DESIGN AND DEVELOPMENT OF A MULTI-CHANNEL MILITARY APPLICATION USING INTERACTIVE DIALOGUE MODEL (IDM) PROVIDING ENHANCED USABILITY

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APPROVAL

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This thesis has also not been submitted for any degree in any university previously

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ABSTRACT

Usability used to be the key quality attribute of the software systems. Usability issues were explicitly considered and evaluated to design and develop different types of applications like e-commerce, e-governance, e-learning, e-health etc. Defence forces were also using different types of applications focusing specific group of users in a specific context like battle, war and special operations. Existing design techniques were proposed mainly for developing general purpose applications. Though, a limited number studies had been conducted focusing on usability and user experience (UX) issues of military applications focusing user-centered design process and usability evaluation. Moreover, no specific design technique as well as usability factors were suggested in existing literature to design and develop military application with enhanced usability. Thus, it was a crucial issue to explore the best suited design technique for developing military application with enhanced usability as well as to reveal the all possible usability factors that were explicitly required in designing and developing a military application. Therefore, the objectives of this thesis were *firstly*, to explore the best suited deign technique for developing military application, *secondly*, to reveal the all possible usability factors that would be suitable for developing and evaluating any military application and *finally*, to develop an example military application in order to evaluate and validate the selected design technique and the revealed usability factors. As such, an Advanced Battlefield Communication System was designed using the Interactive Dialogue Model (IDM) technique, and the application supported the command structure to enable the higher commanders by establishing an audio-video communication link with the front-line troops. An explorative study was conducted following the Focused Group Discussion (FGD) approach with 20 participants to explore the possible usability factors for developing any military application; while an evaluation study was conducted following the field study with 30 participants to assess the applicability of IDM approach in developing military application and to validate the revealed usability factors. As outcome, this thesis found the IDM technique as a suitable design approach for developing both website and mobile applications. A total of 14 usability factors were revealed for designing and developing more usable and user-friendly military applications. Finally an advanced battlefield communication system for Special Forces of was developed for Bangladesh Army.

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LIST OF SYMBOLS

Symbols	Definition
CG	Centre of Gravity
C4ISR	Command, Control Communications, Computers, Intelligence, Surveillance and Reconnaissance
CBT	Computer-Based Training
C-IDM	Conceptual Design
DoD	Department of Defense
DoDAF	Department of Defense Architecture Framework
EORM	Enhanced Object Relationship Model
FIBUA	Fighting in the Build-up Area
FGD	Focused Group Discussion
GUI	Graphic User Interface
HCI	Human Computer Interaction
HFE	Human Factors Engineering
HDM	Hypertext Design Model
HTML	Hypertext Markup Language
ICT	Information And Communication Technology
ILS	Integrated Logistics Support Concept
IDM	Interactive Dialogue Model
JSON	Java Script Object Notation
LG-RAID	Linguistic Geometry Real-time Adversarial Intelligence and Decision-making
L-IDM	Logical Interactive Dialogue Model
MiLE+	Milano Lugano Evaluation Method – version 2
OOHDM	Object Oriented Hypermedia Design Model
OOTW	Operations Other Than War
ORBAT	Order of Battle
P-IDM	Page Interactive Dialogue Model
RTMP	Real-Time Messaging Protocol
RMM	Relationship Management Methodology
RMAF	Royal Malaysian Air Force
SIDE	Semiotic Interface Sign Design and Evaluation
SPKB	Sistem Pengurusan Komputer Bersepadu
SDT	Soldier's Data Terminal
SLR	Systematic Literature Review
UEWDM	UML Extension Web Design Model
UML	Unified Modeling Language
UAVs	Unmanned Aerial Vehicles
UX	User Experience
UI	User Interface
VPN	Virtual Private Network
WSDM	Web Site Design Method

CHAPTER I

INTRODUCTION

1.1 Preliminaries

Usability was used from long time to measures the ease-of-use of an individual's interaction with tool or device made by human [1]. Usability also was the key quality attribute for any computer application as well. Most of the software developers primarily focused on the functionality of an application and rarely concerned about its usability issues. Poor usability affected the utility of the application and frustrates and discourages users to use the application [2]. The ISO 9241-11 standard defined usability as "the extent to which a product could be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [3]. In this case effectiveness focused on the accuracy and completeness by which users achieve specified goals; the efficiency referred to the use of resources with accuracy and completeness and satisfaction referred to the freedom and positive attitudes towards the use of the product [4], [5].

Use of IT applications in different fields was versatile. Different types of applications like e-learning, e-governance, e-commerce, e-health, etc. was being used for long time. Usability issues were explicitly considered and evaluated to design and develop these applications [6]–[10]. However, from the very beginning of information and communication technologies (ICT) usages, defence forces were also using the ICT to enhance the soldiers capacity [11]–[13]. Defence forces used specific type of applications that focused on specific group of users. Moreover, military related application used in a specific context like war, minor operations, special operations (counter terrorism, natural disaster), etc. Thus, a unique set of challenges might require overcoming to achieve the key quality of a military application that included, for example, ease-of-use, satisfaction, learnability, effectiveness, and efficiency, i.e., the usability of military applications. Present day military applications required faster and accurate output which demanded an efficient application to fulfill all requirements with a high degree of precise and professional skill-set.

Military Forces was designed to deal with unexpected situation in the battle field. A command decision might lead to win or lose the battle. Thus well informed commander on different issues on the battle field would enable the decision making process. Battlefield scenario might develop both laterally and vertically any time during an operation. All ranks thus needed to traverse such environment multi-dimensionally. Therefore, any military application should be versatile in multiple platforms. Only a multi-channel approach could satisfy the need of such military application. A multi-channel application would be necessary to provide same services from various devices like mobile, desktops etc.

1.2 Problem Statement and Motivation

Existing design techniques developed for designing applications other than the military application were lightly used to design and develop military applications. ICT based military applications were developed following different design techniques. These techniques were mainly proposed to design and develop general purpose applications. But military applications would need to fulfill specific design requirements as deemed necessary for specific group of users, specific operational condition, intensity of the battle, environment and situation. So, it was an utmost important open issue to investigate which design technique could be used to design and develop a military application for achieving better performance in terms of usability and user experience (UX).

On the other hand, usability was always the key quality of software. Usability factors were used to develop applications of different fields. Erroneous use of usability factors in those fields might contribute negatively in the performance of that application. Gravity of negative effect might or might not threaten human life. But in case of military domain, soldiers face life and death every moment in the war field. Thus, the development of military applications following usability factors might contribute in reducing the life threating risk. To the best of our knowledge, a few studies had been conducted focusing on the usability and UX issues of military applications. These studies assessed and evaluated the usability of military applications in different dimensions. No specific and complete set of factors or parameters were explored to evaluate or enhance the usability standard of military applications. Thus there was a need to explore the best suited deign technique for developing military application providing enhanced usability as well as reveal the all possible usability factors that would be explicitly required in designing and developing a military application.

1.3 Research Objectives

Based on the above discussion, the objectives of this thesis were:

1) Firstly, to explore the best suited design technique for developing military application.

2) Secondly, to reveal the all possible usability factors that would be suitable for developing and evaluating any military application.

3) Finally, to develop an example military application in order to evaluate and validate the selected design technique and the revealed usability factors.

[Keeping in view of these objectives, the Research Questions were:

1) **Research Question (RQ)-1**: "What would be the factors that affect usability of any military application?"

2) **Research Question (RQ)-2**: "How would the IDM be applicable to design and develop a Military application to enhance usability?"

1.4 Overview of Research Methodology.

From the research methodological perspective, this research followed an explorative and empirical research methodology. An overview of the research methodology that was followed was showed in figure 1:

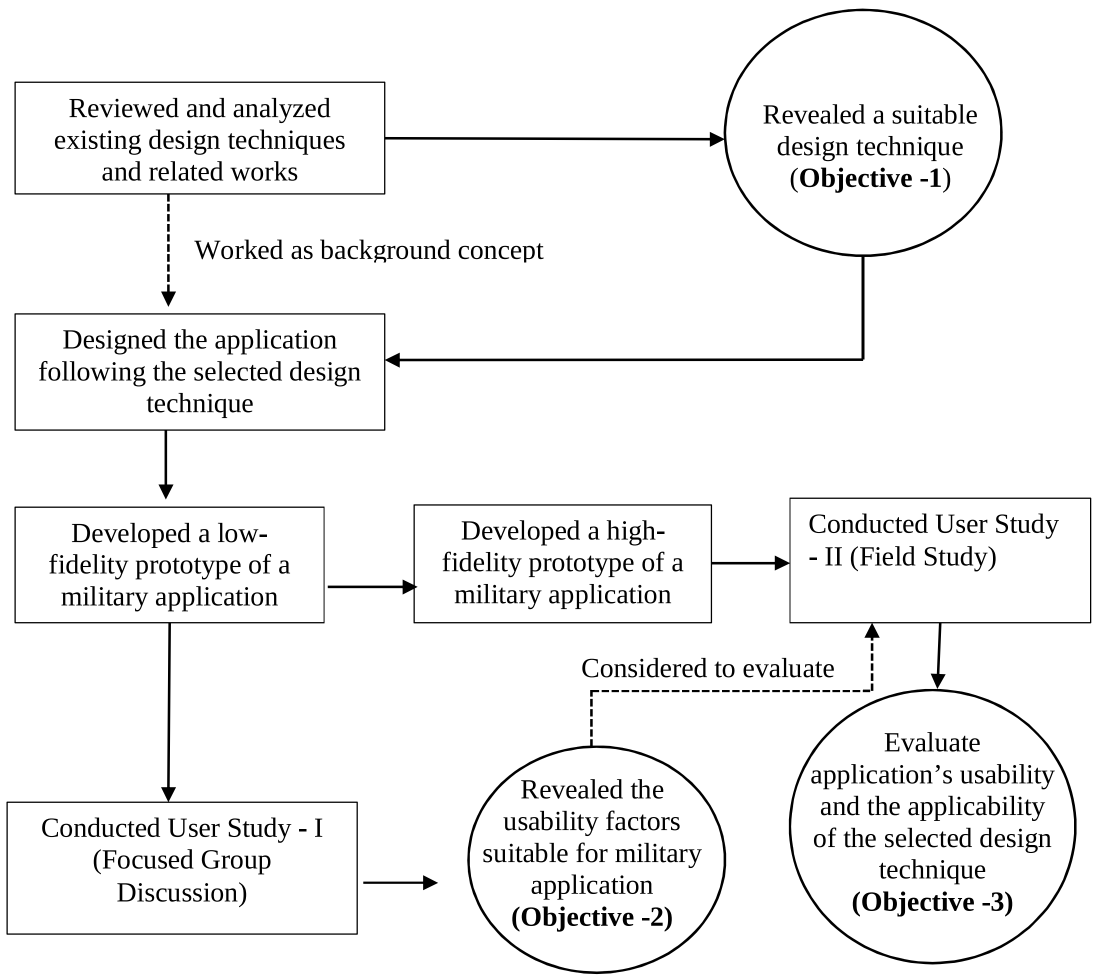

Fig 1.1: An overview of the research methodology

The thesis was carried out in the following steps sequentially:

1.4.1 **Step-I**

A Systematic Literature Review (SLR) approach [14] was followed to identify, evaluate and interpret all available researches relevant to this thesis. The review explored different general purpose design techniques of software development and exiting military applications around the world. The outcome of this step helped to understand the problem statement and conducted an analytical analysis to find out the best suited design techniques for developing a military application. This also helped to select an example military application for explorative study.

1.4.2 **Step-II**

Related literature review worked as background concept and leaded to design an application following the selected design technique. In this thesis, an advanced battlefield communication system was designed for the military personal.

1.4.3 **Step-III**

Following this design, an example military application was developed at basic level (low fidelity prototype) keeping in view of the military communication between the commanders at higher level with the front line troops which functions during any military operation. This application had audio and visual link to communicate each other and allowed higher commanders to view the real time battle scenario sitting in the command post or headquarters.

1.4.4 **Step-IV**

A user study was conducted following the Focused Group Discussion (FGD) [15] method to understand and explore the possible usability factors required for developing an effective military application. A low-fidelity prototype was used as an example of a military application to carry out the FGDs. The FGDs were conducted with varied rank and experience personnel. The qualitative data (text based content) was analyzed using a qualitative data analysis model, named Noticing-Collecting-Thinking model [16] to explore the possible usability factors that would be required for developing a military application.

1.4.5 **Step-V**

A concrete version of high fidelity interactive prototype was developed following the selected design technique. In other word, the low fidelity prototype was refined and updated to develop the high fidelity prototype.

1.4.6 **Step-VI**

A user study was conducted on ground to test the suitability of the selected design technique based on the derived usability factors. The participants used and evaluated the newly developed prototype application on ground and recorded their experiences. Finally, the experimental data was analyzed to verify whether or not the application fulfilled all the revealed usability factors and how much the selected design technique was applicable to design the military application.

1.5 Thesis Scope

This thesis, from broader perspective, covered the general research field including Human Computer Interaction (HCI), User Interface (UI) design, and Military Information Systems. Military applications those were related to specialized operations like Countering Terrorism, Natural Disaster, Fighting in the Build-up Area (FIBUA) etc and minor operations like Raid, Ambush etc were considered. Since the primary contributing field was HCI, this thesis focused on one of the key user quality attributes of software, i.e. usability. Thus, the other key quality factors like security, fault tolerance, reusability, testability, etc were not explicitly brought into the consideration to pursue this thesis. From user perspective, this thesis considered trained military users like officers and soldiers of Bangladesh Army. Thus, the parameters of HCI that were related for special need (disable) users were not considered.

1.6 Organization of the thesis

The thesis was organized as follows:

Chapter-II firstly discussed the theoretical background in depth on the requirements of Military Application, HCI, Usability, Usability Evaluation Method, User Interface (UI) and UX. Next, discussed the different design techniques used for general purpose software development followed by comparative study. Later, works related to HCI focused on military applications were discussed. Finally, a critical summary was made to highlight the research gaps and select a design technique for developing a military application in this research.

Chapter-III discussed the development process of Advanced Battlefield Communication System following the Interactive Dialogue Model (IDM) technique. It highlighted the designing process in three phases. Thereafter it discussed the development of the low-fidelity prototype of this system. This chapter also discussed the study procedure, data analysis and findings of the exploratory study, that was conduct following the FGD to find out the possible usability factors that would be suitable for developing and evaluating any ICT related military application.

Chapter-IV highlighted the development process of Advanced Battlefield Communication System following the selected design technique discussed in preceding chapter.

Chapter-V discussed elaborately the evaluation process of the application including the participants' profile, study procedure, and the study outcomes.

Finally, chapter-VI discussed the findings and verified the attainment of the objectives of the thesis. It also discussed the limitations and implications of thesis. Finally it noted some future works and concluded the thesis.

CHAPTER II

THEORETICAL BACKGROUND AND RELATED WORKS

This Chapter discussed the theoretical background in depth including Military Application, HCI, Usability, Usability Evaluation Method, User Interface (UI) and UX. It thereafter highlighted different design techniques used for general purpose software development followed by a comparative study. Later, existing work that were focused to the HCI issues in design, develop, and evaluate the military application were discussed. Finally, a critical summary was made to highlight the research gaps and selected a design technique for developing a military application in this research.

2.1 **Systematic Literature Review**

A systematic review usually used as a means to identify, evaluate, and interpret all accessible research relevant to a particular research question [14]. Systematic Literature Review (SLR) was carried out to identify, evaluate and interpret all available research relevant aspect related to research question of the thesis. Main sources of review materials were ACM digital library, IEEE Explorer digital library, Springer Link and Wikipedia. Web application, heuristics, usability, usability evaluation, human-computer interaction, focused group, defence software, military application etc were used as search strings by Google Search Engine. Some of the sources like books, magazine were manually collected specially the material related to military operation. The search was restricted up to the 1990. After eliminating the duplicate papers, priority was made. Finally, appropriate papers were selected for literature review.

2.2 Military Application

The military applications were considered safety critical applications. According to Department of Defense (DoD) terminology, United States Military, military application means “The system or problem to which a computer is applied” [17]. Military forces around the world were prepared for long time to deal with life and death situation every moment in the battle field concerning safety of men and materials. Applications designed for military were meant to use in the warfare and support administrative, functional and operational activities. The administrative military applications focused mainly on personnel management, office management, inventory manage, training management etc. The functional applications supported to operate function of the military hardware, equipment and other wares. On the other hand, operational applications were used in the field during combat operation. Military applications were exclusive military nature and different from civilian use. These applications were used by the military personnel only after appropriate military training.

With the developed scenario soldiers used to engage with multidimensional tasks besides traditional operations. The future day typical linear battlefield would be overwhelmed by a combat situation with a 360-degree threat, new high tech weapons, the use of non-traditional forces and terrorism [18]. From the recent deployment of troops worldwide, it could be concluded that military forces would continue to be deployed and used for operations other than war (OOTW). In these operations, a small group of soldiers would be deployed with technologically advanced or specific capabilities. Thus, military application developed for military force would require meeting the demand of the nature of such operations commiserating with the developed situation and intensity of the occurrence.

Military Forces would face diverse and unexpected situation arousing from the thick of the battle. Each situation would be unique in nature with multidirectional complexity. Commanders would need to take appropriate decision after relevant cost benefit analysis. Military application would thus require to provide interrupted information based services to the commanders in demand of diverse situations.

2.3 Human-Computer Interaction (HCI)

Human-computer interaction might refer to the design process, evaluation and implementation of computing systems which would interact with human and its surrounding phenomenon [19]. Computer systems were designed to perform user specific day to day tasks seamlessly. Designers, as such, would be engaged to design these systems considering human behavior, their thinking process and knowledge on the system. Thus designers needed to consider the performance and experience from user perspective while designing the interaction with the system. Human performance evaluation process started with manual tasks in factories at the beginning of the last century [20]. It intensified during World War II with an aim to produce more effective weapons systems for the battlefield. This was the basis of foundation of Ergonomics Research Society in 1949 concerning primarily on the physical characteristics of machines and systems [20]. Since the early 1980s, the term human–computer interaction (HCI) had been used worldwide.

HCI encompassed multi-disciplinary and interdisciplinary subjects. It involved Psychology, Sociology, Computer Science and Engineering, Cognitive Science, Ergonomics, Business, Graphic design and so on [20]. It combined both a craft and a science together. It provided beautiful and novel user interfaces that were artistically pleasing and capable of fulfilling human expectation and requirement [20].

2.3.1 **Usability**

According to ISO 9241-11 usability was "the extent to which a product could be used by specified uses to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". Effectiveness, efficiency and satisfaction were the criteria by which the quality of user-product interaction could be measured. An interactive design process was a development of interactive products that was usable i.e. effective to use, easy to learn, enjoyable user experience etc [21]. The goals of usability were utility, efficiency, learnability, effectiveness, safety and memorability etc [21]. Effectiveness referred to the performance fulfilling its expected outcome. On the other hand, Efficiency referred to the numerous ways and means by which a user could perform intended tasks with minimum steps or effort. Human nature was always change resistant and slow in adapting new system. They always wanted to adapt new system with less effort and time to learn. Users needed to learn a new system before using it. Thus learnability factor of usability referred how easily a system could be learning to use. Again the user had to remember the method of using such system. Memorability referred to how easily a system could be remembered to use. Theses usability goals to help to set usability criteria and specific objectives while designing the system [21].

2.3.2 **Usability evaluation method**

Designing a system following guidelines only might not guarantee good usability of the system. The system needed to be checked after development that users could use easily and like it [21]. Usability Evaluation thus ensured that system meet the set requirements and fulfill users' desire. This evaluation was done throughout the design life cycle of a system. Designers needed to evaluate both design and functionality of a system and suggest solutions accordingly. This evaluation process involved checking the prescribed standards, comparing alternative design solutions and assessing the design against specified goals.

Usability evaluation was performed following different approaches. These were:

1) **Analytical approach**. This approach was based on design guidelines, theories and models e.g. cognitive walkthrough, heuristic evaluation etc.

2) **Empirical approach**. This approach was based on quantitative/qualitative data collected from users e.g. lab/field usability testing, diary etc.

3) **Formative approach.** This approach supported the design process by collecting information.

4) **Summative approach**. This approach measured the usability according to quantitative/qualitative criteria.

Cognitive walkthrough evaluates a design without involving users. It evaluates how well the design supports user in learning task and identifies problems based on psychological principles [22]. Some expertise in cognitive psychology would be required to follow this method. This approach took into the consideration of the people's thought process and actions when they use an interface for the first time. Another approach was Pluralistic walkthrough [23] with a group of users. This Walkthrough could be performed on a paper-based prototype. These would require involvement of usability experts and developers. The purpose of this approach was to find usability problems and suggested improvements.

The other analytical approach was Heuristic evaluation. Heuristics were general principles for interaction design to find usability problems in a UI design. It would identify where design did not follow these principles. Some expert evaluators would be required who independently would check for compliance with usability principles ("heuristics"). Different evaluators would find different problems and communicate their finding afterwards. Finally the findings would be aggregated and usability problems would be identified. Some notable heuristic evaluation methods were Nielsen's 10 Principles [24], Shneiderman's 8 Golden Rules and Tognazzini 16 Principles.

MiLE+ (Milano Lugano Evaluation Method – version 2) [25] was used as another evolution technique. This would be suitable for hypermedia and web applications. This was more systematic and structured than general usability evaluation methods like heuristic evaluation, cognitive walkthrough, pluralistic, task based testing etc. A key concept of MiLE+ was that an interactive application could be evaluated from user experience perspective rather than technical perspective.

2.3.3 User experience and usability

User experience meant the feeling of user on the interaction with the system. This included feel, pleasure and satisfaction when using, looking, holding, opening or closing it. According to Garrett [26] "User experience is not about how a product works on the inside but how it works on the outside. Every product that was used by someone has a user experience: newspapers, ketchup bottles, reclining armchairs, cardigan sweaters". Users experience was always from their perspective, rather than system own perspective. It included more subjective goals. User should feel satisfying while using a system which should be enjoyable, entertaining and fun to use. The user should find the system helpful, motivating and aesthetically pleasing. The user also should feel the system supportive of creativity, rewarding and emotionally fulfilling.

The designer should recognize the user experience while designing a system. He should make a tradeoff between usability and user experience depending on the user and context of use. All the designs might not fulfill all factors of usability goals and user experience together. It might not be always possible to design a process that would be both safe and fun together. Designer might not be able to design user experience but could design for a user experience.

2.3.4 Military Applications and HCI

HCI and Usability were important key quality for development of any software. Usability factors were used to develop applications of different fields. Usability was equally important for military application as well. Erroneous use of usability factors in general fields might contribute negatively in the performance but might not threaten human life. But in case of military domain, soldiers would face life and death every moment in the war field. Thus, the development of military applications following usability factors might contribute in reducing the life threating risk.

2.3.5 Security of military application

Security was one of the important tenets of any military application. Breach of security might jeopardize success of any military operation. Designing of military application with information and network security would be utmost concern for any designer and developer. Emission and transmission from any device must be safe from stealing, eavesdropping etc.

2.4 Design Techniques of Software Development

Design technique was a process of exploring different possibilities, redefining existing design solution, prototype development and continually conducting trial and error before reaching to a final version of application [27]. Existing design techniques for software design were discussed below:

2.4.1 Semiotic Interface sign Design and Evaluation (SIDE) framework

A Semiotic Interface sign Design and Evaluation (SIDE) framework [28] was proposed in [28]. The framework focused on designing and evaluating intuitive interface signs to enhance web usability and user-centric process. This framework was based on five semiotic layers namely semantic, syntactic, pragmatic, environmental and social. It did not support multi-language and multi-channel facilities. However it supported response from user and offer easy navigation.

2.4.2 Web Site Design Method (WSDM)

Web Site Design Method (WSDM) was a user-centered web site designing approach for kiosk Web Sites was proposed in [29]. This designing method was mainly used for data driven website for different types of users. It first divided users into different classes and thereafter data was modeled based on class's viewpoints without implementation details. This model was then converted into programing language source code files before implementation. It could maintain the consistency with multiple languages but did not support multi-channel. It required a high skill set of designers to design the website.

2.4.3 **Relationship Management Methodology (RMM)**

Relationship Management Methodology (RMM), a Hypermedia design and construction methodology was proposed in [30]. RMM designed and developed hypermedia applications following several steps namely slice design, user interface design, run-time behavior design, entity-relationship design, navigational design, conversion and construction design, testing etc. It provided easy navigation but did not support multi-channel and multi-language.

2.4.4 **Object Oriented Hypermedia Design Model (OOHDM)**

Object Oriented Hypermedia Design Model (OOHDM) proposed in [31]. It used navigational tools to map onto relationships of the conceptual model. The model allowed designers to design a low fidelity prototype and later removed the faults generated from the initial design. It helped to organize the navigational space as objects of conceptual model and separated interface issues from navigation issues [32]. This model helped the designers to build different web applications reusing a single conceptual schema. This design model provided easy navigation and multiple languages. However, it did not support multi-channel. It lacks portability, consistency, response and other important user friendly factors.

2.4.5 **UML Extension Web Design Model (UEWDM)**

The Unified Modeling Language (UML) was a general-purpose, developmental, modeling language in the field of software engineering that was intended to provide a standard way to visualize the design of a system [33]. A Unified Modeling Language (UML) [34] based navigation design approach was proposed for modeling complex interactions in web applications was proposed called UML Extension Web Design

Model (UEWDM). This approach provided a systematic and conceptual design modeling in complex web applications. In this approach, navigation design was done through two design models- Navigation Space Model and Navigation Access Model. Navigation space model defined what the users would see and the relationships among navigation classes. Navigation access model defined how the web users reach those classes. This model only provided the feature of Multiple Languages Support.

2.4.6 **Enhanced object-relationship model (EORM)**

The enhanced object-relationship model (EORM) proposed in [35] was an Object-oriented methodology based on three frameworks: Class framework, Composition framework and GUI framework. Class framework expressed the underlying information structure of the application. Composition framework expressed the rules through which navigation capabilities could be defined based on the class framework, and the GUI framework defined how the information and navigation elements were presented to the user. This model could not provide easy navigation but could maintain consistency and support multiple languages.

2.4.7 **Hypertext Design Model (HDM)**

F. Garzotto and P. Paolini [36] proposed the Hypertext Design Model (HDM) to describe hypertext systems. Hypertext development was a structured and systematic approach suitable for large and complex applications. This was developed as part of the HYTEA project by a European Consortium [37]. This system described classes of information elements and navigational structures of complex system without implementation details in a system-independent manner. HDM was mainly used for large scale hypermedia applications where regularity, organization, modernization and consistency were contributing factors. This model had some similarities with the Entity Relationship (E-R) model. The features of HDM included identification of different categories of links with different representational roles. It also distinguished between hyper base and access structures and easily integrates the structure of a hypertext application with its browsing semantics. A significant number of links could be derived automatically from a conceptual-design level description. It could be used as modeling device by setting out the specifications of an application or as implementation device by designing tools that directly supported application development [37]. It provided the feature of easy to navigate, maintained consistency and supported multiple languages. But this design model did not support multichannel feature.

2.4.8 **Interactive Dialogue Model (IDM)**

The IDM [38] was a novel design model specifically tailored for multi-channel applications. The background research, moving from linguistic theories and practices, had led to the development of a channel independent design model (based on dialogue Primitives). IDM approach suggested to start the design in a conceptual channel-independent fashion, and then proceed into a further logical design for a specific channel (e.g. mobile, web). This sequence of technique offered many advantages without complexity. IDM had additional distinctive features: it was lightweight, provides a few sets of primitives (and a simple graphic notation), which were easy to learn and teach. Moreover, it was suitable for brainstorming and generating ideas at early stage during design (or during the shift from requirements to design). Finally, it was cost-effective (it requires little effort from designers) and modular (designers could take the part they wish, not being forced to all or nothing).

The reason IDM was called a dialogue model because using IDM we could consider a web experience as a dialogue between the user and the web site being used. User turns were articulated by selecting specific links, with their attached semantics. Machine turns consisted in providing pages to the user. An interactive application could be considered a kind of dialogue generator, i.e. a device capable of supporting several different conversations with different types of users. The designer of a web site must imagine interesting conversations for the user and provide navigation mechanisms to make them possible. This approach helped shaping an application in a more natural way, avoiding the designer to be concerned, from the beginning, with pages, or information units, or technologies to be used. IDM had been validated both in the academic and industry environments by designing the information intensive application like museum and e-governance sites.

2.5 **Comparison among Different Design Techniques**

The features of the existing design techniques (as discussed above) were compared. The comparative scenario was depicted in Table 2.1. The Table 2.1 showed that though each method had its own merits and demerits, but the IDM techniques include all features like design support for multi-channel applications, portable system design, responsive interface design, provide easy navigation, maintain consistency, channel independent application design, and assist to design information intensive web and interactive mobile application; while the technique did not demand high skill to learn and apply.

Table 2.1: Comparison among different design techniques

Factors	SIDE	WSDM	RMM	OOHDM	UEWDM	EORM	HDM	IDM
Multi-Channel Supportive	X	X	X	X	X	X	X	✓
Portability	X	X	X	X	X	X	X	✓
Response Supportive	✓	X	X	X	X	X	X	✓
Easy Navigational	✓	X	✓	✓	X	X	✓	✓
Multiple Languages Supportive	X	✓	X	✓	✓	✓	✓	✓
Consistency	X	✓	X	X	X	✓	✓	✓
Channel Independency	X	X	X	X	X	X	X	✓
High Skill Demanding	X	✓	X	X	X	X	✓	X
Information intuitive web and interactive mobile application design	✓	X	X	X	X	X	X	✓

A military application demanded versatile use in multiple platforms, where front troops/soldiers needed to use the mobile devices and the higher commander used the desktop at command posts. The portability, responsiveness, and easy navigation were also highly important for developing an effective and usable military application. Thus, the IDM technique was selected for designing the multi-channel military application.

2.6 Review of Different Military Applications

This sub-section would briefly present the existing work that were focused to the HCI issues in design, develop, and evaluate the military application.

A usability study was conducted on Integrated Computer Management System - SPKB (Sistem Pengurusan Komputer Bersepadu) of Royal Malaysian Air Force (RMAF) [2]. SPKB was developed for Royal Malaysian Air Force for asset management to support their supply chain management. This project was based on integrated logistics support concept (ILS). RMAF used SPKB for maintaining assets like aircrafts, radar etc.

Concurrently almost 4000 users used the system to perform their operational duties. The study was conducted to identify the usability problems of SPKB system based on Nielsen’s heuristics and identified a few usability problems to improve the ease of use of SPKB. Few variables like Efficiency, Learnability, Memorability, Errors and Satisfaction were investigated for usability testing for the system. A few factors were identified to improve the usability factors of the system.

User Experience (UX) for a Command, Control Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) System was explored in [39] in order to improve the UX of the soldiers while interacting with the systems under tough situations on the battlefield. It was mainly proposed for U. S. Army to identify human performance and human-system interaction using an iterative user-centered design process. It evaluated seven domains namely system safety, soldier survivability, health hazards, manpower, training, personnel and human factors engineering (HFE). This system tried to improve the soldier centered design activities. The architectural framework of C4ISR was now known as Department of Defense Architecture Framework (DoDAF).

Sungho Kim et el [40] worked on military Computer-Based Training (CBT) system to improve graphic user interface (GUI) in terms of usability. This was used for military education and training. This study explored ten usability criteria i.e. attractiveness, simplicity, responsiveness, informativeness, accessibility etc. As an outcome of the study, accessibility and informativeness were the top appreciated features ofm the system apart from the simplicity part of it.

The necessity of a combination of usability engineering methods in the development of a military training system was investigated through a case study in [40]. They had integrated multiple methods like contextual task analysis, iterative designs, heuristic evaluations, formative, and summative evaluations to evaluate a training system in order to optimize performance of the training system [40].

In another study [41], a heuristic evaluation following the Atkinson et al.'s Multiple Heuristics Evaluation Table [42] was carried out to identify the strengths and weaknesses of UI design of the LG-RAID (Linguistic Geometry Real-time Adversarial Intelligence and Decision-making), which was a game based tactical training system. It was designed for Army personnel undergoing training on the development of tactically correct courses of action. As outcome, they found a number of usability problems of LG-RAIDs that were not considered during the design phases of some specific features and functions in the UI. They also highlighted the importance of user's cognitive capabilities for designing UIs.

A similar study was conducted in [43], where thinking out loud method [44] was followed to evaluate the usability of a system that used to operate the Unmanned Aerial Vehicles (UAVs). The study dealt with the problem of information overload on the controller when numbers of UAVs were monitored which create problem for HCI. These resulted in reduced the situational awareness of the operator. Based on the evaluation outcome, the system was designed alternatively. The alternative designed showed better usability and system performance.

A usability evaluation of a mobile medical information system for military physicians was carried out at the Finnish Defense Forces in field conditions [45]. They studied 7 military physicians at the Finnish Defense Forces on evaluating the characteristics and the features of the system, and properties and the features of the mobile device-Nokia 9210. They identified the potentials to fine-tune the usability of medical database and user-friendly and easy to use device to increase the quality of health care in the battlefield.

2.7 **Critical Summary**

From the background study we found that HCI and Usability were important key quality for development of any software. Usability factors were used to develop applications of different fields. Erroneous use of usability factors in general fields might have negative impact in the performance but might not threaten human life. But in case of military domain, soldiers would deal with life and death situation every moment in the war field. The development of military applications following usability factors might contribute in reducing the life threating risk. Thus, Usability was equally important for military application as well. Again, Military force worked in multidimensional space to meet the demand of the situation. There was a necessity to develop application that would support multi-channel facility. It also required fulfilling specific design requirements best suited for specific operational condition, battle scenario, situation etc. From the study, we found that a few studies had been conducted focusing on the usability and UX issues of military applications. These applications were developed following different design methodology tailored and customized from the general purpose application. These studies assessed and evaluated the usability in diverse dimensions in a scattered way. No specific and complete set of factors/parameter were explored to measure/evaluate or enhance the usability standard for military applications.

From the design method, this thesis also found that there was no specific technique designed for multichannel. After going through all general techniques this thesis made a comparison with IDM on basis of some design factors and user interface properties. IDM was found appropriate design technique for developing military application which could be used for designing the both information intuitive web and interactive mobile applications. Thus, this research focused on IDM design technique to develop an example military application to explore the usability factor needed to develop military application and to investigate the suitability of the technique by assessing the factors that would be required to develop a military application with enhanced usability.

CHAPTER III

PROTOTYPE DESIGN AND EXPLORATORY STUDY

This Chapter discussed the development process of first version of the prototype. It highlighted the designing process of Advanced Battlefield Communication System using IDM in three phases: Conceptual Design (C-IDM), Logical Design (L-IDM) and Page Design (P-IDM). Based on these designs, a prototype of Advanced Battlefield Communication System as an example military application was developed. Finally, the study methodology was discussed to conduct the exploratory study to find out the possible usability factors that would be suitable for developing any military application.

3.1 Designing Advanced Battle Field Communication System Using IDM

A prototype of Advanced Battlefield Communication System was developed using IDM. In this application, an exclusive battlefield scenario was portrayed to the higher echelon of military through the eye of a front line troops. Audio, video and textual communication feeds were planned to connect with a small group of front line troops and generated those feeds in web page and mobile application to provide multichannel facilities. The application consisted of web for viewing, apps for communication and hardware for transmitting audio-video feed to the web or mobile. The detailed design methodology for developing the application was discussed in the subsequent sections.

3.1.1 Designing the Conceptual IDM (C-IDM)

Conceptual design was the first step of the design process in IDM. It followed some strategy to plan the content of the system would. This was a conceptual schema which formulates necessary “dialogue strategies” for interacting with the application without specifying medium or channel like web, mobile application. It had three simple design elements: “topic,” “relationship,” and “group of topic” [38].

3.1.2 **Design elements of C-IDM**- Basic Concept

- **Topic:** Topic in C-IDM was viewed as conversation between the user and the interactive application as two persons in real world converses on some subjects. This conversation might be categorized by ‘Single Topic’ and ‘Multiple Topics’. Single topic involved conversation on a single subject with single instance. On the other hand, ‘multiple topics’ encompasses multiple subjects with multiple instances [38]. The subjects might be arranged or identified in different categories which were known as ‘Kind of Topic’.
- **Relationship:** It was the connection or transition between the topics**.** During a conversation multiple subjects might be discussed and subject might mingle or change from one to another. Relationship determines the strategy of switching from one kind of topic to another. It was represented by a directed line from one kind of topic to another kind of topic in the design with cardinalities. Cardinalities were indications of the number of topics instances [38]. This could be one-to-one (1:1) or one-to-many (1:n).
- **Group of Topics:** A group of topics was a set of instances of a multiple topic [46]. It determined a specific group of topics or possible subject of conversation [38]. A family of group of topics represented ‘multiple groups of topics’.

3.1.3. **C-IDM of the Proposed Application**

Based on the above theoretical background, the C-IDM of the proposed prototype was designed as shown in Fig 3.1:

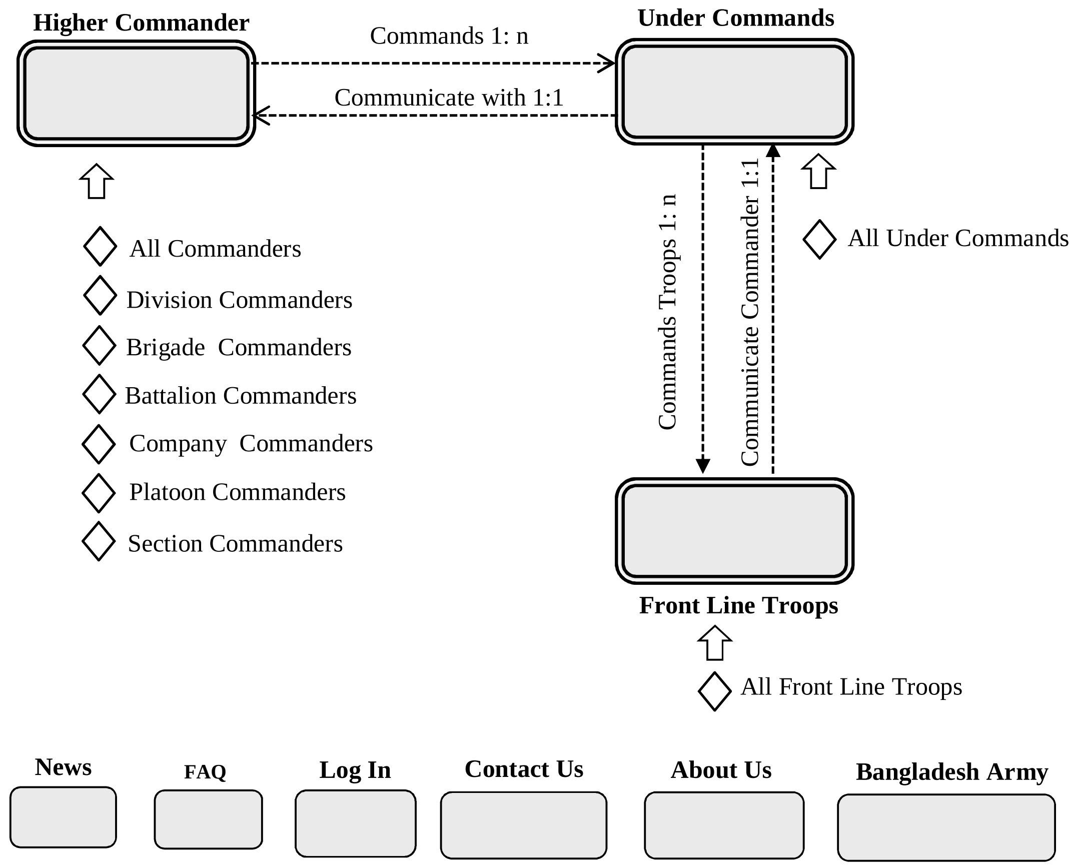

Fig 3.1: C-IDM of the proposed application

There were three 'Kind of Topics' in the C-IDM for the proposed application: 'Higher Commander', 'Under Commands' and 'Front Line Troops'. Single Topics were News, FAQ, Log In, Contact Us, About Us, Bangladesh Army, etc. Relevant relations indicated the relations between two multiple topics with cardinality in the application. For example, each 'Higher Commander' was allowed to command multiple 'Under Commands' but one 'Under Command' could communicate with only one 'Higher Commander'. Similarly, One 'Under Command' was allowed to command several

‘Front Line Troops’ whereas each ‘Front Line Troop’ could communicate with only one ‘Under Command’. Therefore, the multiple topics ‘Higher Commander’ was connected to ‘Under Command’ with relevant semantic relationship with 1: n cardinality and ‘Front Line Troop’ was connected to ‘Under Command’ with relevant semantic relationship with 1: n cardinality. Group of topics defined a specific group of topics. For example, division commanders indicated commanders who command a division. Similarly, there were other groups of topics in the conceptual design like battalion commanders, company commanders, platoon commanders, section commanders etc having almost the same motive as the other group of topics stated above with slight change in the rank and position of the army personnel. The design followed the existing chain of command of Bangladesh Army.

3.2 **Designing the Logical IDM (L-IDM)-Basic Concept**

Logical design was the second step of the design process in IDM. After the conceptual design had been defined, logical design decided the channel through which the application might be conveyed [38]. It could be traditional web, an oral channel, an interactive TV or a mobile channel. The logical design could be seen as a detailed version of the conceptual design. It decided the constraints imposed by the type of device available on a given channel like screen size, keyboard, smart pen, mouse etc. It also decided on the media being used like audio, visual text, images, graphics, or video etc. [38]. It took consideration of the expected performance and the typical scenarios of use like home or office desktop, walking or standing contexts, mobile use on car, etc. The level of details could change, according to the specific needs of the project. It was mainly a channel dependent design. It specified the movement of dialogue combined user experience [38]. It had three design elements: “Dialogue Act,” “Transition Act” and “Transition Strategy”.

3.2.1. Design Elements of L-IDM

- **Dialogue Act**: Dialogue was the conversation between user and application but dialogue act was the move of the dialogue within a topic which could be single or multiple. These acts were based on the channel specification and user needs.
- **Transition Act**: Single dialogue did not require addition act to change from a Kind of Topic to another Kind of Topic. However, when there was a need to change from subject to many new subjects, an addition dialogue was needed which was called transition act. A strategy should be developed in a way that a user could access all the new topics.
- **Introductory Act**: It allowed the exploration of a group of topics as a whole. It consisted of an introduction followed by a list of the topics belonging to the group. Introductory acts were the unique starting points for the dialogue, in the sense that any dialogue started with an introductory act. It supported the access and exploration of all the topics belonging to the group.

3.2.2 L-IDM of the proposed application

Following the C-IDM schema, L-IDM for the web version (See Figure 3.2) and handheld version (See Figure 3.3) of the proposed application were developed.

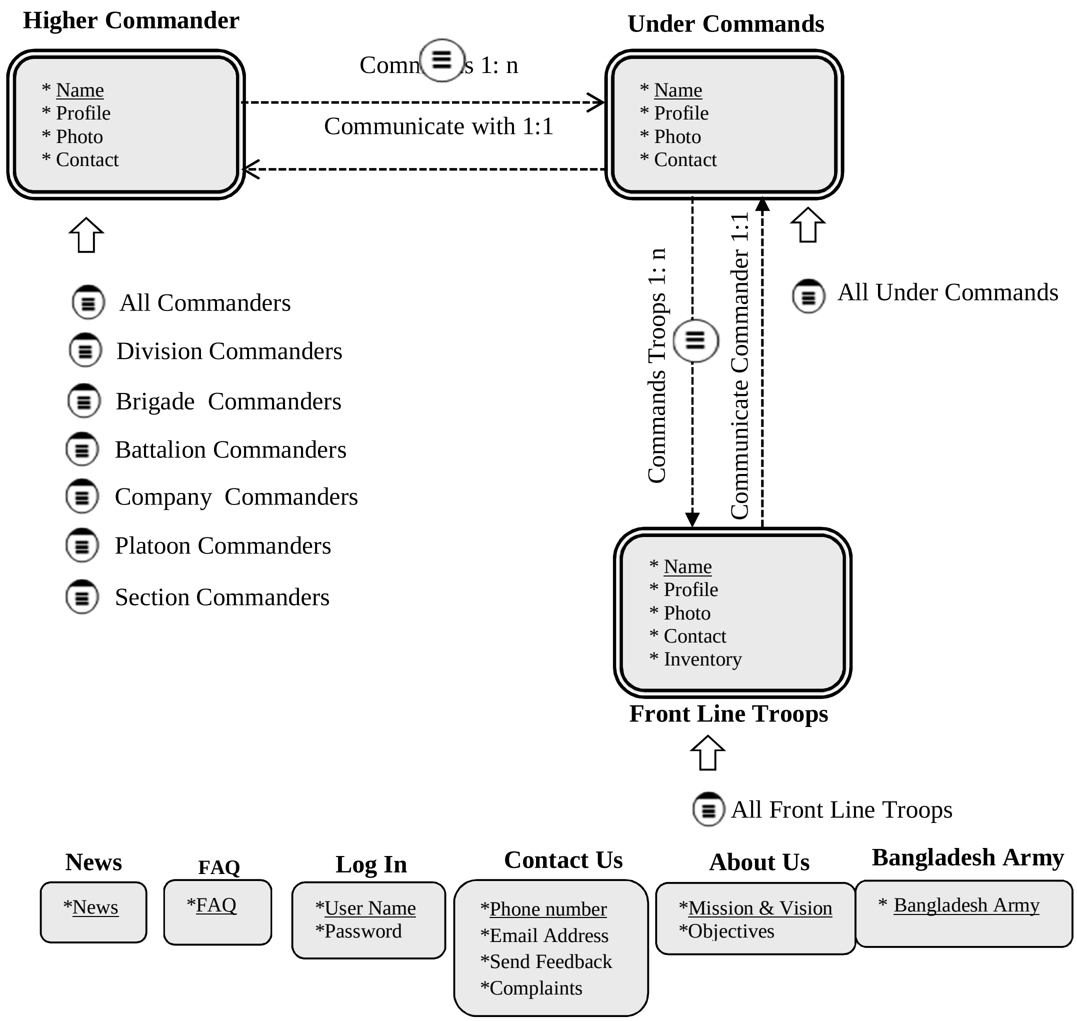

Fig 3.2: L-IDM of the proposed application (web version)

Fig 3.2 represented the web version where kind of topics “Higher Commander” was fragmented into different dialogue acts such as name, profile, photo, contact details of each higher commander. ‘Name’ ‘profile’ and ‘photo’ of the higher commander were necessary for identification and verification while ‘contact details’ could be helpful for the higher commander to communicate with the other commanders in the ladder of the organization. The dialogue ‘name’ was a default act which was shown as underlined. In the same way other kind of topics ‘Under Commands, and ‘Front Line Troops’ contained respective dialogue acts like ‘name’, ‘profile’, ‘photo’, ‘contact details’.

However, ‘Front Line Troops’ had an addition dialogue act named ‘inventory’ which contained the inventory status of arms, ammunition etc. of the front line troops. Single topic like ‘Bangladesh Army’ had a single dialogue act which briefly described work policies and other news of Bangladesh Army which might help the user to get a better overview of both Bangladesh Army and the website.

The transition act of the relation ‘commands’ would help to switch from one ‘higher commanders’ to many ‘under commands’ who were commanded by him. Likewise ‘Commands Troops’ transition act would help one under command to switch between many front line troops under him (1:n semantic relation) with direct access to default dialogue act ‘name’. On the other hand ‘Communicate with’ and ‘Communicate Commander’ relation had one to one relation which did not require any transition act as it had direct access to default dialogue act of target topic.

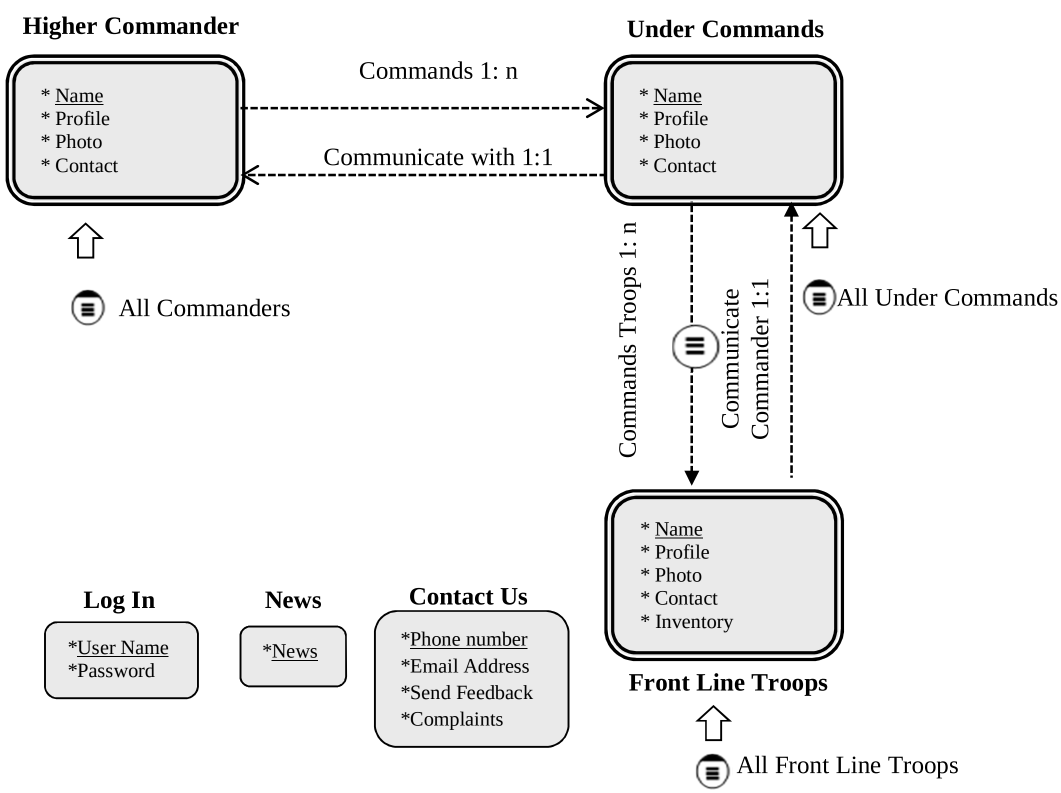

Fig 3.3: L-IDM of the proposed application (mobile version)

Fig 3.3 represented the mobile version which contained all the kinds of topics excepts the single topics ‘FAQ’, ‘About Us’ and ‘Bangladesh Army. The single topic ‘ Contact Us’ contained multiple dialogue acts like ‘Phone number’, ‘Email Address’, ‘Send Feedback’ and ‘Complaints list’ to get in touch with the administrator of the web as present in most of the web site.

3.3 **Designing the Page IDM (P-IDM)-Basic Concept**

According to the corresponding L-IDM design, pages were designed form each act containing the necessary elements of the dialogue [38]. During page designed each dialogue act, introductory act and transition act were converted into a page. Relevant topics, group of topics become landmarks of the page. At this stage page design did not consider wireframe, layout or graphic design. Visual communication designers then made layout and graphic design on the finally rendered page [38].

3.3.1 P**-IDM of the proposed application**

Following the P-IDM design technique numbers of pages were designed for the proposed application. Some of the pages were discussed below:

- **Home Page**: This was the index page where users encountered at the first instance. This was the mirror of the whole application and hosted all links to other pages. Kinds of topics- ‘Commanders’, ‘Under Commands’ and ‘Front Line Troops’ became landmarks of this page which would be accessible from all pages without changing its location and position. In this application these were placed at the upper top part top of home page. Single topics were placed at the bottom part of the page and group of topic were placed on the left side of the page (See figure 3.4 and 3.5).

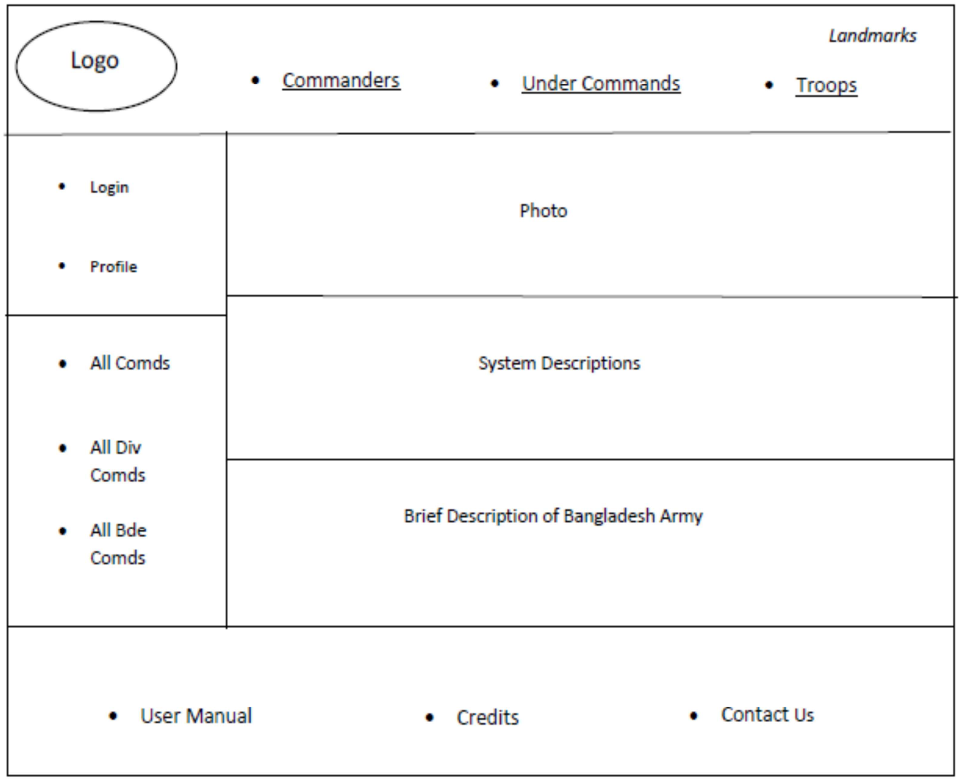

Fig 3.4: Page design (home page web version)

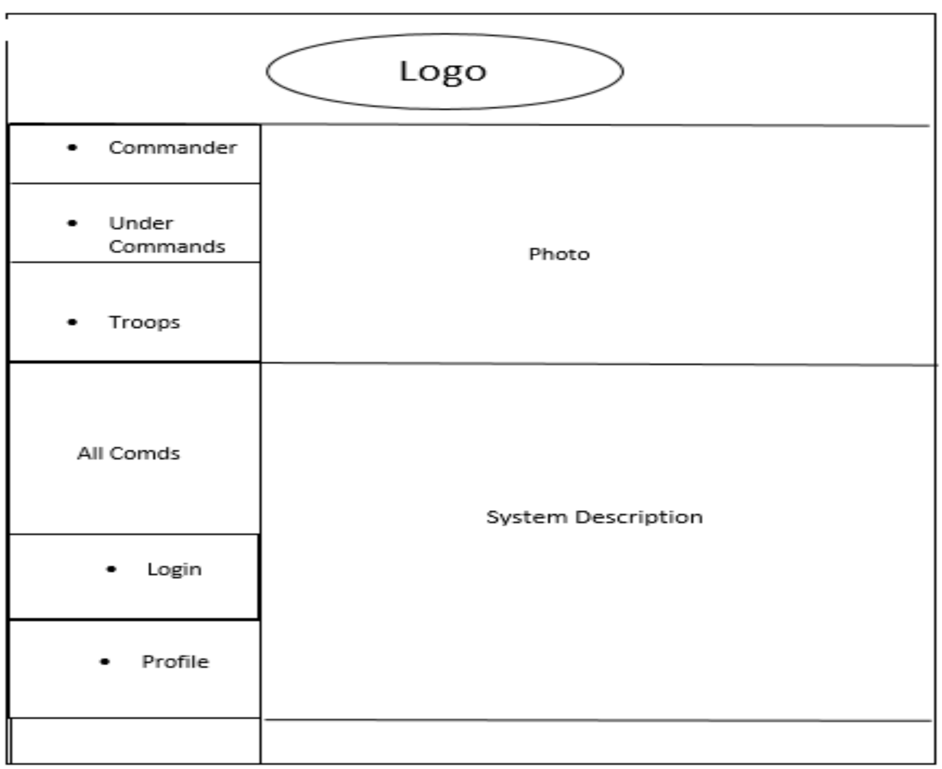

Fig 3.5: Page design (home page mobile version)

- **Introductory dialogue act (all div commanders)**

All div commanders were considered as introductory dialogue act as they were considered as group of topic as a whole. This page contained the basic information of all the division commanders. If the user wished to see the information of all divisional commanders, this page would act as an introduction to the group of topic all div commanders. If anyone wished to see more information of one particular division commander, he would be directed to another page containing that information by clicking on the view details information for that particular division commander (See figure 3.6).

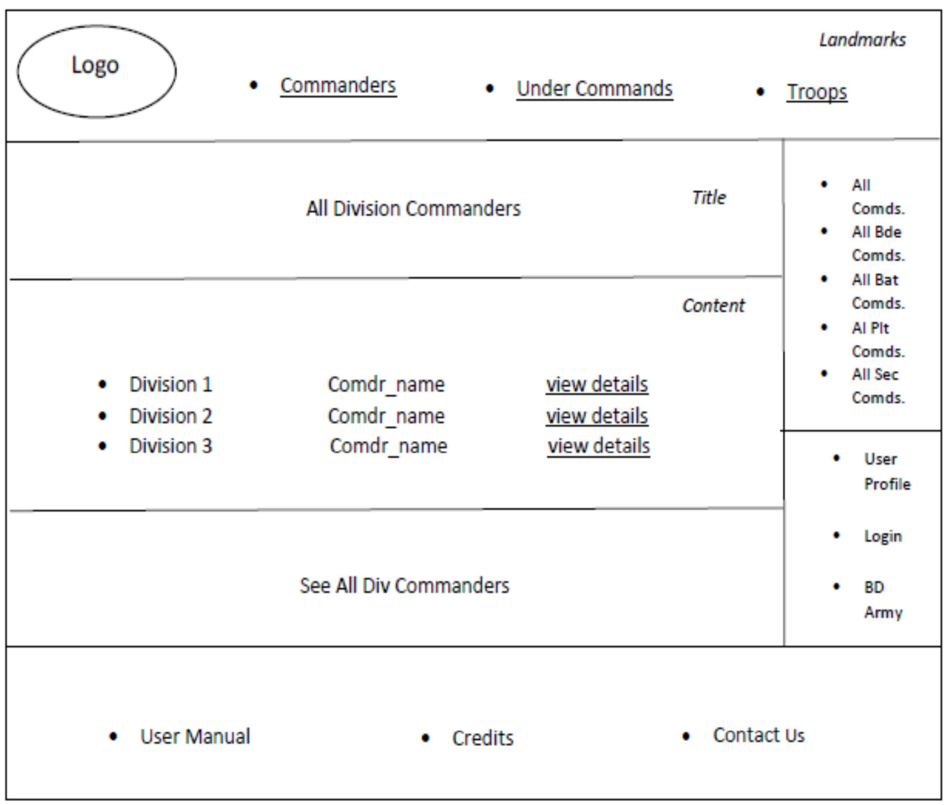

Fig 3.6: Page design (introductory dialogue act)

- **Transition act (commands troops)**

Commands Troops was a transition act from commander to front line troops. This transition act page would generate the list of troops under the supervision of any commander with one to many cardinality (See figure 3.7).

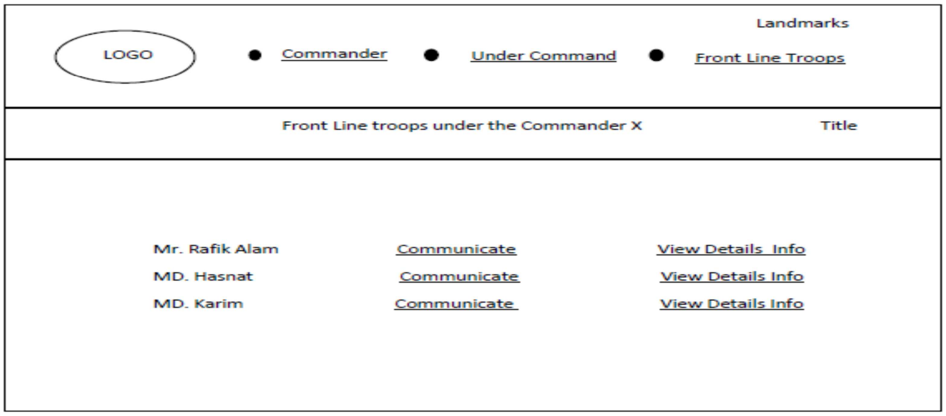

Fig 3.7: Page design (transition act)

3.4 Designing Low Fidelity Prototype of Military Application

After completing the page designing, a low fidelity prototype application was developed to find out the suitable usability factors. The functional diagram of the application was shown in Figure 3.8. The camera was connected to the SDT/smart phone using Wi-Fi to provide a video feed to web page or handheld version page. Head phone was connected to the SDT/smart phone via blue tooth to make an audio channel with the commander with their under commands for necessary interaction. The SDT/smart phone was connected to central server via 3G/4G/Radio Relay. Live streaming from camera with audio could be accessed by any level of commanders using desktop/laptop/smart phone in the command post/headquarters following one to many and one to one relationship (See figure 3.8).

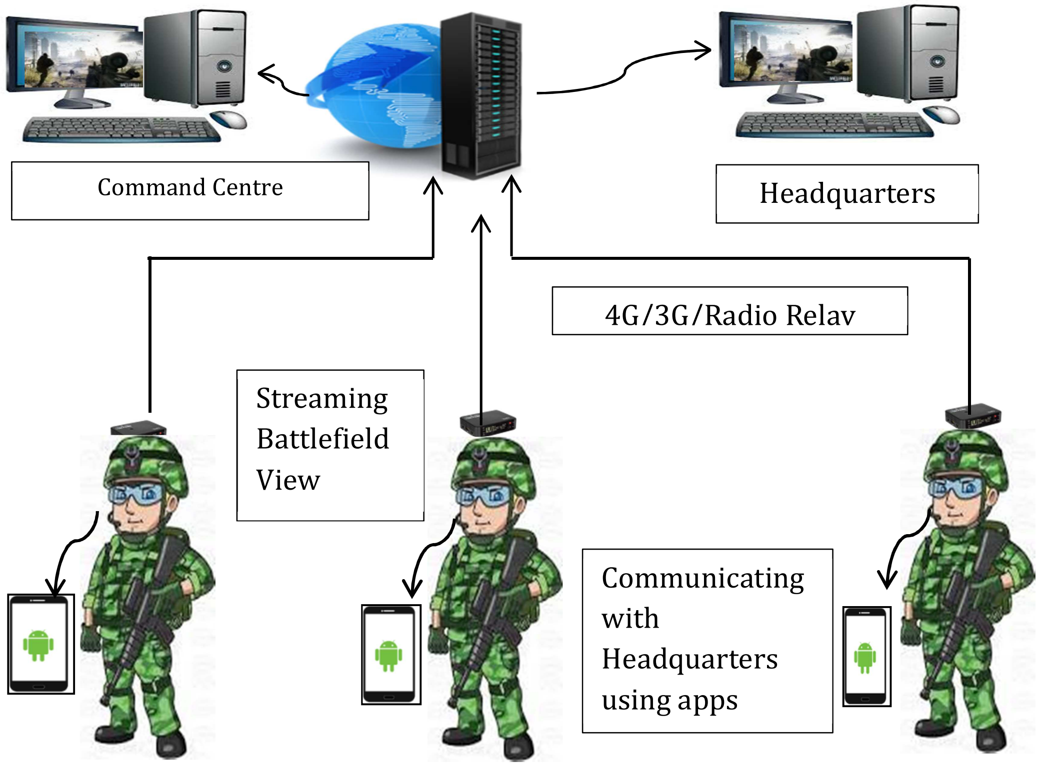

Fig 3.8: Functional diagram of the prototype application

3.4.1 **Designing of mobile apps**

A mobile application was designed to establish audio communication between the troops and commanders. Troops could easily log on to the server from user interface and establish one to one communication with each other.

3.4.2 **Configuration of different servers**

There were different servers used for the prototype. These were:

- **Provisioning Server-** No sequel Apache Cassandra server was used for user registration and log on with Node.js framework.
- **Web Server-** For developing web application.
- **Video Broadcasting Server –** For streaming the multimedia content.
- **Audio Calling Server –** For establishing audio call.
- **Location Server –** For locating the troops' current location.

3.4.3 Signaling architecture

- **Login/Authentication**

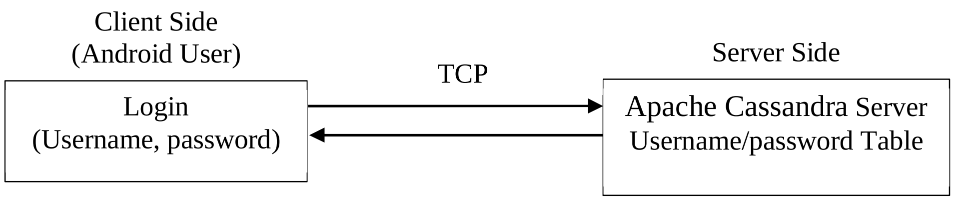

Fig 3.9: Signaling architecture of login/authentication

User would log on to mobile or desktop version using user and password which would be provided beforehand**.**

- **Video streaming architecture**

Camera from the front line troops would capture the live stream and sent to a publisher. This publisher could be either software encoder or hardware encoder. A code was written to compress the stream and push to stream server. This code could be run in multiple devices like smart phone, laptop, raspberry pi etc. Hardware encoder could be any streaming device embedded with suitable codec and code. This stream would be sent to broadcasting/ streaming server. This server would publish this stream into web or smart phone. The architecture for video streaming is shown in Figure 3.10.

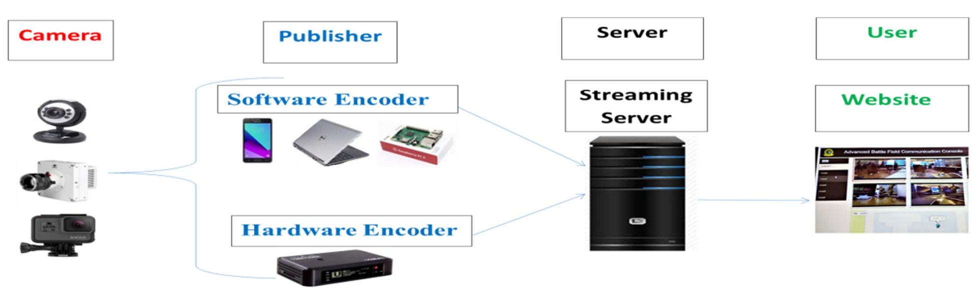

Fig 3.10: Architecture of video streaming

- **Video streaming management**

  Captured video packets would be larger size requiring larger bandwidth and processing power. This needed to be compressed using suitable codec like H264, VP6, VC1, MP2 etc. The codec would convert each packet into a small video object. These object required to be stored in a container known as video format i,e: FLV, MP4, MOV, AVI etc. This would contain millions of video objects. Now these objects needed a transport track to move the container from server to media player like Real-Time Messaging Protocol (RTMP), Real Time Streaming Protocol (RTSP) framework. Live Video Streaming Management is shown in Figure 3.11.

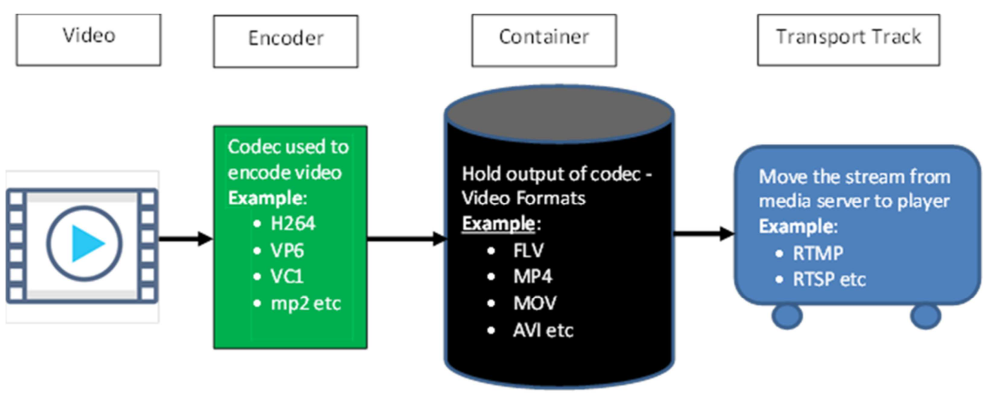

Fig 3.11: Video streaming management

- **Video streaming signaling**

  Steaming camera would capture the video and broadcast video packet using UDP (User Datagram Protocol) for establishing low-latency and loss-tolerating connections. Laptop, Raspberry pi or Smart Phone could be connected to the streaming camera using Wi-Fi or Bluetooth to capture the packets. In case of software encoding scheme, the captured packet would then be encoded using a suitable codec / script (might be developed with python or other suitable language) which might be run in any suitable device. The encoded packet would be sent to Broadcasting Server using Hyper Text Transfer Protocol (HTTP). This server would then publish the encoded packets to web/apps using RTSP or RTMP. In case of hardware encoding scheme, video encoder would directly capture the stream, encode and directly transmit to streaming server using Real-Time Messaging Protocol (RTMP) to publish the stream into the web/app. The video streaming signaling process is shown in figure 3.12.

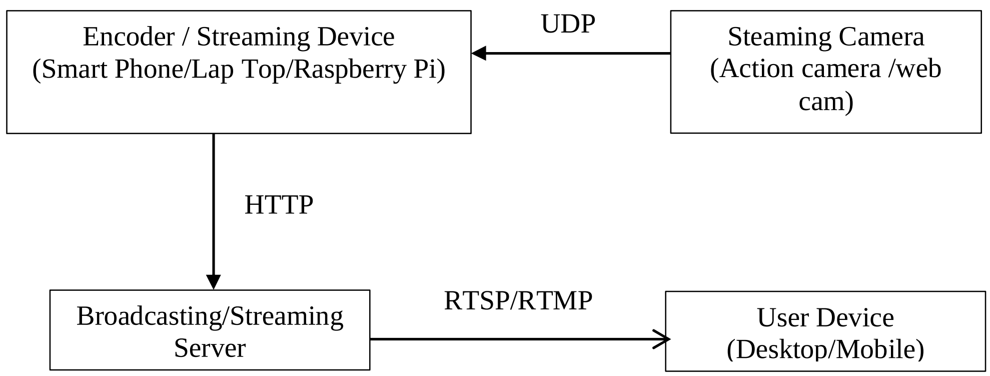

Fig 3.12: Signaling architecture of video streaming

- **Audio calling**

A mobile app would be developed by which front line troops could call one to other and with their higher commanders. The signaling architecture is shown in Figure 3.13. User would connect to audio calling server and establish call with the destination subscriber. This system would require a cross-platform telephony system for real-time audio communication. This might use Session Initiation Protocol (SIP) trunking system.

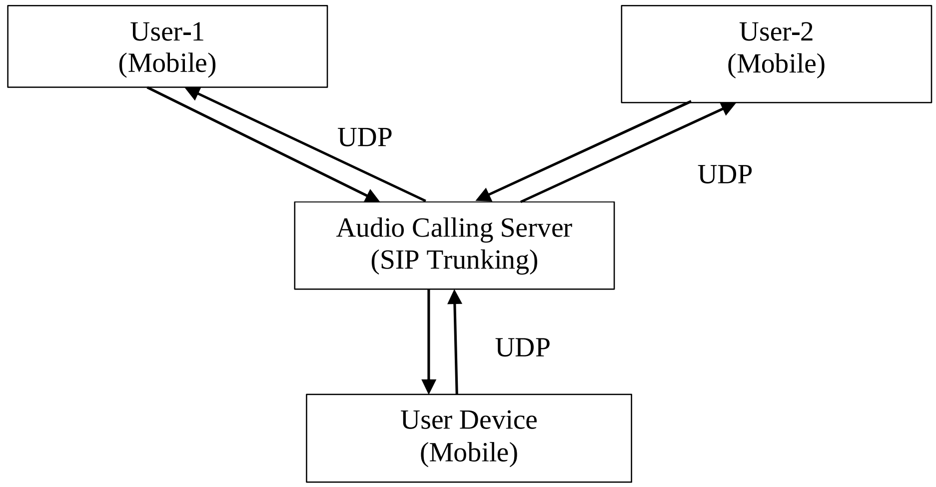

Fig 3.13: Signaling architecture of audio calling

- **Location identification service**

Apps would collect the location of an individual using GPS module and send the information packet to the server. This server would work as database for storing the location information and project in the web/app (see figure 3.14). Headquarters would be able to identify the current progress of the battlefield scenario.

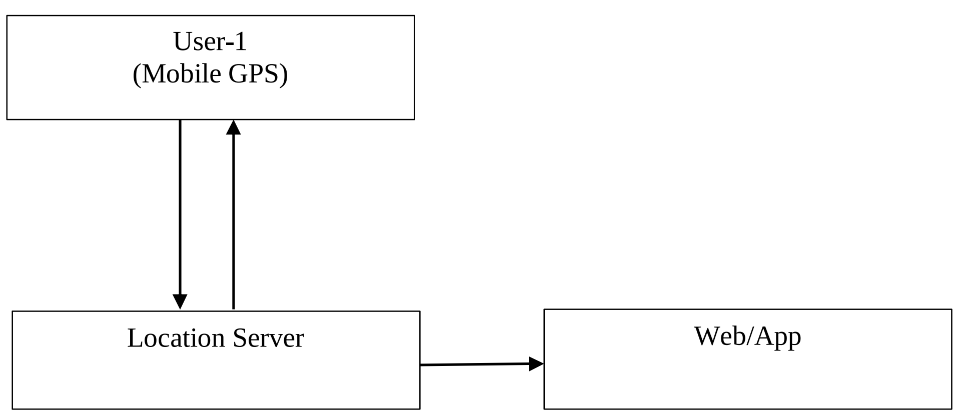

Fig 3.14: Signaling architecture of location service

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3.5 Exploring the Usability Factors

An explorative study was conducted to reveal the all possible usability factors that impacted the usability standard of a military application. The study was conducted the following the FGD. The researcher/student conducted the FGD session as moderator while supervisor act as facilitator. The study was carried out following the steps below:

3.5.1 Recruit and invite participants

An invitation was sent to about 50 military personnel from the rank Brigadier to Private. Some were invited personally. However, two sessions of FGDs could be conducted. During the FGDs, a total of 20 military personnel were present. All participants were male having age 28 ± 4.8 (mean ± standard deviation). Their service rank ranged from Private to Lieutenant Colonel with average length of service experience was 9.5 ± 3.2 (mean ± standard deviation). Five participants had about 1-2 years, other four participants had 3-5 years and rest of them had more than 5 years of experiences of using ICT related applications and tools, for example, router, switch, server, navigation systems, wireless communication systems, and the like.

3.5.2 Conduct the FGD session

Each FGD session was conducted following the steps below:

- **Initial Brief**: At the very outset of the discussion, the participants were briefed about the objectives of the study and their (participants) role during the session. Two issues were ensured very meticulously so that participants could provide unbiased opinion to the topic discussed in the FGD: firstly, tests would be conducted to test the application (that was being developed) not the participants, and secondly, that their identity would not be disclosed in anywhere in any form of publication. To maintain the ethical issues a concerned paper was signed by each participant with a view to protect the integrity and privacy of the information from unauthorized disclosure.

- **Demonstration**: The developed application was presented (slide form) and a demonstration was shown to the participants for 30-40 minutes with a brief question and answer session to make them clear about the application.
- **Open discussion**: In the discussion phase, the pre-set questions were raised one by one until all doubts were exhausted. Note keeper noted all the points. The whole secession was audio recorded as well.
- **Transcribe and analyze the data:** The audio record of the FGD session was transcribed in a word document. The qualitative data (text based content) was analyzed using a qualitative data analysis model, named Noticing-Collecting-Thinking model.

3.5.3 Data analysis and findings

The study found a total of 14 factors that would impact the usability standard of a military application (see figure 3.15). The frequency was counted basing on the number of participants raised or discussed a particular factor. The participants were also asked to rate the observed factors based on its severity as: Major, Moderate and Minor. The values assigned on these categories were 3, 2, and 1, respectively. In this paper, the weighted score of importance of a factor (x) was calculated by multiplying the frequency (f) with the average score of severity (s) (see the equation no.3.1).

$$Weighted \quad Score \quad (x) = f(x) \times \left(\frac{1}{f} \sum_{i=1}^{f} S(x)_i \right) \text{.........(1)}$$

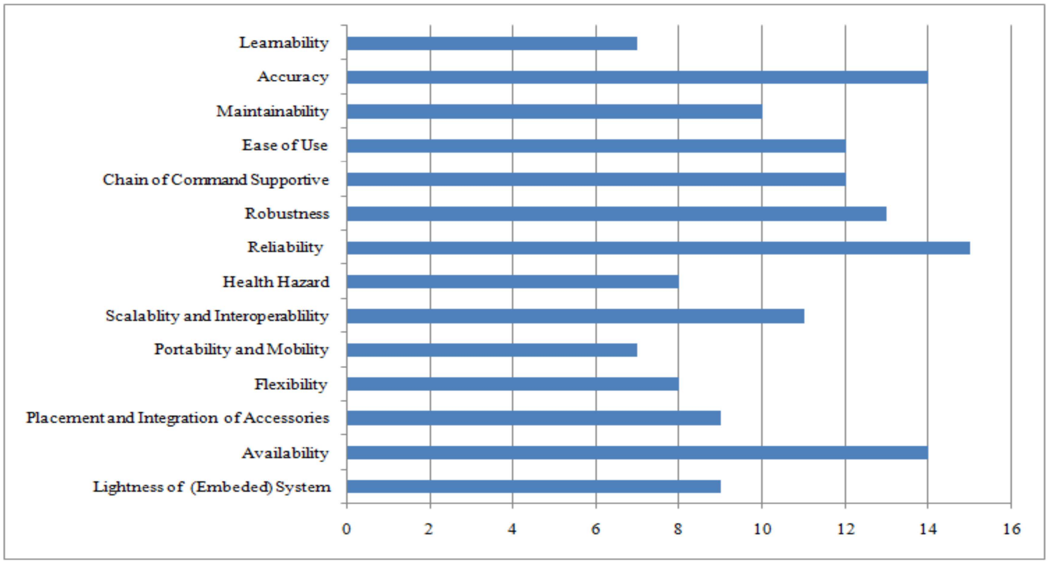

Fig 3.15: Observed usability factors with frequency

Based on the weighted score, the factors were classified into three groups:

1) Highly important - weighted score was more than or equal to 30.

2) Moderately important - weighted score was greater than or equal to 20 and less than 30 and

3) Less important - weighted score was less than 20 (see figure 3.16).

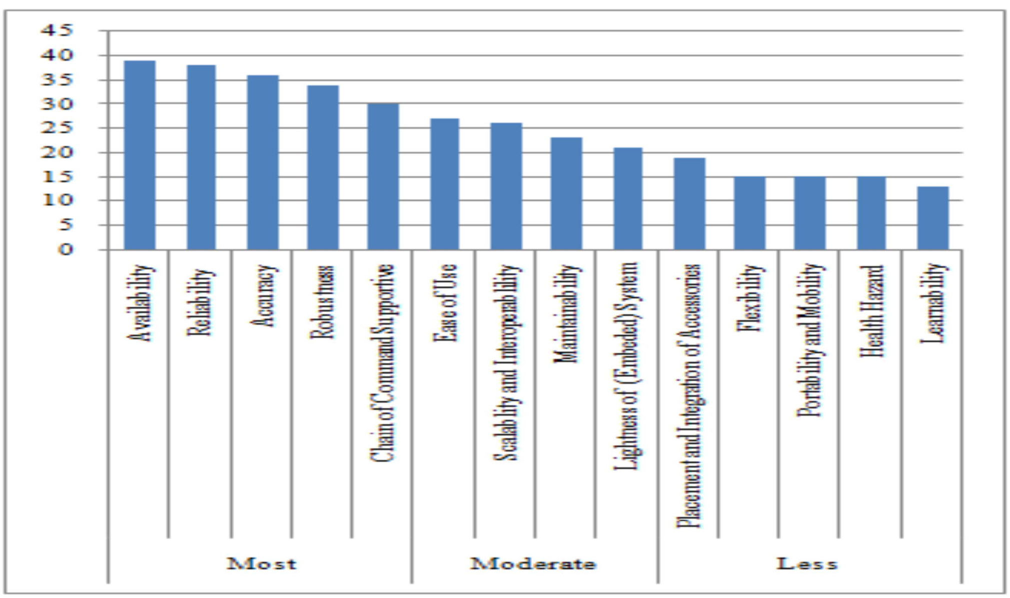

Fig 3.16: Importance of observed usability factors

The observed usability factors were briefly discussed in the following paragraphs:

A. **Availability**

Availability defines the proportion of time that the system was functional and working. Maximum number of participants (70%) considered availability as a highly important (weighted score was 39) usability factor. They felt that the application should be fully functional to provide services at all the time. Some participants suggested that the equipment should have the capability to switch from one mean of connectivity to the other (e.g., WiFi to Bluetooth) to make the application available instantly. Some expressed that redundant use of some equipment as well as keeping multiple (e.g., WiFi, Bluetooth, 3G) means of connectivity might also improve the application's availability. One said ”...the equipment should support WiFi, Bluetooth and Global System for Mobile (GSM) technology simultaneously to ensure the application's functionality all the time...”.

B. **Reliability**

Reliability referred to the measure of how long the application performs its intended function accurately. A total of 15 participants out of 20 (75%) stated that the application should be reliable. The factor scored (38) as highly important. Unreliable system might influence the outcome of situation. Many participants thought that reliability would enhance the efficiency of the application and directly contribute to the morale and confidence of the troops deployed on ground. One participant responded as ”...soldiers deal with live and death situation, so there should not be any dearth of reliability...”.

C. **Accuracy**

Accuracy referred to the measure of how accurately the application was performed. The accuracy or effectiveness was also rated as highly important (36) and about 70% participants raised their voice about this factor. They felt that there was no scope of error in any military application. An error in the application might lead to death. Many suggested that the equipment should perform accurately to do any task. One participant responded as ”...accurate and timely information will assist them a lot to bring success...”.

D. **Robustness**

More than half (65%) of the participants demanded that military application should be robust enough to sustain the roughness of the condition and fierceness of the situation. They also considered it as one of the highly important factors (34). Few opined that this application must be robust enough to function effectively in adverse and hostile environment. The transmission should withstand solar flares, bad weather and hostile jamming. Some participants thought that robustness would also enhance the efficiency and effectiveness of the application.

E. **Chain of command supportive**

The chain of command was considered as the main strength for any armed forces. Majority of the participants (60%) opined that the application should uphold the operational chain of command and rated it as most important usability factor (30). The control and access policy of the network to monitor the battle view through the camera should support the command channel. Only immediate higher level command should order the under command following this network. The functionality of the application must support the conventional and practiced chain of command. One said ”this application should not force to change the established chain, rather strengthen the chain”. Another participant opined ”...This application would not survive if it conflicts with the existing chain of command...”.

F. **Ease of use**

Simplicity was the key to make the application easily adaptable. Many participants (60%) opined that the application should be easy to use and rated it as moderately important usability factor (27). Many opined that complex application’s functionality might lead to confusion during active operation. Moreover, the design of different elements should be consistent. It would help the users to use the application comfortably. Some brought out the issue of soldiers’ movement through different types of terrain following different tactical movements. Wired connection might hinder their movements and sometimes might get struck in obstacles resulting disconnection. One said ”...wired connection might restrict their movements...” Another suggested that ”...wire could be sewed with the uniform and only the end can be exposed...” However, majority suggested that application itself should be simple and easy to operate to make it effective and efficient.

G. **Scalability and interoperability**

A total of 11 participants (55%) raised the scalability and interoperability issue as moderately important factor (26). They shared their experience of joining different forces in operations at different points of time as situation demands and as per Order of Battle (ORBAT). Thus this required interoperability capability and accessibility amongst deployed forces within and between organizations. Compatibility of signaling format and communication protocol (of different devices) was essential to ensure that the application was capable of laterally and vertically scalable.

H. **Maintainability**

Half of the participants (50%) opined the maintenance issue as a moderately important factor (23). Participants stated that soldiers might operate in small group in a remote place without support from rear. Thus the application should be easy enough to maintain and troubleshoot so that minor problems could be repaired by soldiers in the field without (the help of) skilled manpower. Some viewed the issue very seriously as timely execution of any military operation was of utmost important. Minor trouble should not hinder the functionality of the application causing a devastating effect on the outcome of the operation. One said ”...the accessories should be easily repairable and replaceable to make the application always available...”.

I. **Lightness/Weight of accessories**

A total of 9 participants (45%) stated about the lightness or weight of the accessories (e.g., camera) of the studied application and scored as a moderately important factor (21). They opined that a typical soldier would carry considerable amount of weight in the field due to gears, apparatus, weapons and other necessary accessories. This condition might vary according the nature and location of operation. Some indicated that, additional weight in addition to personal weapon might seem burden to some soldiers. However, all agreed that this would depend on the situation and context of use. If the helmet would be used in the critical or emergency situation, soldiers might find it as friendly and useful apparatus which would help them to connect their higher commanders at any time. One participant responded as ”...soldiers in the machine gun or mortar section usually carry more weight than normal foot soldiers. Likewise, soldiers assigned with this helmet would carry it considering as personal weapon. Weight should not be considered as any concern...”.

J. **Placement and integration of system accessories**

Almost half of the participants (45%) discussed the integration issues of additional accessories and scored as less important (19) factor. Some opined that the soldiers would feel uncomfortable to wear the helmet with different shape as it might be identifiable from others. This might give them the sense of insecurity as they might be easy target to the enemy. Some opined to put the camera in the body instead of helmet but this would pose problem while soldiers in dash down position. One suggested putting the camera on the top of helmet or on the weapon. One participant disagreed and stated as ”...putting addition accessories in the weapon will disrupt the aiming of soldier and increase the pressure on the hand muscle...”. Another participant responds as ”...adding Camera, LED, etc. might disrupt the helmets Centre of Gravity (CG)...”.

K. **Flexibility**

Though a total of 8 participants (40%) stated the issue of flexibility but the factor was weighted as less important (15). Some participants suggested that the application should provide freedom to place the camera and SDT/smart phone anywhere in solders’ helmets and hands, respectively; so that the application should not curtail the flexibility of solders movement and hinder operational activity. One stated ”...the application should flexible enough to perform with same effectiveness and efficiency...”.

L. **Portability and mobility**

Many (40%) suggested that the application should be portable and mobile and rated as less important usability factor (15). Soldiers need to deploy at any time and at any place without prior notice. Thus the gears and apparatus should be deployable at any place any time easily with short notice. Some raised the issue of operating the application while moving on vehicle or during fire and move technique. One said ”...that the application might be used either on vehicle or man pack which necessitates to make the application portable...”.

M. **Health hazard**

Similar to the issue of flexibility, the health hazard factor was stated by 8 participants (40%) and rated as a less important (15). Few participants reminded that the application would use the Wi-Fi, Bluetooth and GSM technology for the network connectivity. These would definitely generate enough electromagnetic wave which might be hazardous to health. To reduce the ill effect of the radiation, some participants opined to switch on the application as and when required. Soldiers concern about health hazard might affect the effectiveness of the application and decrease their overall efficiency. One stated “...Soldiers should be made clear that radiation will not have adverse effect, otherwise they were not going to use this application...”.

N. **Learnability**

About one third of the total participants (35%) stated this issue and rated the factor as less important (13). They reminded that soldiers would use the application under battle stress in the thick of war. The application should be easy to operate with less training. It should be easy enough to train and learn easily and quickly. They opined that soldiers need not to memorize any process of the application. One said ”...even if the soldiers use the application after a long time, they should be able to easily reestablish their proficiency...”.

3.6 **Discussion on Study Outcomes**

This study observed a total of 14 factors that impacted the key attributes of usability (i.e. effectiveness, efficiency and satisfaction) of a military application. Table 3.1 showed a comparative analysis of the usability factors that were revealed from this study with the existing literature as discussed in Chapter II.

Table 3.1: Comparative view of the usability factors

Factors	[2]	[14]	[16]	[18]	[19]	This Study
Attractiveness/Aesthetic				X		
Reliability			X			X
Availability/ Redundancy			X		X	X
Ease of Use/Simplicity		X	X	X		X
Portability/Mobility		X	X			X
Flexibility						X
Effectiveness / Accuracy				X	X	X
Health Hazard			X			X
Placement and Integration of Accessories						X
Maintainability	X	X	X		X	X
Robustness/ Sustainability			X			X
Scalability and Interoperability			X			X
Chain of Command Supportive						X
Trainability/Learnability/Memorability	X	X	X	X	X	X
Lightness/ Weight of Accessories						X

The Table 3.1 showed that only one factor, i.e., the aesthetic or cosmetic property was not found in this study, while participants of this study raised their voice to make the application simple and easy to use. Though, the comparative analysis showed that most of the factors exist in the existing literature in a scattered way, but some were innovative. Moreover, different studies stated different factors and no previous study (or not a single article) explicitly presented the complete list of factors that might be suitable or related to the military applications. After exploratory study, 14 possible factors were revealed as stated above that would be suitable for developing and evaluating any ICT related military application. These factors would be validated after developing a high fidelity military application following IDM technique as discussed in the subsequent chapter.

CHAPTER IV

DEVELOPING THE APPLICATION

This chapter discussed the development process of Advanced Battlefield Communication System that was designed following the IDM technique. It consisted of an indigenous advanced combat helmet, android based mobile applications, SDT device and web application aiming to portray the Command and Control structure of a Bangladesh Army.

4.1 Developing the Concrete Version of the Application

4.1.1 Overview of the application

An interactive prototype application of Advanced Battlefield Communication System was developed for military. Using the proposed application, commander in different tiers would be able to visualize the actual picture of the battlefield through live streaming, which in turn would help them in the process of decision making about battlefield. This application would be used in specialized operations like countering terrorism, natural disaster, etc. This application could also be used in military minor operations like Raid, Ambush and Special Operation like Fighting in the Build-up Area (FIBUA), etc. The proposed application was cost-effective, thus the application could be easily affordable and deployable for the soldiers of developing countries. The application could enable higher commanders to establish an audio-video communication link with the front line troops.

4.1.2 **Components of the application**

The application incorporated the following components:

- An indigenous advanced combat helmet integrating a camera, encoder and audio device.
- An android application for audio communication and location service. A smart phone or a soldier's data terminal (SDT) device was used.
- A web application that would be used by the higher commander from headquarters or command post.

4.1.3 **Developing the web application using IDM**

Website for Advanced Battlefield Communication System was developed based on the design obtained in P-IDM (page design) phase. As mentioned in the previous sections each page design obtained in P-IDM phase was converted in a web page using preferred language.

This website with the title Advanced Battlefield Communication System contained the list of all formation as higher commanders and a communication portal as reflected in the conceptual design. The communication portal contained the video feeds coming from the field soldier fitted with cameras on the helmet and headphone in the ear. This front line troops were under the command of a particular commander who was conducting the operation. All the requirements as identified with the IDM process were converted into some command button in the web. One of the web sites was developed with HTML (Hypertext Markup Language) for front end design and PHP with MySQL database for backend.

The index page contained all the basic elements of the website which were linked with the secondary pages as per transaction act and relation. Figure 4.1 represents a snapshot of the home page of the website developed using IDM.

Fig 4.1: Home page of developed website

Snapshot of introductory dialogue act page is shown in figure 4.2 for all div commanders designed in P-IDM. This page showed the list of divisions with their commanders. Other design strategies in the corresponding P-IDM design were also reflected on the web page.

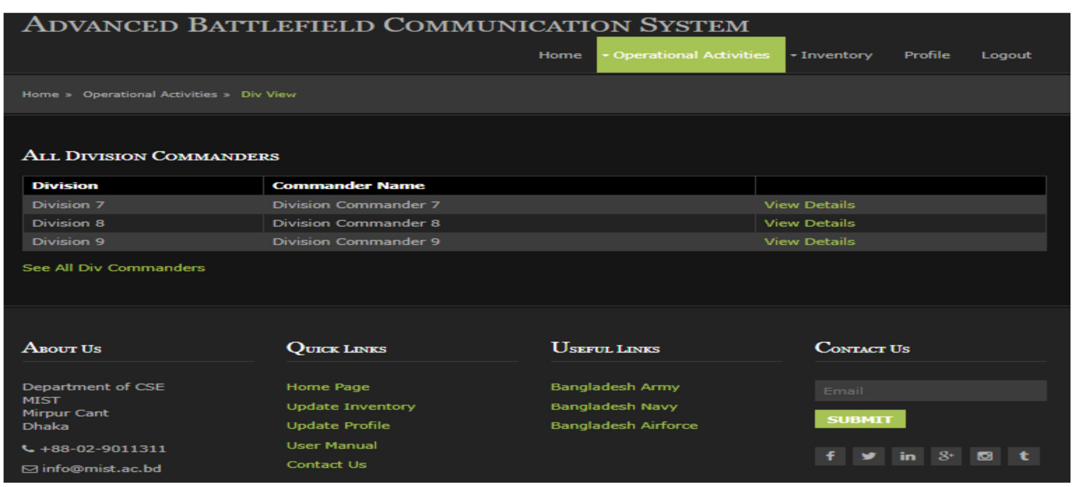

Fig 4.2: All divisional commanders page of developed website

Figure 4.3 showed the index page of the mobile version of the application. It had all the features rearranged for the mobile.

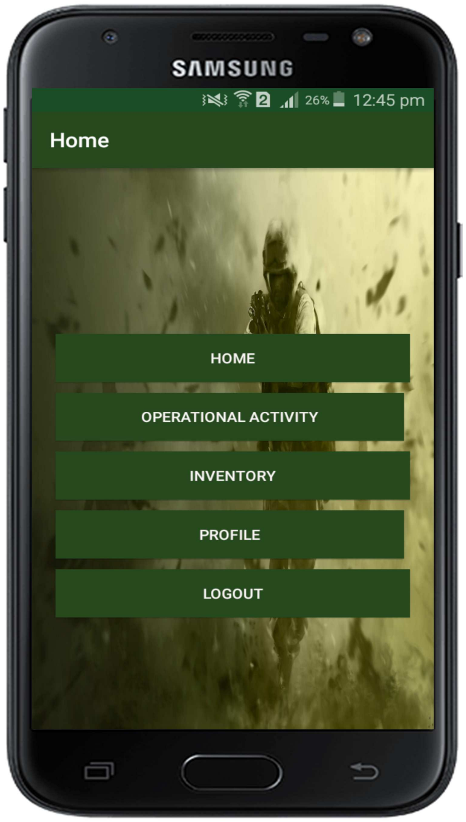

Fig 4.3: Home page of developed mobile application

4.1.4 **Developing another web application without using IDM**

Figure 4.4 represented another version of web that contained the live video feed coming from the cameras placed on the helmets of the troops. To maintain the cardinalities stated in the conceptual design, the video feed were connected accordingly. For example, to maintain the 1: n relationship between a commander and troops, video feeds of those under command soldiers were connected to the display.

Fig 4.4: Web page of console for headquarters

4.1.5 Developing video streaming service

- **Video streaming with software encoder.** Video streaming service was initially experimented using software encoder. The architecture was followed as shown in Figure 4.5.

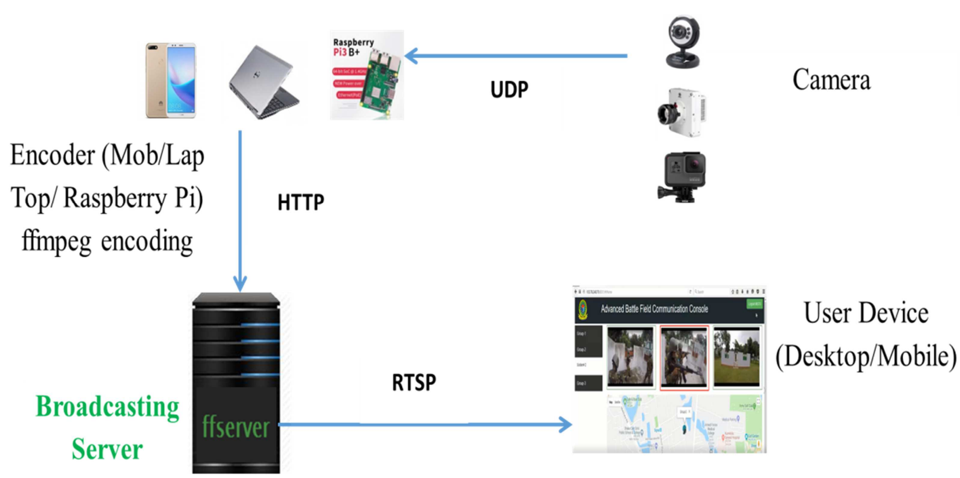

Fig 4.5: Video streaming using software encoder

Video was stream using ffserver as broadcast server and ffmpeg codec was used for compression. Laptop, Raspberry Pi or Mobile could connect to the action camera using Wi-Fi and captured the packets. The captured packet was then encoded using a script (developed with python language-see Appendix A) and sent to Broadcasting Server (ffserver) using Hyper Text Transfer Protocol (HTTP). This server then published the encoded packets to web using Real Time Streaming Protocol (RTSP).

Numbers of steaming cameras were tested to stream live video from the battle filed. Web camera produced blur video and could not stream when troops were operating in intense battle action. Phantom S990 provided better resolution video but failed to seamless streaming during movement of troops. Hero GoPro Black5 delivered best service in respect of regulation and movement. Considering the motion capture capability, robustness and latency, GoPro HERO5 Black camera was finally used**.** It was waterproof up to 33ft (10m) without housing. It captured the live steam and transmitted the encoder. Steaming camera (GoPro Hero) worked as hotspot and broadcasted video packet using UDP (User Datagram Protocol) for establishing low-latency and loss-tolerating connections. The detailed study was noted as shown in Table 4.1.

Table 4.1: Performance of camera

Items	Device Specification	Comments
	Web Cam	Blur Resolution, Motion Insensitive
	Phantom S990	Good Resolution, Motion Insensitive
	**Hero GoPro Black 5**	**Good Resolution, Motion Sensitive**

Smart phones (Samsung – J2, J6, A7 and Huawei - p9 lite), notebook (ASUS and Lenovo) and Raspberry pi (Model 3B and 3B+) were tested sequentially for encoding the video. However, the processing power of smart phone, Raspberry pi (quad core) and lower processing power note pad (core duo and quad core) could not process the video properly. Amongst the smart phones Huawei - p9 lite performed better, On the other hand, Core i3 and core i5 processors yielded better performance (Dell Core i3, Core i5). But the size and weight of the device restricted the soldiers to carry the equipment at the back. It hindered the flexibility and impacted negatively in operational efficiency. The performance was listed as shown in Table 4.2.

Table 4.2: Performance of software encoder

Items	Device Specification	Comments
 	Samsung – J2, J6, A7 **Huawei - p9 lite**	Inconsistent stream, less processing power, one wireless module
 	Lenovo Core duo Asus Quad Core	Stream stopped after 5/10 minutes, less processing power, laptop overheated
 	Raspberry pi 3b raspberry pi 3b+ (quad-core)	Stream stopped after 5/10 minutes, less processing power
	**Dell Core i3, Core i5**	Consistent Stream, laptop overheated

Video camera was connected to the Wi-Fi module of smart phone to capture live stream. An app was developed the retransmit the packet to streaming server using mobile data. But smart phone technically could operate either in mobile data or Wi-Fi mode. Both modules could not be activated simultaneously. As such a Virtual Private Network (VPN) was created to make both modules active. In such case, paid version VPN Speedify (see figure 4.6) was used to activate both mobile data and Wi-Fi module simultaneously. Wi-Fi was connected to camera to receive video stream and mobile data was used for connecting with streaming server to transmit video.

Fig 4.6: VPN using Speedify

- **Video Streaming with Hardware Encoder.** Video streaming service was later experimented using hardware encoder. The architecture followed is shown in Figure 4.6.

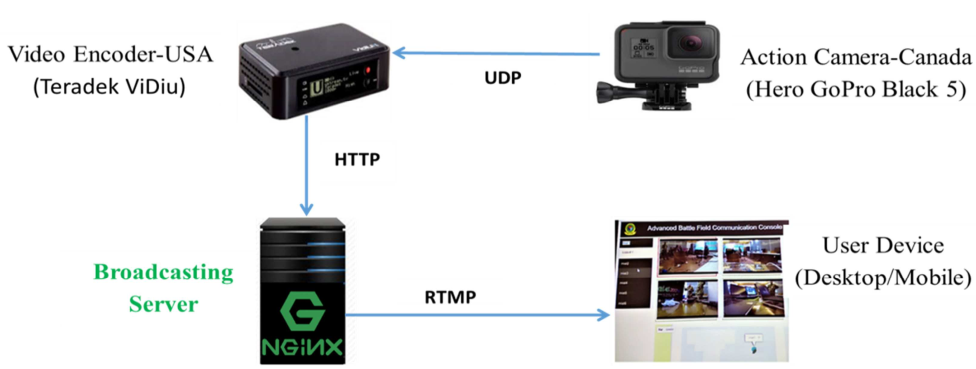

Fig 4.7: Video streaming using hardware encoder

Video was stream using NgingX server as broadcast server and H.264 codec was used for compression. Teradek VidiU Encoder (see figure 4.7) could broadcast live high definition video directly to the web without any other device. It was connected with camera using Wi-Fi, captured stream and transmit to web directly. Data connectivity was given either by mobile data or Wi-Fi as it supported both mood. It used Real-Time Messaging Protocol (RTMP) interface to stream live video content to web /app.

4.1.6 Developing audio calling service with android application

Front line troops could call one to one using the apps amongst them and with their higher commanders. User needed to connect to audio calling server (FreeSWITCH) which was developed as a cross-platform telephony platform for real-time audio communication with FusionPBX rerouting wrapper. FusionPBX worked as web-based Graphical User Interface (GUI). This server was built using Apache Web Server with light-weight SQLite database. This connection used Session Initiation Protocol (SIP). Once the session was established the audio packet was sent using UDP. The audio calling architecture was followed as shown in Figure 4.8.

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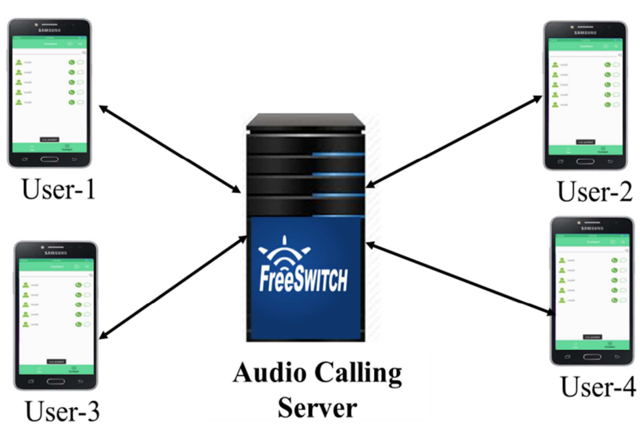

Fig 4.8: Audio calling using android app

Each solder was provided with a wireless headphone which was connected to SDT (smart phone) with Bluetooth. This headphone was chosen carefully to avoid unnecessary wire accessories which would otherwise hinder the movement of the solders. Moreover the wired connection would curtail the flexibility and susceptible to wear and tear. Thus Sena SPH10 Bluetooth Intercom & Stereo Headset (see figure 4.9) was used. The audio calling application had a button which allowed audio conversation to transfer automatically to the solder's ear. With this device conference call could also be made.

Fig 4.9: Sena SPH10 Bluetooth intercom & stereo headset

4.1.7 **Developing location identification service using android application**

Location of the front line troops was projected in the web by which commanders at headquarters could easily identify the current progress of the battlefield scenario. Apps had the facility to send location to the web as shown in Figure 4.10.

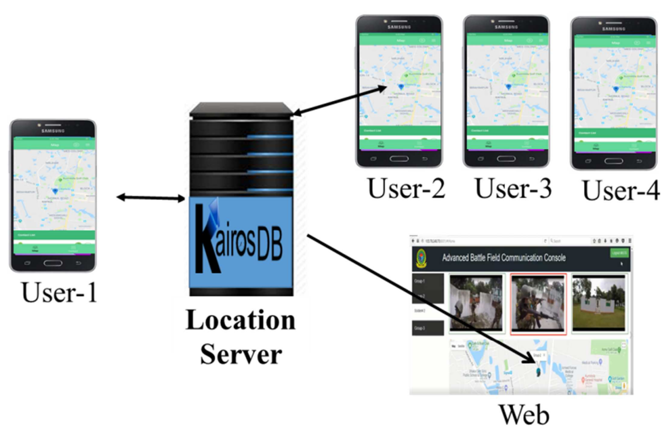

Fig 4.10: Location service using android app

A time series database KairosDB server was deployed on top of Cassandra. Mobile app collected the location from Global Navigation Satellite System (GNSS) module of mobile device. It collected the timestamp and pushed to KairosDB server as JSON (Java Script Object Notation) object. Apps and Web requested location service from KairosDB and published in web/app.

4.2 Configuring the Application

It was a real challenge to configure the functional system integrating all these accessories. A python script was developed to encode and stream the captured video which ran on the notepad /laptop. A number of tests were conducted with different option in respect of pixel setting, data rate, frame per second etc. Some of the test instance as shown in figure 4.11 were performed in the laboratory.

Fig 4.11: Configuring the application

4.3 Analyzing the Performance of the Application

It was identified that lower power processor could not process the video stream effectively. Raspberry pi 3 Model b+, Core Dou, Octa-core, and even Core i3 processor could not stream the video efficiently. It was found that streaming camera was pushing video packet 3.30 MBps speed and encoder pushed 664 Bps to server during normal activity (see Figure 4.12).

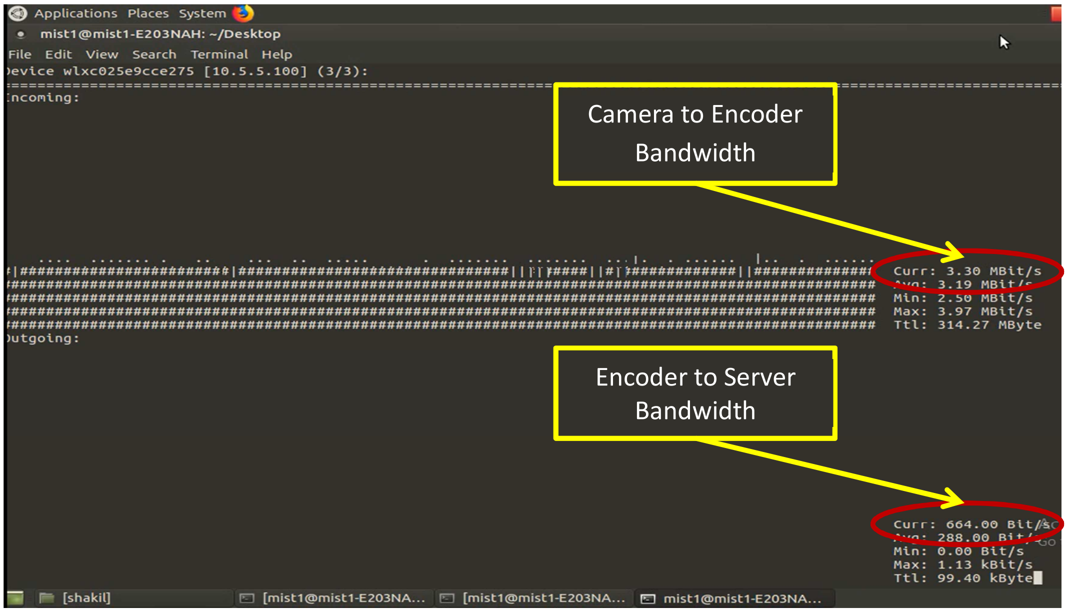

Fig 4.12: Bandwidth requirement analysis during normal activity

However when troops performed dash down, running and other intense activity, the packet size increased up to 2.45 MBps (see Figure 4.13) from encoder to server. This created congestion on the buffer and video streaming was interrupted or blocked. Thus internet speed of more than 4 MBps was a minimum requirement to push the video from the encoder to broadcast server.

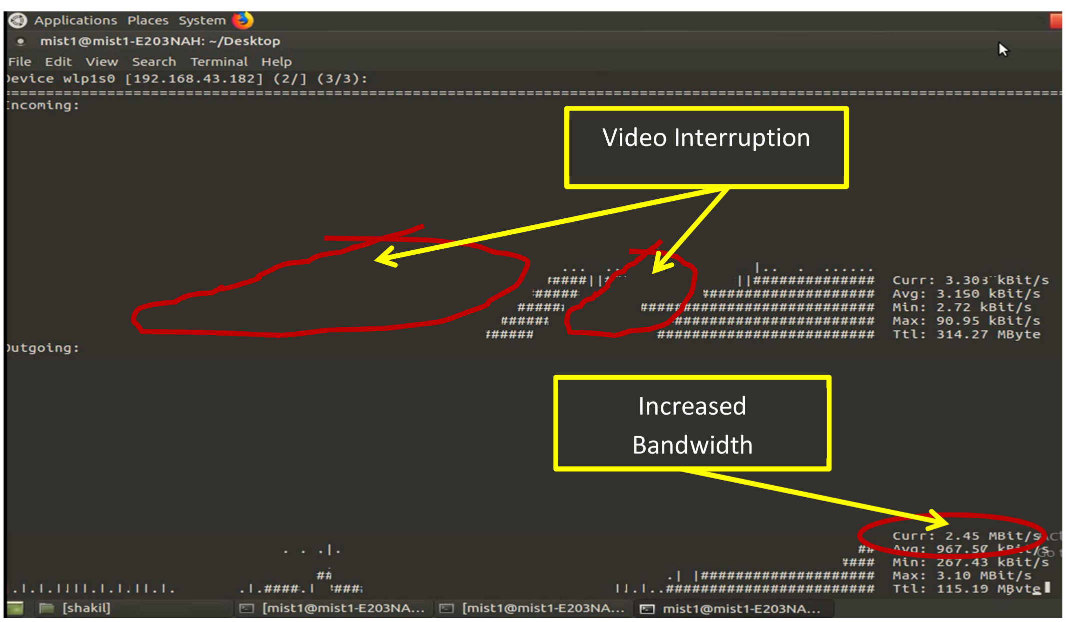

Fig 4.13: Bandwidth requirement analysis during intense activity

When troops were engaged in moving, running or engaging in various actions, the low power processor could not handle the traffic and buffer overflowed as shown in figure 4.14 and stopped video streaming.

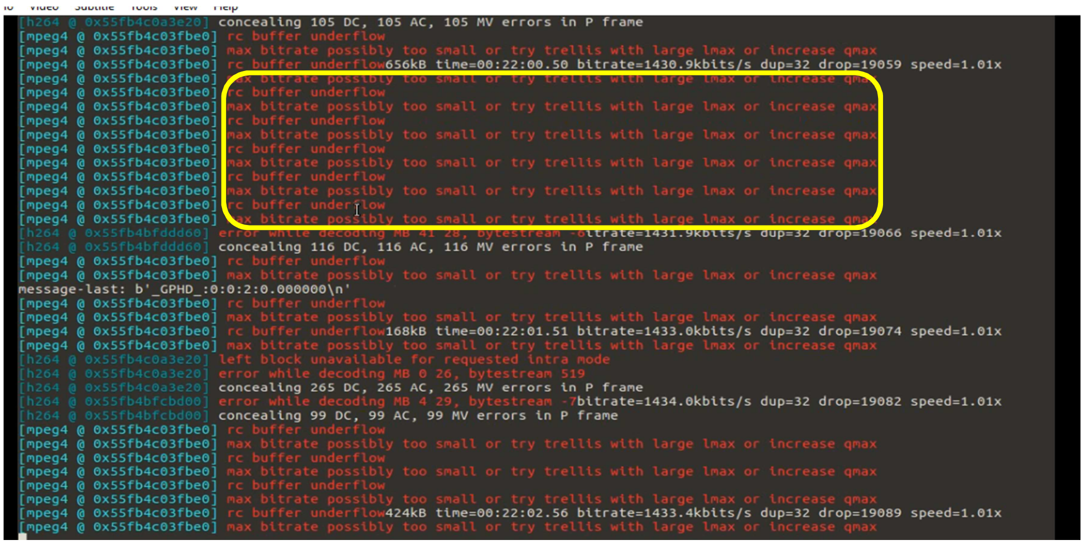

Fig 4.14: Buffer overflow during intense activity

It was noticed that lower processor below core i3 utilized less CPU cores and threads. It utilized less only half of its processing power as shown in Figure 4.15.

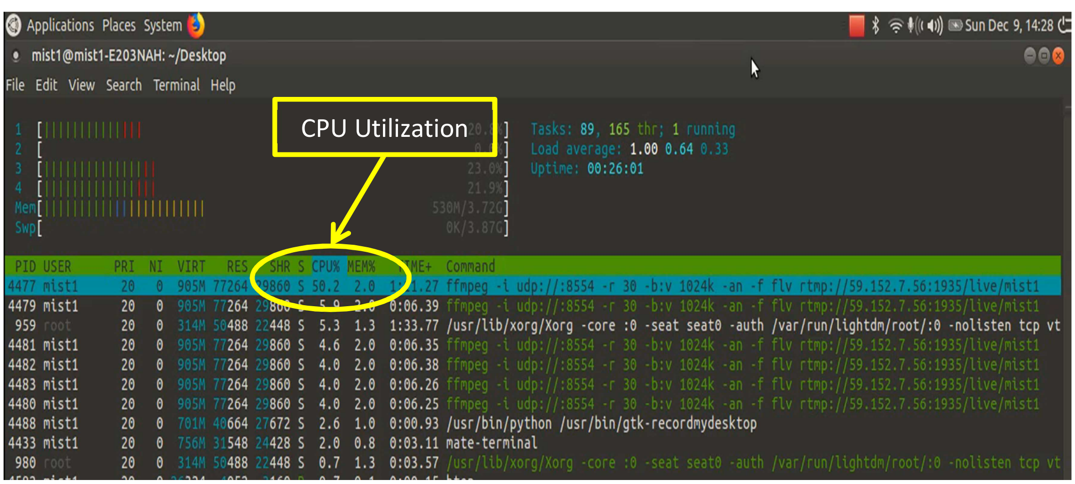

Fig 4.15: CPU utilization width lower processing power

However, Core i5 processor performed better utilizing more than 186 % CPU usage (see Figure 4.16). Taradeak ViDiu was finally selected as encoder as it performed better.

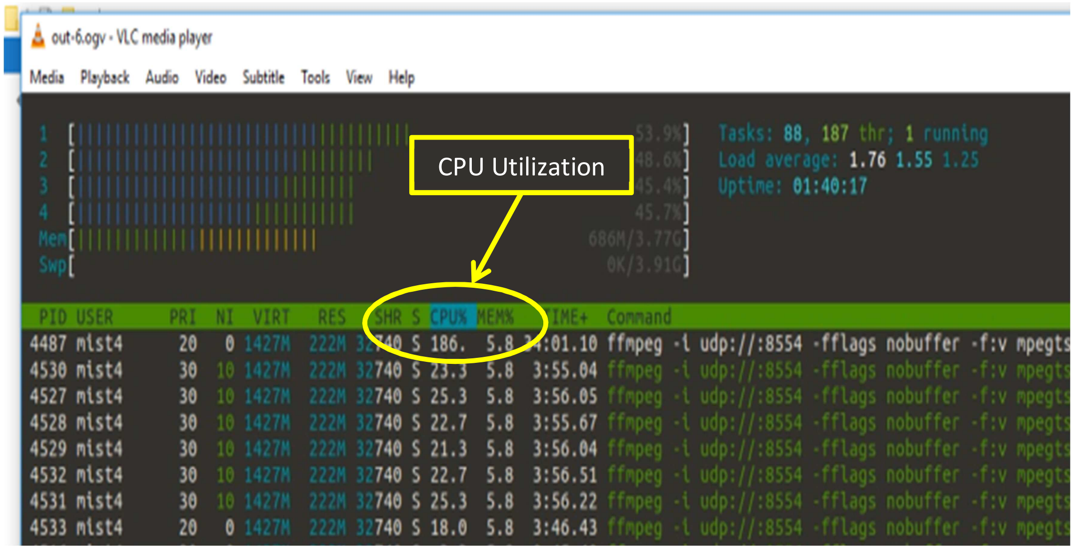

Fig 4.16: CPU utilization width higher processing power

CHAPTER V

EVALUATING THE APPLICATION

This chapter briefly presented the evaluation procedure, participant's profile, data analysis and results.

5.1 **Participant Profile**

A battlefield scenario was depicted and troops participated in the action with all gears. A total of 30 soldiers from fighting arms were selected to conduct the filed study. All participants were male having age 30 ± 7 (mean ± standard deviation). Their service rank ranged from Private to Lieutenant Colonel with average length of service experience is 12.55 ± 7.12 (mean ± standard deviation). 8 participants had about 1.5-5 years, other 13 participants had 11-15 years and rest of them had more than 15 years of experiences of unit service. User experience in ICT related applications were mostly below 1 year duration.

5.2 **Study Procedure**

The system was evaluated through filed study in 5 sessions (each session took 30 minutes) at different location around Dhaka Cantonment. Each session was carried out following the steps below.

- At first, once a participant agreed to be the test participant, his demographic information was collected, and a test-consent form was also signed with him.

- Then the participant was provided with a short training to demonstrate how to use the system and participants were allotted with more time to get acquainted with the system.

- A battlefield scenario (clearing a house) was created and troops participated in the action with all gears. Participant was asked to perform the following tasks:

  Task 1 (T1): Communicate with higher commander with audio

  Task 2 (T2): Communicate with under command with audio

  Task 3 (T3): Video streaming while dash down and scrolling

  Task 4 (T4): Video streaming while running and clearing house

- At the end, the participant was asked to rate a few statements (questionnaires) for assessing the performance and usability standard (rating scale used: 1 -5)

The battlefield communication system was evaluated with real soldiers through field study in 5 sessions.

5.3 Analysis and Result

The outcome provided both the objective (based on observed experimental data) as well as subjective (based on participants rating scores) results with respect to each usability factors that were revealed through first study.

5.3.1 Availability

Availability was the percentage of time or probability the system was in operable state. In an average, it functioned for 24.8 minutes (Std dev = 1.30) and interrupted for 5.2 minutes (Std dev = 1.30). The availability varied from 77% to 87%, while the average availability was 83% (see Figure 5.1). The system down or interruption happened mainly due to internet bandwidth, camera malfunction, headphone blue tooth connectivity and wire disconnection (see Table 5.1).

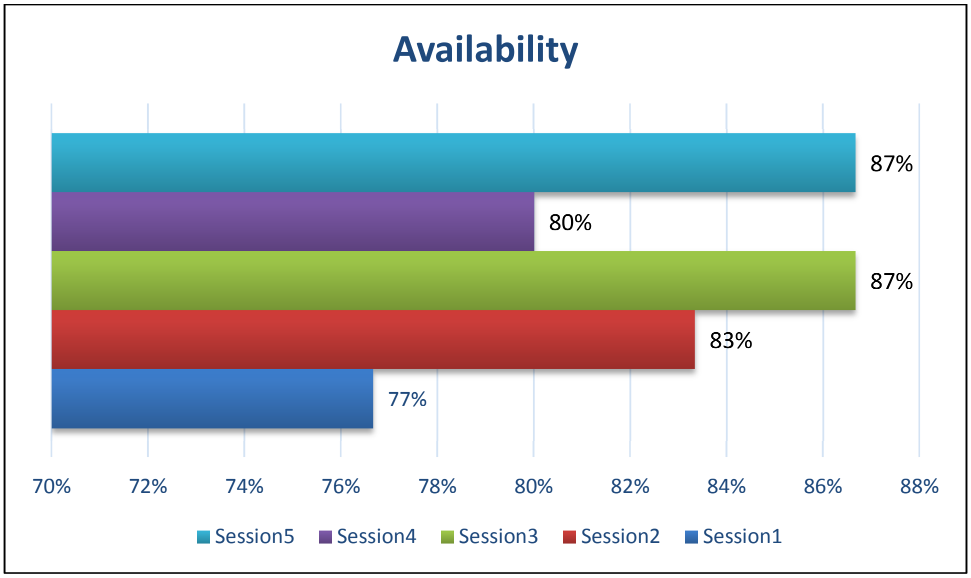

Fig 5.1: System availability in different session

Table 5.1: Reasons for system down

Session	Duration of the session (Mins)	Non Functional (Mins)	Functional (Mins)	Camera malfunctioned (No)	Head phone malfunctioned (No)	Encoder malfunctioned (No)	SDT malfunctioned (No)	Wire Connection Error (No)
session 1	30	7	23	0	1	2	1	0
session 2	30	5	25	1	0	0	1	1
session 3	30	4	26	1	1	0	0	0
session 4	30	6	24	0	1	2	0	0
session 5	30	3	27	1	0	1	0	0

The subjective rating (see Table 5.9) showed that participants were agreed that the system was available during the experiment (mean = 3.33, Std dev = 0.88) and they were able to perform the system functionality smoothly (mean = 3.80, Std dev = 1.00). The later score was better than the first statement which indicated participants were comfortable to perform the task when the system was active/available but in general they experienced system unavailability in every session due to several reasons.

5.3.2 **Accuracy**

Accuracy referred to the successful completion of system's task. During the experiment, commanders at the Headquarters/rear monitored the live action of the operation with audio visual effect. They could also talk to the troops on ground with developed apps. The audio-visual action was viewed in the web. The average system accuracy was 21.5 ± 1.29 (mean ± Std). A good level of accuracy found in audio related tasks (T1 & T2) comparing to the video-streaming related tasks (T3 & T4) (see Figure 5.2). The percent of accuracy varied from 80% to 92%, while the average availability was 86% (see Table 5.2).

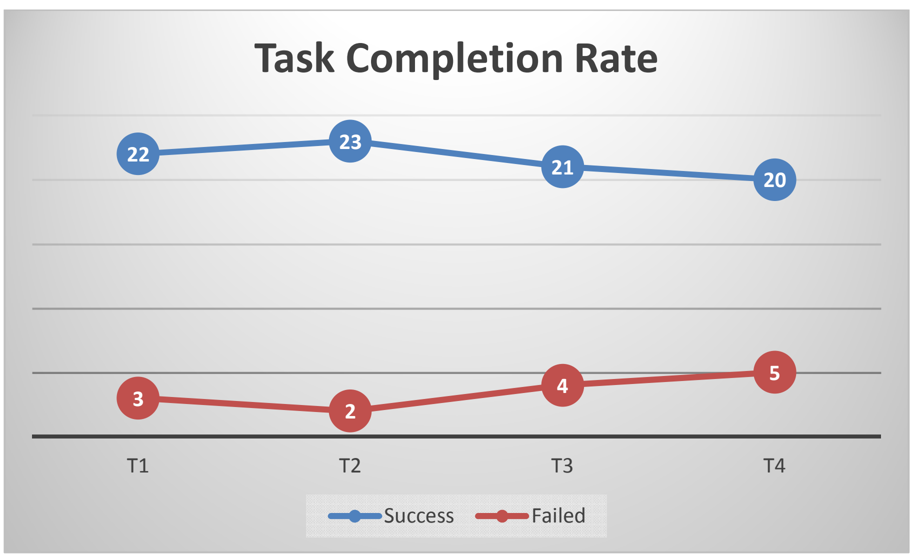

Fig 5.2: Mean values of success and failure to accomplish different tasks

Table 5.2: Success rate of task completion

Tasks	Success	Failed	Success Rate
T1: Communicate with higher commander with audio	22	3	88%
T2: Communicate with under command with audio	23	2	92%
T3: Video streaming while dash down and scrolling	21	4	84%
T4: Video streaming while running and clearing house	20	5	80%

The subjective rating (see Table 5.9) showed that participants were agreed that the system functionality were very much similar to the task required during the actual battlefield (mean = 3.70, Std dev = 0.92) and their opinion about receiving the appropriate outcome during the entire duration was also satisfactory (mean = 3.57, Std dev = 0.86).

5.3.3 **Robustness**

The troops conducted an exercise on special operation where situation was depicted as counter termism activities which involved running, dash down, assault, crawling, different location and time of the day. They were asked to evaluate the performance on the functionality of the system without failure while running, dash down and assault. In fact, the test-sessions were carried out in different context, including: Environment (indoor vs outdoor), Different location (MIST and 47 East Bengal training ground), Weather scenario (rainy day and sunny day), and Fighting posture (troops running, dash down, assault, and crawling). The study results showed a good level of robustness. The system behaved almost consistently in each session and the contextual effect was not significant to system performance (see Table 5.3).

Table 5.3: System's downtime and uptime in every session

Session	Downtime	Uptime	Context
1	7	23	Indoor environment, MIST, sunny day, all fighting posture
2	5	25	Outdoor environment, 47 East Bengal, sunny day, all fighting posture
3	4	26	Outdoor environment, 47 East Bengal, sunny day, all fighting posture
4	6	24	Outdoor environment, 47 East Bengal, sunny day, all fighting posture
5	4	26	Outdoor environment, 47 East Bengal, rainy day, all fighting posture
Average	5.2	24.8	

The subjective rating (see Table 5.9 and Figure 5.3) showed that total 17 out of 30 (56.67%) participants were fully and strongly agreed that the system performance was consistent irrespective of their context. The average score to this statement was also satisfactory (mean = 3.43, Std dev = 0.82).

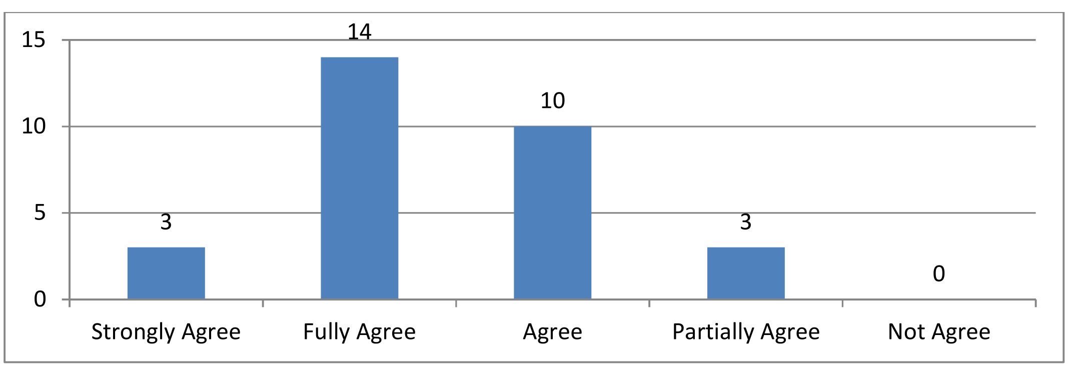

Fig 5.3: Participants rating about the robustness of the system

5.3.4 **Reliability**

Reliability measured how long the item performs its intended function accurately irrespective of the user of context. Different sessions were conducted in different environment as presented in Table 5.3. The study showed that system uptime and downtime, as well as task completion success rate was almost consistent in different context and sessions (see Table 5.1 and Table 5.4). Table 5.4 represents the frequency of total malfunction occurred to each component during the test-sessions. The results indicated that in different context each session showed almost consistent (1-2) behavior, except the encoder error of Task 3 (frequency = 3). The subjective rating showed that the system worked well in indoor (mean = 3.73, Std dev = 0.87), outdoor (mean = 3.80, Std dev = 0.92), and indoor and outdoor (mean = 3.77, Std dev = 0.86) environment (see Table 5.9).

Table 5.4: Malfunction occurred to each component

Task	Camera Error	Headphone Error	Encoder Error	SDT Error	Wire Connection Error
T1	0	2	0	1	0
T2	0	1	0	1	0
T3	1	0	3	0	0
T4	2	0	2	0	1
Total Malfunctioned	3	3	5	2	1

5.3.5 **Chain of command**

The chain of command was setup with Company/Battalion commander who monitored the action from Headquarters/Rear. Task group command led the action in the field as follow: Battalion/Company commander to Group commander to sub group 1/2/3. The subjective evaluation showed that (see Table 5.9), participants were strongly agreed on that the system design maintained the chain of command (mean = 4.80, Std dev = 0.45), while they opinioned that supervision from headquarters would curtail their flexibility and initiative in the field (mean = 4.20, Std dev = 0.54), However, their actions could be monitored from the headquarters without direct guiding or interfering their actions.

It was worth to mention here that one session was conduct on real time in the presence of the Chief of Army Staff, Bangladesh Army on 16 Jul 2018 where top command echelons of Bangladesh Army were present. Besides, informal discussion with other level of commanders suggested that ground action should not be directed from the headquarters violating the existing chain of command. They also expressed that commanders at Headquarters should monitor the action and prepare to meet any unforeseen situation like reinforcement, casualty evacuation etc.

5.3.6 **Scalability and interoperability**

The performance was tested with 2, 4, 5, and 6 participants and found that video streaming was interrupted while more number of cameras (participants) was used due to the bandwidth sharing. The system performed well (without interruption or task failure) in every session while the number of participants (as field soldiers) was 2 and 4. Again, interruption occurred 1-2 times in every session, while participants increased to 5 and 6. The system was tested with both Wi-Fi and GSM data and Wi-Fi showed better performance (see Figure 5.4). Figure 5.4, showed the total number of task failure considering the 5 sessions depending on the use of different types of data connectivity.

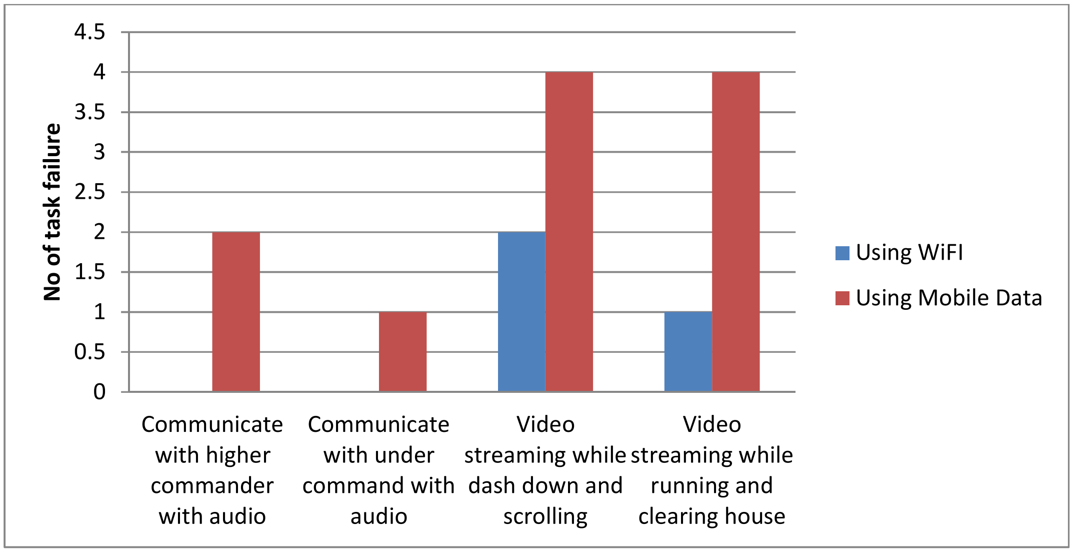

Fig 5.4: Task failure to different types of data connectivity

Participants' opinion was collected in both scenario like separate use and the combined use of the WiFi and Mobile data connection. The subjective rating (see Table 5.9) showed that participants were more satisfied when the WiFi data were used (mean = 3.85, Std dev = 0.82), comparing to the mobile data use (mean = 2.93, Std dev = 1.17) as well as the combined (WiFi and Mobile) data use (mean = 3.43, Std dev = 0.93).

5.3.7 Maintainability

During the period of field experiment, the system stopped functioning sometimes. The users were trained to make the system functional and thus they successfully revived the system at their won. The study results (see Table 5.5) showed that the average repairing times was 1.85 minutes (total failure 13 and total time 24 minutes) while they asked helps to troubleshoot in average 0.77 times. The subjective feedback (see Table 5.9) also showed that participants found the system maintainable (mean = 3.40, Std dev = 0.81) and it was easy to repair and troubleshoot (mean = 3.30, Std dev = 0.71).

Table 5.5: Summary of troubleshooting /repair during exercise

Tasks	Repaired	Time taken to repair (mins)	Asked for help (frequency)
T1	3	5	2
T2	2	3	1
T3	4	9	4
T4	4	7	3

5.3.8 Lightness/Weight of accessories

The system items were fixed on the helmet in the front and back making a balance in the weight and center of gravity. Total weight of the accessories was 430 grams (see Table 5.6). They also did not find it burden during operational activity. It was easy to perform action while putting on the helmet. However, maximum users (67%) did not feel difference while putting on the helmet with all accessories (see figure 5.5). The subjective feedback (see Table 5.9) showed that participants graded low (mean = 2.20, Std dev = 1.19) to statement of 'experiencing extra weight of the system' while good scores (mean = 3.70, Std dev = 0.60) were observed to the statement of 'Do not experiences any burden the accessories'.

Table 5.6: Weight of the accessories

Ser	Items	Weight in gram
1	Camera - HERO5 Black	118 gm
2	Headphone - Sena SPH10	23 gm (0.8 Ounce)
3	Encoder - Teradek VidiU	142 gm
4	SDT - Huawei P9 lite	147 gm
Total		**430 gm**

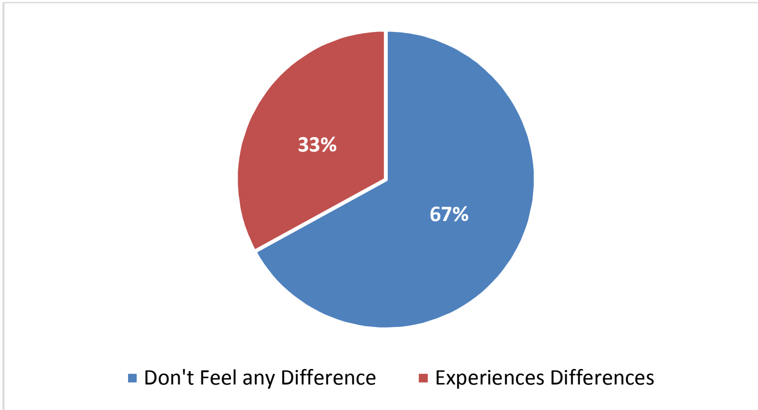

Fig 5.5: Participants experiences while uses the accessories

5.3.9 **Placement and integration of system accessories**

The camera was placed on the front side of the helmet and the video encoder was fixed at the back of the helmet (see Figure 5.6). All participants found this position comfortable. The troops set the system on ground. The success rate (without asking help) to connect and integrate all accessories for initial set-up is showed in Table 5.7. The subjective rating (see Table 5.9) showed more than 3 to all statements related to placement and integration of system accessories; that includes position of the camera on the center of the helmet, positioning the portable device on the lower part, position of the accessories could be done in any parts, and the initial setup of the system was easy.

Fig 5.6: Positioning of the camera and video encoder

Table 5.7: Connecting and integrating all accessories for initial set-up

Session	Success (No of Troops)	Failed (No of Troops)	Percent of Success
Session 1	5	1	83.33%
Session 2	4	2	66.67%
Session 3	4	2	66.67%
Session 4	5	1	83.33%
Session 5	3	3	50.00%

5.3.10 **Ease of use**

Once initialized, the system automatically streamed the video and the audio channel was activated. The headphone was connected to mobile using blue tooth. They felt easy to fix all accessories in the system. Maximum (93.33%) participants agreed that the system was easy to use and did not feel any complexity (see Figure 5.7).

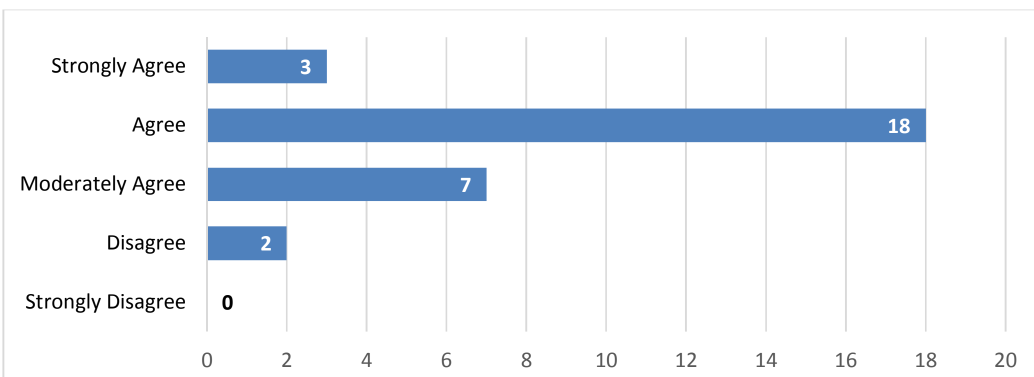

Fig 5.7: Participants opinion about the ease of use of the system

The subjective rating related to the statements – 'The system was easy to use', 'Understanding the system functionality was easy to grasp', 'setting-up the system by putting all accessories was very simple' showed very satisfactory, while the participants scores related to the statement of ‘The system create confusion while operate’ showed a very poor result (mean = 1.50, Std dev = 0.78) (see Table 5.9).

5.3.11 **Flexibility**

The application primarily used wireless system. The wired connection was also used within helmet which works as an independent item. It was easy to put on helmet and put off. Other connections were with WiFi or Blue Tooth. As such it did not curtail the flexibility of troop’s movement during operation. Most of the users (90%) agreed on the flexibility of the system and provide an average score of 3.63 ± 0.76 (mean ± Std dev).

5.3.12 **Portability and mobility**

The system (hardware part) was light and the volume was also small. It did not require addition space to carry from one place to another place. It was easily portable and deployable at any place any time. The only requirement was availability of bandwidth or internet connectivity. The system was also tested on vehicle while on move which provided uninterrupted streaming within any network coverage. Participants also agreed on the portability and mobility of the system (mean = 3.57, Std dev = 0.73) (see Table 5.9).

5.3.13 **Health hazard**

The system used the Wi-Fi and blue tooth connectivity. Live streaming from helmet emitted electromagnetic wave. Since the helmet was of steal made, it would reflect the wave from directly penetration to brain cell. However, others wave could also pass through the body cell. It might create some health hazard. The users felt that the system might put hazard to the health. However, maximum users agreed to control the emission by putting minimum power output and keeping standby while not in function. Participants rating (mean = 3.83, Std dev = 0.85) also showed that they were agreed that the system would not create health hazard, if the system could be controlled (see Table 5.9).

5.3.14 **Learnability**

Soldiers would use the application under battle stress in the thick of war. Participants were trained in average 11.2 ± 1.19 (mean ± Std dev) minutes and took practice time in average 6.4 ± 1.08 (mean ± Std dev) minutes (see Table 5.8). As discussed above, participants were able to perform their tasks and maintain/repair any system failure during the test-session. The results thus indicate that the system was easy to learn and operate. Participants were also agreed (see Table 5.9) that it was easy to learn and operate the system (mean = 4.00, Std dev = 0.71).

Table 5.8: Training and practice time

Session	Training Time in mins	Practice Time in mins
Session 1	10	6.4
Session 2	12	6.5
Session 3	11	6.6
Session 4	13	6.8
Session 5	10	5.6
Average	11.2	6.4

Table 5.9: Summary of the subjective rating to different factors

Ser	Usability Factors	Feedback Statement	Scores (Mean ± Std Deviation)
1	Availability	The system was available during the experiment	3.33 ± 0.88
		The system was functioning smoothly during the entire duration	3.80 ± 1.00
2	Reliability	The quality of service in indoor condition	3.73 ± 0.87
		The quality of service in the field condition	3.80 ± 0.92
		The service of the system both indoor and field condition	3.77 ± 0.86
3	Accuracy	Functionalities were like the actual battlefield	3.70 ± 0.92
		Received accurate output during the entire duration	3.57 ± 0.86
4	Robustness	Performed consistently in every situation	3.43 ± 0.82
5	Chain of Command	The system support chain-of-command	4.80 ± 0.45
		Supervision from headquarters would curtail their flexibility and initiative in the field	4.20 ± 0.54
6	Scalability and Interoperability	System perform well using the WiFi connection	3.83 ± 0.82
		System perform well using the mobile data	2.92 ± 0.93
		System perform well using both the WiFi and Mobile data together	3.43 ± 0.93
7	Maintainability	The system is easy to maintain	3.40 ± 0.81
		The system is easy to repair and make functional	3.30 ± 0.71
8	Lightness/Weight of Accessories	Experiencing extra weight of the system	2.20± 0.50
		Do not experiences any burden the accessories	3.70± 0.60
9	Placement and Integration of System Accessories	Position of the camera on the center of the helmet	3.60± 0.50
		Positioning the portable device on the lower part	3.70± 0.84

		Position of the accessories could be done in any parts	3.23± 0.97
		The initial setup of the system was easy.	3.63± 0.72
10	Ease of Use	The system was easy to use	3.83± 0.70
		Understanding the system functionality was easy to grasp	3.67± 0.71
		The system create confusion while operate	1.50 ± 0.78
		Setting-up the system by putting all accessories was very simple	3.57 ± 0.73
11	Flexibility	The system was flexible to set-up and operate	3.63 ± 0.76
12	Mobility & Portability	system could be deployed at any place any time easily	3.57 ± 0.73
13	Health Hazard	The system will not create health hazard, if the system could be controlled by putting min power output and keeping standby while not in function.	3.83 ±0.85
14	Learnability	The system was easy to learn and operate with less training.	4.00 ±0.71

CHAPTER VI

DISCUSSIONS AND CONCLUSIONS

This concluding chapter briefly presents the main outcomes, thesis contribution, the limitation of this thesis and the future research implications.

6. 1 Main Outcomes

The thesis provided the four main outcomes. The outcomes were briefly discussed below.

6.1.1 Revealed a suitable design technique

HCI and Usability were key qualities to develop any software. This study identified that applications developed for military forces should support multi-channel facility fulfilling specific design requirements. Military applications would be used in different context in terms of the (military) operational condition, battle scenario and situation. Though a few studies had been conducted focusing on the design, usability and user experience (UX) issues of military applications, but these applications were designed and developed following different design methodologies that were tailored and customized from the general-purpose applications. This thesis analyzed and compared the existing the design techniques and found that the Interactive Dialogue Model (IDM) as a more appropriate design technique for developing both website and mobile applications for military forces. The IDM technique supported easy navigation, maintain consistency, responsive design, used to design multi-channel applications (both the website and mobile applications), did not demand high skill to apply, and differentiate between channel independent and dependent applications; while most of the methods like HDM [36], UEWDM [33], WSDM [29], OOHDM [31], and EORM [35] were not supported these features all together.

6.1.2 **Explore the usability factors for military application**

Previous studies did not explicitly present the complete list of factors that might be suitable or related to the military applications. This research revealed a total of 14 usability factors that would be suitable for developing and evaluating any military application; that includes: reliability, availability, accuracy, ease-of-use, robustness, chain-of-command supportive, scalability and interoperability, maintainability, portability and mobility, flexibility, placement and integration of system accessories, lightness/weight of accessories, health hazard and learnability. Among these, most of the factors exist in the existing literature in a scattered way (i.e., different studies stated different factors), while some were innovative like the chain-of-command supportive, placement and integration of system accessories, lightness/weight of accessories, and health hazard.

6.1.3 **Develop a multi-channel military application**

This thesis presented an advanced battlefield communication system for Special Forces of Bangladesh Army. The application consisted of an indigenous advanced combat helmet with video camera and video encoder, android based mobile applications, soldier's data terminal (SDT) device and web application. The main objective of this application was to portray the command and control structure of a military force. It worked as a medium of communication between the higher-level commanders and front-line troops. This customized and robust communication system would enable a soldier to transmit real-time battlefield scenario by audio and video transmission to the higher commanders and receive orders and instructions from higher commanders. In a small group operation, they would be able to communicate between them as well. The system was developed in this research as an indigenous system and no existing system was developed indigenously, though such kind of system was not new or innovative in context of the developed nations. The system thus obviously would enhance the capability of Bangladesh Army and reduce the cost purchasing such kind of device from abroad.

6.1.4 Evaluate the applicability of IDM

The Advanced Battle Field Communication System was designed following the IDM design technique and the system was evaluated with 30 participants to measure how much the revealed usability factors were supported by the developed system. The study showed that system performed well in terms of all the revealed factors. The subjective ratings were also very satisfactory that also indicated the acceptability of the software with respect to the all revealed factors. Since the system was highly depended on the data connectivity provided by third party and a few other hardware accessories, the limited bandwidth and the uses of the existing hardware accessories (due to the lack of opportunity to explore other good quality of hardware accessories) led the system to show unavailability, less reliability, and took little bit longer time to complete the tasks successfully in few cases. The system failure or error occurred mainly due to the malfunction noticed in camera, head phone, encoder, and SDT; and for the low bandwidth or poor data connectivity. However, there were no difficulties found due to design issues of web and mobile application. Moreover, the user interface of the web and mobile application assisted participants to understand the problem and fix it within a very shortest possible time and most of the cases the system was fixed by the participants with asking less number of helps from the moderator. In sum, the research showed that IDM technique could be an effective technique for designing and developing any web based military application providing enhanced usability. Though IDM was testing in different context like cultural heritage web domain, electronic government, etc. but no study was conducted before on those assess the IDM's applicability in context of military application. The outcome of this research indicated that the IDM was quite applicable in design and developing the military applications; thus contributing to the field of HCI and the military information system.

The thesis aimed to provide the answers to two research questions: (RQ1) "What would be the factors that affect usability of any military application?" and (RQ2) "How did the IDM applicable to design and develop a Military application to enhance usability?" The findings as discussed above provided the effective answers to RQ1 by revealing the usability factors for military applications, while the findings suitable design technique, developing a military application following the selected design technique and evaluated the performance the application with respect to the observed usability factors provided the answer for RQ2. The elaborated and effective answers to the research questions led to achieve the objectives of this thesis.

6.2 Thesis Contribution

6.2.1 Contribution to UI designers

Outcome of this would help the UI designer to develop any application related to military forces.

6.2.2 Contribute to usability expert

Usability expert might consider these derived usability factors to develop any military application. The outcome of this paper thus contributed to the Military Information Systems and HCI by providing a clear picture of what factors should be considered to develop any usable and useful military application.

6.2.3 Contribution to military organization

Usability factors were used to develop many applications of different fields. Erroneous use of usability factors in those fields might contribute negatively in the performance of that application. Gravity of negative effect might or might not threaten human life. But in case of military domain, soldiers would face life and death every moment in the war field. Thus, the development of military applications following usability factors might contribute in reducing the life threating risk.

6.2.4 Contribution to effective war field management

The battlefield scenario was always uncertain and changes unprecedented way owing to its fluidity. Intensive awareness of the situation of battlefield would enhance better decisions making and better counter-measures. Application as revealed in the study would be useful to monitor the live battlefield scenario and take action accordingly.

6.3 Limitations of the thesis

6.3.1 Uses of qualitative analysis approach

A qualitative data analysis approach was used in this thesis. Qualitative data analysis had its own limitation, because it depended on individual's experience, knowledge, cognitive power, and the like. To avoid bias in the analysis, the results were discussed with experts, using a systematic approach, while a review process was also part of the analysis.

6.3.2 Less number of participants

The evaluation process was replicated by only 30 participants which was a very small sample of total strength of Bangladesh Army. Again, the FGD was conducted with only 20 participants.

6.3.3 Only one application was developed as case study

The study considered only one application as an example case of military applications to justify the research findings. Different applications would have different requirements and functions. Only one application did not truly represent standard military application. Usability testing with only one application lacked completeness in determining the standard set of factors as yardstick.

6.3.4 Problems related to data connectivity

Data connectivity was one of the key concerns to develop the battlefield communication system. The GSM and Wi-Fi connectivity were prime requirement to run the application. Dependency on data connectivity restricted the use of the system in remote places. Moreover, poor bandwidth affected the functionality of the application.

6.3.5 Explored less number of hardware accessories

This study integrated few hardware components like camera, encoder, mobile phone etc. with the system. Many applications would have more number of accessories and diverse use. This research explored only a few devices to find the best suitable device due to the lack of availability such devices in Bangladesh and for the limited research budget. Thus, scarcity of components restricted the development and evaluation study to some extent.

6.3.6 Limited method were used to explore usability factors

To find out the all possible usability factors for military application only the FGD method was used. Some other methods like interviewing, user studies could be used to evaluate the usability factors and applicability of the system. However, to validate the reveled factors an extensive empirical study was conducted following the user studies and post-test questionnaires.

6.3.7 Insecure means of communication

The GSM and Wi-Fi connectivity were main sources of data connectivity. Civilian means of communication were always susceptible to security breach. Insecure means of communication without encryption made the application vulnerable and risky.

6.4 Future Research Implications

Future research would be conducted to re-solve many open issues that were observed through this research. Firstly, this explorative study was conducted following the FGDs. Future research could be conducted using other methods to explore and/or evaluate the usability factors for military application.

Secondly, military communication means could be used as primary means of communication as civil means might not be available during the time of conflict.

Moreover civilian means of communication were insure. Thus, the application could be implemented using more secure, reliable and strong military communication means with high bandwidth for data connectivity and then evaluate the system performance in terms of the revealed usability factors to see how the performance differ with the present system.

Thirdly, a total of 50 participants were recruited in this research, while the FGD was conducted with 20 participants and 30 participants were involved in the field study. Future studies could be carried out with an increased number of participants.

Fourthly, more hardware devices could be explored to find out the more effective devices to improve the overall functional performance of the system.

Finally, diverse environment and multiple situations should be explored to make the list exhaustive and meaningful. Thus, a few other military applications could be developed following the either the IDM approach or any other design approach, and then evaluate the system in terms of the revealed usability factors in order to make the usability factors more generalizable.

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APPENDIX A

PYTHON SCRIPT FOR VIDEO ENCODING

```
import sys
import socket
import urllib.request
import subprocess
from time import sleep
import signal
import json
import re

def get_command_msg(id):
	return "_GPHD_:%u:%u:%d:%1lf\n" % (0, 0, 2, 0)

## Parameters:
VERBOSE=False
## Sends Record command to GoPro Camera, must be in Video mode!
RECORD=False
## Saves the feed to a custom location
SAVE=True
SAVE_FILENAME="gopro5feed3"
#SAVE_FORMAT="ts"
SAVE_FORMAT="h264"
#Send video using http connection to ffserver location
http://103.78.248.70:8330/feed2.ffm
#Send video using rtmp connection to ffserver location
"rtmp://103.78.248.70:1935/live/mist4"
#Send video using rtmp connection to NginX server location
"rtmp://103.78.248.70:1935/live/mist3"

SAVE_LOCATION="rtmp://59.152.7.56:1935/live/mist3"
def gopro_live():
	UDP_IP = "10.5.5.9"
	UDP_PORT = 8554
	KEEP_ALIVE_PERIOD = 2500
	KEEP_ALIVE_CMD = 2

	MESSAGE = get_command_msg(KEEP_ALIVE_CMD)
	URL = "http://10.5.5.9:8080/live/amba.m3u8"
	response_raw =
urllib.request.urlopen('http://10.5.5.9/gp/gpControl').read().decode('utf-8')
	jsondata=json.loads(response_raw)
	response=jsondata["info"]["firmware_version"]
	if "HD4" in response or "HD3.2" in response or "HD5" in response or "HX" in
```

```
response:
        print(jsondata["info"]["model_name"]+"\n"+jsondata["info"]["firmware_version
        "])

## HTTP GETs the URL that tells the GoPro to start streaming.

        urllib.request.urlopen("http://10.5.5.9/gp/gpControl/execute?p1=gpStream&a1=
        proto_v2&c1=restart").read()

        if RECORD:
        urllib.request.urlopen("http://10.5.5.9/gp/gpControl/command/shutter?p=1").rea
        d()
                print("UDP target IP:", UDP_IP)
                print("UDP target port:", UDP_PORT)
                print("message:", MESSAGE)
                print("Recording on camera: " + str(RECORD))

## GoPro HERO4 Session needs status 31 to be greater or equal than 1 in order to start
the live feed.
                if "HX" in response:
                        connectedStatus=False
                        while connectedStatus == False:

        req=urllib.request.urlopen("http://10.5.5.9/gp/gpControl/status")
                        data = req.read()
                        encoding = req.info().get_content_charset('utf-8')
                        json_data = json.loads(data.decode(encoding))
                        if json_data["status"]["31"] >= 1:
                        connectedStatus=True

## Opens the stream over udp in ffplay. This was a known working configuration by
Reddit user hoppjerka:

        https://www.reddit.com/r/gopro/comments/2md8hm/how_to_livestream_from_a
        _gopro_hero4/cr1b193

                loglevel_verbose=""
                if VERBOSE==False:
                        loglevel_verbose = "-loglevel panic"
                if SAVE == False:
                subprocess.Popen("ffplay " + loglevel_verbose + " -fflags nobuffer -f:v
                mpegts -probesize 8192 udp://:8554", shell=True)
                else:
                        if SAVE_FORMAT=="ts":
                                TS_PARAMS = " -acodec copy -vcodec copy "
                        else:
                                TS_PARAMS = " -vcodec libx264 copy -y "
                                SAVELOCATION = SAVE_LOCATION #+
        SAVE_FILENAME + "." + SAVE_FORMAT
                        print("Recording locally: " + str(SAVE))
```

```
                print("Recording stored in: " + SAVELOCATION)
                print("Note: Preview was not available when saving the stream.")
#subprocess.Popen("ffmpeg -i 'udp://:8554' -fflags nobuffer -f:v mpegts -probesize 8192
" + TS_PARAMS + SAVELOCATION, shell=True)
#subprocess.Popen("ffmpeg -i 'udp://:8554' -fflags nobuffer -f:v mpegts -probesize 8192
" + TS_PARAMS + SAVELOCATION, shell=True)
#subprocess.Popen("ffmpeg -i 'udp://:8554' -fflags nobuffer -r 25 -s 320x240 -b:v 128k
" + SAVELOCATION, shell=True)
            subprocess.Popen("ffmpeg -i 'udp://:8554' -r 30 -b:v 1024k -an -f flv " +
            SAVELOCATION, shell=True)

            print("message-2nd:", MESSAGE);
            if sys.version_info.major >= 3:
                MESSAGE = bytes(MESSAGE, "utf-8")
            print("message-3rd:", MESSAGE)
            print("Press ctrl+C to quit this application.\n")
            while True:
                print("message-last:", MESSAGE)
                sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
                sock.sendto(MESSAGE, (UDP_IP, UDP_PORT))
                sleep(KEEP_ALIVE_PERIOD/1000)
            else:
            response = urllib.request.urlopen('http://10.5.5.9/camera/cv').read()
            if b"Hero3" in response:

    PASSWORD=urllib.request.urlopen("http://10.5.5.9/bacpac/sd").read()
                print("HERO3/3+/2 camera")
                Password =  str(PASSWORD, 'utf-8')
                text=re.sub(r'\W+', '', Password)
                urllib.request.urlopen("http://10.5.5.9/camera/PV?t=" + text +
                "&p=%02")
                subprocess.Popen("ffplay " + URL, shell=True)



def quit_gopro(signal, frame):
    if RECORD:
    urllib.request.urlopen("http://10.5.5.9/gp/gpControl/command/shutter?p=0").rea
    d()
    sys.exit(0)

if __name__ == '__main__':
    signal.signal(signal.SIGINT, quit_gopro)
    gopro_live()
```