group communication policies to be in place to regulate propagation of the communication dimensions from multiple users. The policy specification scheme is built upon the proposed MCM model.

Sub-Group Communication Specification:

Let SP represent the function indicating the sub-group private communication activity and formally presented as $SP : U_x \times U_y \times C \rightarrow D \times E \times W$ where ;

$SP_{g_i}(u_x, u_y, c) \subseteq \{u_x \in U, u_y \in U \mid ((u_x, u_y) \in UU) \cap (u_x, g_i) \in UG) \cap ((u_y, g_i) \in UG) \cap (c \in GC(g_i))\}$ and $\forall u \in (GA(g_i): CM(c).w = \text{public}) \cup (SP_{g_i}(c).w = \text{private}) \cup (SP_{g_i}(c).w = \text{exclusive})$.

There are only two users in each sub-group where both can be from the same group or one of them can be outsider (subject expert). Hence, we formally define the sub-group communication specifications as follows:

Let a denoted the number of users in g_i where $|g_i| = a$, and let SP denoted the sub-group communication activity in g_i . Hence, the total number (denote as b) of SP in g_i is determined as $b = (a!/2!(a-2)!)$ where, $a \geq 3$.

- **Inter-group Communication Specification:** Let EM represents the function indicating inter-group communication and communication specifications are defined as follows :

EM: $U_{g_1} \times U_{g_2} \times C \rightarrow D \times E \times W$ where, $|g_1| \geq 2$ and $|g_2| \geq 2$.

$EM(u_{g_1}, u_{g_2}, c) \subseteq \{u_{g_1} \in CM(g_1), u_{g_2} \in CM(g_2) \mid ((u_{g_1}, u_{g_2}) \in UU) \cap (u_{g_1} \in UL) \cap (u_{g_2} \in UL) \cap (c \in (GC(g_1) \cup GC(g_2)))\}$ and

$\forall u \in ((GM(g_1): CM(c). w = public) \cup (GM(g_2): CM(c). w = public) \cap EM(c). w = private)$ where, $g_1 \in G$ and $g_2 \in G$ and each group has its own member assigned by $GM(g_1)$ and $GM(g_2)$.

• Intra-group Communication Specification

Let AM represents the function indicating the intra-group communication and defined as $AM_{gi} : P \times P \times C \rightarrow D \times E \times W$ where,

$AM_{gi}(p_x, p_y, c) \subseteq \{p_x \in H_{gix}, p_y \in H_{giy} \mid ((p_x, g_i) \in UG) \cap (p_y, g_i) \in UG) \cap (p_x \in UL) \cap (p_y \in UL) \cap (c \in GC(g_i))\}$, $\forall u \in (GM(g_i) : CM(c). w = public) \cup (AM_{gi}(c). w = exclusive)$. Group owner can create many small groups in $g, AM_{gi} : P \times P \times C \rightarrow D \times E \times W$ and the number of group members for these small groups is specified as follows:

Let a denoted the number of users in g , where $|g_i| = a$ and z denotes the number of selected users to perform exclusive communication where $z < |g_i|$. Hence the total number of small group in g , is determined by $b = (a!/z!(a-z)!)$ where, $a \geq 4$, and the small group for intra-group communication specification is defined as a set, $H_{gi} = \{h_{gi1}, \dots, h_{gib}\}$

4. Implementation and Discussion

The prototype of Multi-dimensional Communication (MCM) has been implemented using scripting language called JACIE (Java-based Authoring language for Collaborative Interactive Environments). The language is designed to support rapid prototyping of application with multimedia and collaboration features 4. Moreover, JACIE provide communication primitives such as channels and interaction protocols which hide the network programming. The prototype application is a proof-of-concept Online Meeting for the collaborative management to shared information and resources through multiple communication channels. A snapshot of the main interface of the online meeting with 5 users is shown in Figure 5.

The application is equipped with the whiteboard which is shared to all users, document sharing (Google doc) and two type of communication channel;

synchronous and asynchronous. Text, audio, video and sharing still picture is real-time communication while e-mail is for asynchronous type of communication. These communication channel act as a dimension controller that ensure only target user is connected and allow participate in the activity.

In order to measure the practicality and usability of MCM mechanism, a survey study ($n = 15$) was conducted to explore the users desires on the multi-dimensional interaction with privacy in group activity. The participants are workers with diversified ethnicity, including male and female who had different kind of knowledge and experience about collaborative application. There are only five users per session of online meeting and they will be guided on how to use all communication channels and create the sub-group and small groups of users. The participants are given step by step instruction to initiate the sub-group, inter-group and intra-group communication activity. As users completed the activity, they answered the questionnaire. Each question was ranked 0 to 5 which represents least satisfaction and full satisfaction respectively. Figure 6 shows the average weight scored for each question. The time taken by each user to perform the multi-dimensional activity in a session is not taken into consideration as it varied from one group of users to other group of users based on their background. The standard deviation is 0.78.

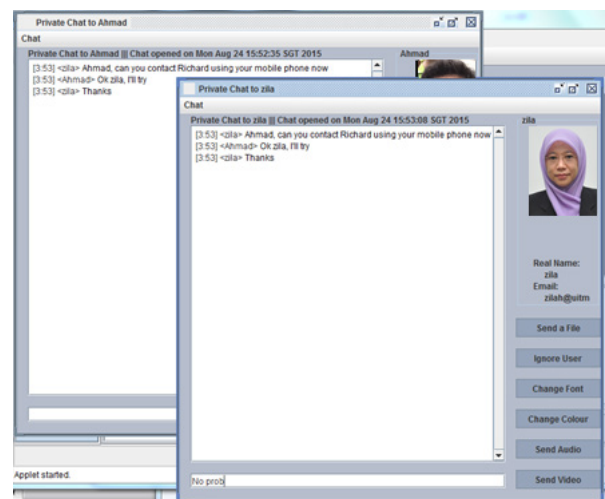


Figure 5. Online meeting interface: Communication controller.

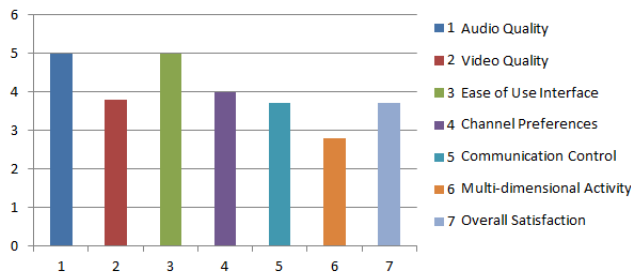


Figure 6. Average weight scored for the questions.

5. Related Work

In modern society, group collaboration becomes a constant feature of a successful organization. In any collaborative work (work or non-related work); the content of resources involved in such activities might be changed. Moreover, provisioning of new knowledge and data transformation need to be control and coordinate effectively. Hence, many researcher highlights the important of communication in improving the coordination of group collaborative work^{5,6}. The communication in the collaborative environment is central to work activity. It should dynamic and flexible to cater not only routine workflow but also on ad-hoc and emergency scenarios. In such scenario, the activity needs support for it dynamic sharing resources among the group members. Various approaches have been proposed to make the collaborative activity normally function in the odd situations. The approach such as dynamic permission that violates group collaborative policy⁷ and replication of authorization policy to target users⁸ are created to handle such scenarios.

In CWE, the group work consists of distributed activities that include communication and joint task with other groups in producing business artifact. These groups have its formal inter-organizational relationship involving resources sharing and responsibility for implementing and evaluation of the joint task. Hence, the group space activity is divided into different dimensions namely sub-group, inter-group and intra-group⁹⁻¹¹ (Goren and Bornstein, 2000) dimensions. Each of the groups has multi-layer¹² of the collaborative relationship that requires multi-dimensional communication to coordinate the explicit and implicit joint activity. Many research works focus on solving communication issues within group collaborative activity by enhancing the communication dimension. The existence of this dimension is to provide and support users with seamless communication between multiple

groups collaborative activities^{7,13}. A number of works have identified and supported the communication dimension in their group activity. The work also shows significant improvement in the collaborative work^{14,15}. For example, in software development area, developers participate in at least two communication dimensions namely coordinate and expertise communication¹³. The developers also need to coordinate the interaction with others remote developer over the project assignment. On the same time, the user also needs to communicate with experts over the subject matters in the other communication dimension platform. Hence, it is norms for collaborative group activity constitutes with many communication dimension in the collaborative working environment.

6. Conclusion

In general, collaborative working environment is branded by flexibility in sharing the process, connecting and coordinating group of dispersed users. Most of the group works had their predefined communication channel and served as a single dimension platform. Such platform is not support user preference of communication media in performing the group activity. Hence, the needs for various communication dimensions are very significant in promoting the flexibility in controlling and coordinating mechanism for group work activities. In this paper, we have proposed novel solution for multitask group activity that enhanced sharing and group workflow in dynamic group collaborative environment. A multi-dimensional group communication model was formulated along with the communication channel and collaborative relations mapping specifications. We introduced an approach to representing and reasoning about our proposed model by analyzed typical communication patterns in three scenarios. User-to-user and user-to-group dimensions relations are used to manage the flow of information by using suitable communication channels. These communication channels act as group task governance and its constraints must be satisfied by all the collaborative relations elements. We left the multi-dimensional group communication policy scheme, corresponding policy evaluation and its constraints as one of our future work.

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