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MOHAMMAD JOHIRUL ISLAM
ONTOLOGY-BASED MOBILE INTERFACE ADAPTATION FOR
MONITORING COLLABORATIVE SUPPLY NETWORK ASSETS.

Master of Science Thesis

Examiner: Prof. José Luis Martínez Lastra
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ABSTRACT

MOHAMMAD JOHIRUL ISLAM: Ontology-Based Mobile Interface Adaptation for Monitoring Collaborative Supply Network Assets.

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Collaboration has been an essential part of Supply Chain Network because of involvements of different users at different level of the network. Communication and information exchange between buyers and sellers and transportation agents are considered as few of the main steps of collaboration in supply networks. Thus, an interface for all such communication and information exchange with quick response and monitoring of different stages of supply chain processes becomes a prime requirement in modern supply chain markets. An advanced management system for collaborative supply networks is the current demand of the market and this can bring competitiveness and free flow of information throughout the networks. One of the main focuses of such management system would be an advanced monitoring system of the Collaboration processes and stages of supply networks. This thesis focuses on research about the development of a simple mobile tool for monitoring collaborative Supply Networks and its assets.

Advanced computational ability and enhanced data processing with in different web and mobile applications are gaining popularity in recent times which also increased the requirement of a dynamic atmosphere for the processing and computation of these data. Interactions of static types are designed in such a way that they are not always capable of handling big and complex data. This is because of the non-deterministic perspectives of pervasive computing environments. Adaptive user interfaces are commonly used in different software systems and popular for enhancing the performance of the users by taking care of general user context variables of the original systems such as user-context and user environment. This thesis work also emphasized on implementation of adaptive interfaces that can be used for collaborative Supply networks. The research work extended up to the possibility of adaptation of collaboration processes by modifying simple variables based on user context.

This thesis research work aimed to design an ontology for collaborative supply network and implementation of user modeling with collaborative supply network model. The idea of using ontology with mobile tools is to apply different semantic rules in the collaborative supply network, which will help it to work more efficiently and help in adaptation in different level.

PREFACE

This thesis work has been an extraordinary journey on learning and research on Collaboration and supply Networks. Though the focus has been research on collaborative supply networks and modern application development with adaptive features, other related studies on ontologies and reasoning tools were very informative, intuitive and worthy learning for automation and software developments. I had the opportunity to learn and implement real life web application development on Java and mobile application development on android, which has been an extraordinary experience and resourceful knowledge for me.

The examiner of my thesis work is Professor José Luis Martínez Lastra, who has been a very friendly and open person to share knowledge and ideas. He has not only been the examiner of my thesis, but also supported and provided moral guidance for the thesis work.

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The thesis work is the last part of my M.Sc. in Automation Engineering program and the example of my hard-earned degree reflection. While doing the thesis research I had the opportunity to work in FAST-Lab of Tampere University of Technology, which is a life time experience and I had the opportunity to learn more things than just academic stuffs. I had the opportunity to interface first time the Finnish working culture and environment. I really want to thank Professor again for availing me such prospect to work in FAST-lab. I also want to thank all my colleagues in FAST-lab while working there specially Wael, Xu, Angelica, Navin and Anne. You guys have been awesome as always. All my colleagues were very helpful and friendly throughout the time of my working there.

Last but never the least, I want to mention the support from my family- special my wife, who supported me in every way to complete this thesis work and my masters as well. Some small thanks will not cover her deeds.

Finally, for the readers, thanks for considering and hope my work will come into some help of yours.

Thank You

Tampere, 18th October 2018

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LIST OF SYMBOLS AND ABBREVIATIONS

AI	Artificial Intelligence
ASTUTE	Pro-active Decision Support for Data-Intensive Environments
C2NET	Cloud Collaborative Manufacturing Network
CN	Collaborative Network
EU	European Union
HCI	Human Computer Interaction
HMI	Human Machine Interface
HRI	Human Robot Interaction
HTML	Hyper Text Markup Language
HTTP	Hypertext Transfer Protocol
IDE	Integrated Development Environment
Java EE	Java Enterprise Edition
JDK	Java Development Kit
JS	Java Script
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
OS	Operating System
OWL	Web Ontology Language
P2P	Peer to Peer
POP-mail	Post Office Protocol-Mail
RDF	Resource Description Framework
RDFa	Resource Description Framework in Attributes
RDFS	Resource Description Framework Schema
REST	Representational State Transfer
SMS	Short Message Service
SPARQL	Simple Protocol and RDF Query Language
SWRL	Semantic Web Rule Language
TCP	Transmission Control Protocol
TUT	Tampere University of Technology
UCP	User Collaborative Portal
UI	User Interface
UML	Unified Modeling Language
W3C	World Wide Web Consortium

1. INTRODUCTION

1.1 Background

Collaborative process, in terms of definition simply indicates the processes which are accomplished in collaboration with different working groups. In recent times of globalization, large projects and tasks are being fulfilled with collaboration of different research organizations [1] or collaboration between different teams in a single organization. Because of its effectiveness, collaborative processes are becoming popular and many systems are now adopting the collaborative approach.

Collaborative network can be defined by the networks of processes that are accomplished with collaboration of different person or organizations. Collaboration in supply networks are very useful and common in current time of globalization [2]. Supply network is a network of different organizations, where one or more consignments are supplied to the manufacturer or the buyer with contribution of different team or working groups. These working groups can be different organizations. Since Supply networks requires effort of different organization or working groups, this network more likely to adopt collaborative system more perfectly.

Collaborative Supply Network is becoming popular day by day because of its performance and promptness in response for providing supply entities to the clients [3]. The collaboration in Supply network helps to expand the supply chain and to improve the effectiveness. Thus, supply network becomes vast by combining and collaboration of different organizations and supply group both locally and globally [4].

Since Collaborative supply network requires actions from different working groups or organizations, proper communication among these groups is the main key of success [5]. Maintaining the communication can be complicated somehow due to variety of organizational attitude, diverse mode, way and standards for communication. For these reasons, the collaborating organizations or teams should follow a single medium. This medium can be either a dedicated communication channel or also can be a software with which every related entity will relate to each other. This can be very vital and effective because this can provide necessary information to the correct receiver which will help them to decide and plan further and thus the productivity and effectiveness will enhance overall.

1.2 Motivation and Justification

The use of an application or software can be a game changer in Collaborative Supply Networks. Performance of the users largely depend on the interfaces of the application. While user-friendly interface increases the productivity, complex interfaces reduce the overall performance of the user. Thus, an interactive user-friendly application for Collaborative Supply network becomes a global requirement for the network.

For development of user-friendly interactive application, the most important part is to develop interactive interfaces of it. There are many ways to make interfaces interactive with the user [6], [7]. Such a very effective and user-friendly way is development of adaptive User Interfaces. While an application can be developed for any platform of use, a mobile application with adaptive interfaces can be very useful for the users

Adaptive interfaces are user-friendly, and it helps users to use the interfaces actively through focusing on the user requirements by maintaining other conditions favorable for the user. Ontology has been proven an effective concept for automating knowledge driven manufacturing [8], asset managements and development of Human Machine Interfaces (HMI). The use of Ontology along with mobile application will make the application smarter because the use of ontology opens the opportunity of Artificial Intelligence (AI) application with in mobile application [9].

1.3 Problem Definition

Monitoring Collaborative Supply Network is very important for certain users who are related with network and managing the assets. While using a tool for monitoring, user often face difficulties in customizing the interfaces and adjusting the tools. Since the tasks are time dependent and often situations demand customizations, users face difficulties in focusing on the task or loose time in other works. Users' ambient condition may vary depending on many facts. Although these facts depend on person to person, but the criteria of these ambient conditions' variables are not unlimited. Thus, customization of HMI has become some essential criteria of visualization of any process. The research on identifying these facts and definition of these criteria can be very crucial. Also working condition and location might vary also. Sometimes users' uses different type of devices. Thus, there are many variables that can be automated on the application level to achieve desired ambient condition and to ease the work of the users.

1.4 Research Question

User interfaces with adaptation features can be helpful for users in many ways of decision making and planning. Usually the adaptive features are implemented separately only focusing on the variables that are only related to information visualizations. But adaptation may take place in the operation of a Collaborative Supply network and planning of different operation. One of the main concerns of this work was to evaluate the possibilities of adaptation services inside the Collaborative Supply Network for better and autonomous supply operation and planning.

Another important topic to research while studying on the possibilities on adaptation inside collaborative supply networks was to research on adaptive patterns and development of concepts and philosophy of the patterns, their functionalities and adaptation effect. Thus, this research was also focused on finding such answers of this concepts and philosophy.

The architecture of development of user interface with adaptive feature for manufacturing systems has been successfully implemented and tested previously and well recognized. Another research focus was to evaluate the reusability of the architecture for Collaborative Supply Networks and adopting the concept of user model of visualization. The reference architecture is an EU project implementation named ASTUTE (Pro-active decision support for data-intensive environments) [10], [11].

It is worth to mention that this reference architecture was mainly used for developing HMI for the low-level use or mainly factory floor level. The research for using the similar concept architecture for High level usage has been also required. Research area also consists of understanding the reference architecture ASTUTE and its implementation and possible adaptive features for the Collaborative Network (CN) users.

Development of user model is not uncommon for development of User interfaces. But in most cases these models are discrete from the original databases or information knowledgebase. Research for integration of these user models into one and development of a generic user model for Collaborative Supply Network was also required for this thesis research work.

Based on above explained research areas, the thesis has been focused on finding out the following questions:

- What is the possibility of adaptation service inside Collaborative Supply Network and how that affects the autonomous operation of Supply chain?

- What are the possible adaptive patterns for such systems and what can be the concept and philosophy of development?
- What is the possibility of using any reference architecture and how to do that?
- How to combine of the user model for user interface with the original model for collaborative supply chain?

1.5 Thesis Objectives

The thesis work has been focused on finding and solving the research questions. Thus, different thesis objectives have come to be solved to attain the goal. The thesis research work mainly focused on two parts: research and gather relevant information and knowledge that are related to the research questions and development of solutions based on through research on Collaborative Supply Network and adaptation.

One of the main objectives of this thesis work is research on collaborative Supply networks and different user models that are related which are often called as meta models [12]. The goal is to narrow down the classes and properties and unified them in a single and most possible generic user model for collaboration in supply network.

Another objective of this entire thesis research work is to evaluate adaptation inside the Supply Network and to attain that goal research on different type of available adaptive patterns are required. This study is to find out the possible adaptive options for Collaborative supply networks and to develop some concept and philosophy of adaptive operation and planning for collaboration in supply networks.

Another objective of this research work is to develop a mobile tool for a collaborative Supply System where the interfaces of the mobile tool have the adaptive feature to ease the decision making and usage of the user.

A well and renowned development (ASTUTE) related to adaptive interface has some similarities in implementation of adaptive interfaces with the current development. Reusability of the architecture and user model of ASTUTE becomes another objective of this research work in development of user model for adaptive interfaces of collaborative supply network.

Another important goal is to propose a set of adaptive patterns based on the through research on different collaborative models and supply networks and the reference development for interface adaptation.

To test the developed user model, Cloud Collaborative Manufacturing Networks (C2NET) project has been considered as the level of implementation of this research work as C2NET focuses on collaboration in supply network too. Thus, the study and research on the use cases of C2NET has become another objective of the thesis work. Testing the implementations following one selected use case is also required for the thesis.

In summary, the thesis work is based on following objectives:

- A thorough study and research on different supply networks and different collaborative networks and research on the user models of the respective ones.
- Evaluation the adaptation possibility both inside the collaborative supply networks and on the respective user interfaces.
- Research and development of different concepts and philosophy of adaptation in planning and operation inside the supply networks.
- Reusing the reference architecture for the development of the user interfaces.
- Propose a set of adaptive patterns for the user interface and development of the user model which can be combined with the original network model.
- Development of an android 'mobile tool and testing the user models with the mobile tool.

1.6 Limitations and Assumptions

The research field for this thesis work is very vast which persuades to focus on the above-mentioned objectives only. Also, some assumptions are needed to be established during the thesis work. There are also some recommendations that have been provided at the later part of this thesis.

Since the research has been focused on adaptation of collaborative supply network, both the functionality adaptation and interface adaptation, implementations only focused on interface adaptations, though the findings of planning adaptation and operation adaptation are also presented in the form of concept and philosophy only.

The development work was limited to the development of one specific type mobile tool (android-based application). Although the mobile tool is only the client part, the server side can connect to any kind mobile or web tools.

While the interfaces of mobile tool might display different information and data regarding Collaborative Network and supply networks, the knowledgebase associated with the development of application only stores information of user context for adaptability of the interfaces.

The idea of mobile tool development is only for testing the possibilities of the reference architecture. So, the interfaces were very basic showing only the main functionalities.

Limited adaptive patterns are implemented with the mobile tool though many possible adaptive patterns are described.

While development of the research work, there has some assumptions that are considered as assumptions. Though these assumptions do not provoke the implementation largely but moderated the support materials accordingly.

Since ASTUTE has been the reference and example of user model development and a source of quite good number of adaptive patterns for interface adaptation, only the concept of user model for visualization and classes of the models are adopted in this research work.

The user model developed for collaborative supply network has been restructured in the form of adopted user model from ASTUTE. The reforming has been done in such a way that ASTUTE concept of user model has not been affected and different classes related to collaboration and supply network remains secured too. In the process of adaptation, some minor naming convention has been modified to match to vibe of Collaborative supply networks.

In the level of implementation, the mobile tool has been assumed as an exclusive monitoring tool of Collaborative Supply Networks. Thus, the mobile tool has no option of making any modification of any process of the network.

2. INDUSTRIAL PRACTICES AND LITERATURE REVIEW

2.1 Collaboration systems

In general, Collaboration systems can be called to those methods or systems that are achieved by collaborative work force. Here the term comes Collaboration or collaborative. Collaboration means working together where everyone contributes his/her own part. The output of the collaborative systems often cannot be achieved alone or difficult to achieve [13]. Thus, Collaboration Systems can be defined as a form of information systems which helps to overcome difficult situations or achieve better results while developing or creation of value in the way of combined effort [13]. Information exchange is the mandatory condition of a collaboration system. All the participants in a collaborative system solves a problem through information exchange as per requirement of the task [14].

Few very essential parts of collaboration systems are Collaborative Network (CN) and Collaborative Process (CP). The collaboration system is described in more details on the following parts of this chapter.

2.1.1 Collaborative Network

Collaborative Network (CN) can be simply defined by an information exchange network that is used for accomplishing team work. A collaborative network can be an active information network for helping different users from different places and different specialty to contribute on a single project or solve a problem as one team. So, a collaborative network can be called as the workplace for a global team. Different researchers defined CN in different ways. A good and standard definition can be found in [15] where CN has been defined by a combination of Businesses, working individuals or team members and different related organizational entities where these particulars contribute their capabilities and resources to achieve goals [15].

In general, collaborative networks are organized in such way so that they are prompt in functionality which requires more agility and ingenuity. As of the global trend of the organizations, regardless the size of organization whether large or small it is quite common that different organizations follow different ways to satisfy the need of the customers. Thus, different need might require different collaborative networks to fulfil the needs.

So, it is quite common to observe the participation of an organization in different Collaborative Networks. It will be the network administrator in certain networks do the job. These networks may have competing purposes or be comprised of competitive firms.[16]. Figure 1 illustrates a simple Collaboration network inside a single organization.

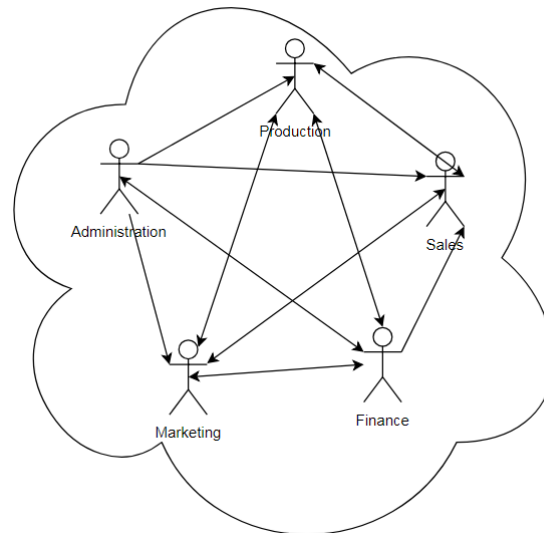


Figure 1: A typical Collaboration Network inside an Organization

Thus, Collaborative Network itself becomes an organization and hence competition develops among different networks inside the organization. This way changes the nature of the competition inside an organization and the new competition can no longer be defined by services, brands or products, rather by networks of humans and relationships. This human network work across limits in persistence of value delivery to the members and customers. Here the old saying about relationship comes that they cannot be purchased or fabricated rather they need to be developed with care from scratch by the individuals, not by the organizations. [15]. Figure 2 shows a simple comparison of collaborative Network in the form of example with other networks.

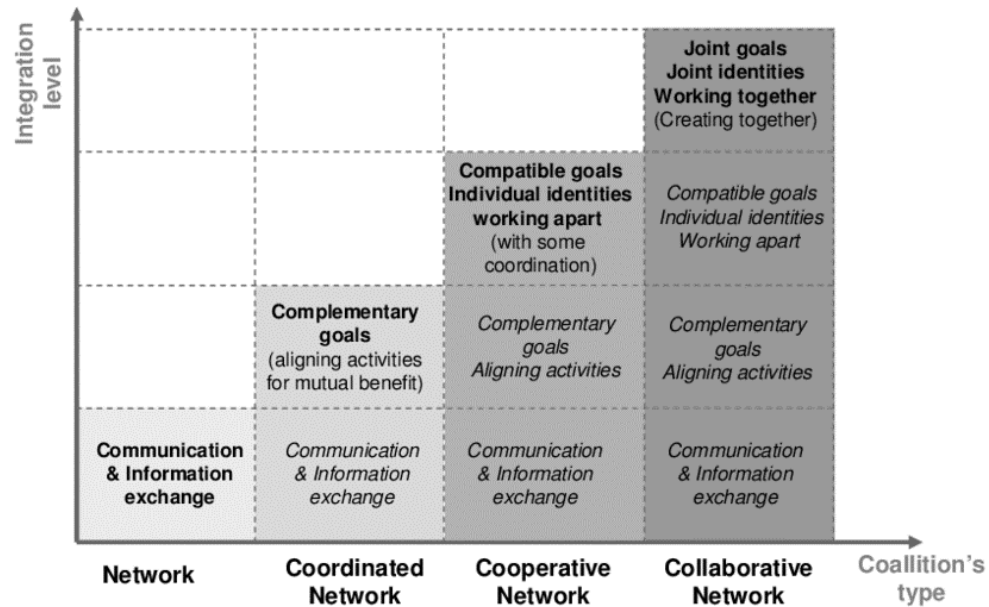


Figure 2: Simple comparison of Collaboration Network with other types [17]

This new mode of competitiveness brings benefits to those people who can use the collaborative network in best possible ways through proper assembly and management of networks. To succeed and growth development of economy in the corporate world, modern firms and organizations not just emphasizing on specialized expertise on certain fields but also to the ability of collaboration and proper expansion of Collaborative networks with proper use. While there is such importance of collaboration in organizational activities, unfortunately many CEOs and business leaders acknowledged the fact of missing of collaboration in their organization while they agreed about the necessity of it. Thus there is a major gap between the reality and the conceptions which points that it is utmost important to change the ways of thinking, acting, interacting, relating, working, and managing inside the organization. [15]

2.1.2 Collaborative Process

In simple words, A collaborative process can be defined by the work flow to obtain a certain goal by collaboration of teams or organizations. Nevertheless, a collaboration process requires one or more Collaborative Networks and this also follows different ways of collaboration depending on the type of work, goals and organizational structures [18]. Collaborative Processes can be described as the set of concepts or ideas, work steps or methodologies, work activities and resources that individuals or teams or organizations

can utilize to achieve goals or accomplish collaborative tasks [19]. Thus, a complete collaborative process can be divided into following steps that can be followed to design a collaborative process:

- i. **Getting Started** by introducing the tasks and initial planning.
- ii. **Team selections** and mobilizing
- iii. **Setting direction** and goals for each team.
- iv. **Taking Actions** by developing actual strategy and following the plan through accomplishing tasks by individual teams.
- v. **Reviewing and Refining** the process throughout the process by providing guideline and support.

Since Collaboration is closely related with continual ongoing negotiations [20], this view about collaborative process sums up three general steps of collaboration [21]: Pre-negotiation, Negotiation and Post-negotiation. Negotiation is the most common and widely used form of social communication. People negotiate on certain topic or task to get the best out of the available resources; in this way, collaboration process is defined as process of negotiation.

2.1.3 Applications and examples of Collaborative Network:

In the age of recent globalization, Collaboration is everywhere and thus there are a lot of fields of application of Collaborative Network. Basically, all the tasks can be done in collaboration, but that might not be the best solution for that task. Different industries have different work plan and thus do different things differently. This makes sense as each type of industry has individual needs and requirements. Some industry focuses on research, some on work force and productivity, some do the research work individually and some do them jointly with other organization. So, Collaboration network can be present in any field of application, but each organization develop their collaboration network on their own way focusing on their individual needs and practices.

Over the time researchers tend to map these networks and their behaviors. Such a finding is that the industries that works with dynamic technology usually have many open networks. These open networks usually connect to companies that are research oriented with agreement with that industry. These research-oriented companies may be located on different geographical location. Such dynamic technology user industry examples are Biotechnology and Microelectronics. Their open networks only deal with less fragile information of the company, but these networks allow more research work from other sources

and new inventions. Thus, they move fast forward. On the other hand, other type of industries like pharmaceutical, chemical and automotive tend to keep the company secrets strictly and for this reason they have very less open networks and only collaborate with selected number of known partners. Less open network limits the overall progress of the network and the company. [22]

Not only the technology-oriented industries use the collaborative networks, but also corporate industry and supply chain use the collaboration networks. Collaborative Networks are kind of essential for Supply chain networks. They have mainly open networks and open to new suppliers and sources. These open networks help the supply chain to be competitive in the market and keeps the supply chain more active. The corporate industry uses the Collaborative network in a bit different way; they develop and use the CN in such a way, so that they can gain more productivity. Such an example is establishing different branches in different location, which not just helps in local sales and support or management but also distribution of work in different parts. Also, these branches can be globally in such places with different time zone, which helps the organization to run 24 hours.

2.2 Human-Machine Interaction

Human-Machine Interaction (HMI) is the field of study of the ways and methods of communication and data exchange between humans and machines. This multidisciplinary field is enriched with the combination of Human-Computer Interaction or HCI, Human-Robot Interaction or HRI, Artificial Intelligence or AI, Robotic and Micro Robotics, Humanoid robots and exoskeleton control [23]. HMI can also be compared with a dynamic methodical system, via an interface for human-machine interactions. This is a vast field of research that has been conducted for more than 57 years [24]. Design of this interaction systems are the combination of art and science which have wide acceptance in different sectors of application domain. In fact, the good designs have been able to attain a high value in different markets of many products of industrial, transportation, medical and entertainment systems [24].

Controlling and problem solving can be categorized as the main human task in human-machine interactions where controlling involves different task of both continuous and discrete types which can be either open or closed loop activity. On the other hand, problem solving comprises of larger numbers of reasoning tasks in the field of resource planning and management. [24]

The visualization of HMI is a very integrated and essential part of this study. The visitations are applied into displays with the use of computer graphics and dynamic picturization of different views of process visualization [25]. The views can be either topological

or component-oriented where this dynamic representation is applied while different complementary views can be presented for providing the functional knowledge. Thus, inclusion of audio with visuals combines into auditory displays which are now becoming more popular in industrial and other related sectors for representation of alarms, warning and state information [26]. This can also reduce the load on visual reasoning and combines audio with visual representation.

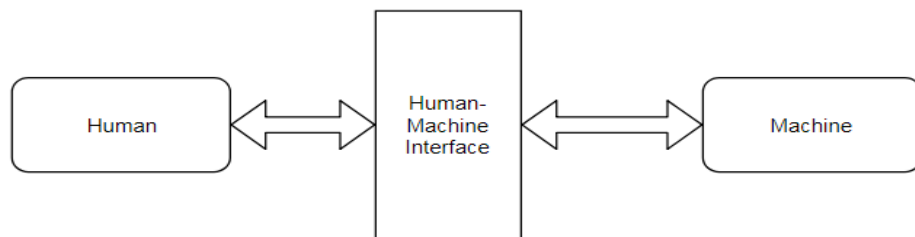


Figure 3: Human-Machine Interaction Process

Figure 3 represents the simple explanation of the Human-Machine Interaction process and the components and their positions. A more explained view can be Figure 4 where the components of this systems are explained with their activities and actors.

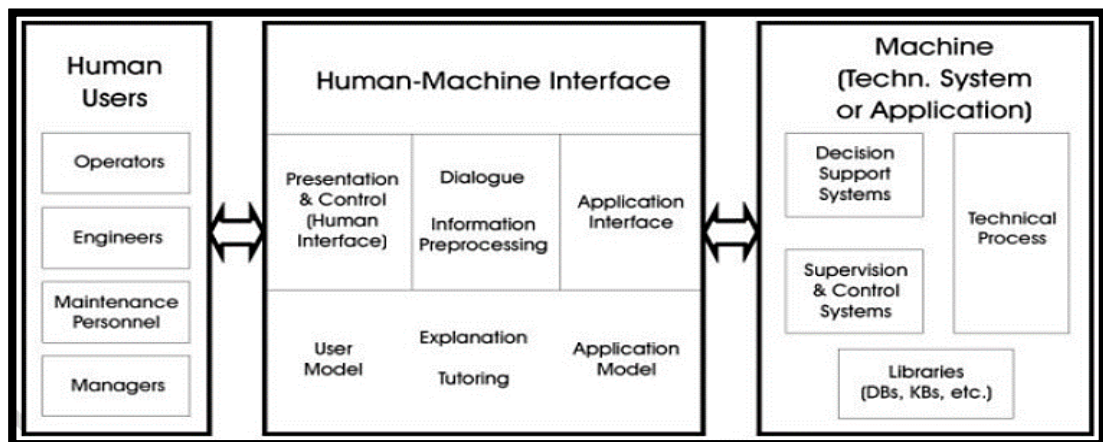


Figure 4: Main functionalities of the human-machine interface between human users [24]

The Knowledge-based systems can work parallelly with HMI which can provide decision. This advanced means of support can improve human-machine interaction. Technical and practical support and error preclusion are instances for user-oriented functionalities.

2.2.1 User interfaces

User interface (UI) is the most essential and basic media for Human-machine interaction. User interface can be defined as the method of information and instruction exchange between Human and Computer (Machine) [27]. UI can also be expressed as the part of information device with which human contact machine. This UI can in many forms. Such as an UI can be a computer screen or a key-board or a computer mouse or a whole compact computer. The main goal of UI is to establish a communication channel with machine and to do effective operation and control of the machine through information exchange of human and machine.

Thus, the concept of user interface can be very broad and can be exemplified as the features of computer Operating System (OS), machinery control interfaces, hand tools and process controls. And application of UI in different field arises different design consideration while development of the interfaces marks significance on its performance.

In general, development of an easy and efficient, enjoyable and reliable user interface for machine operations to produce desired results can be defined as the goal of user interface design. The design considerations can be the need of the user to provide minimum efforts to obtain optimum outputs. This also imply that the machine will eliminate the maximum amount of undesired results. [28]

2.2.2 Adaptive Interface

Since mobile devices have gained more usability and acceptance as multimedia devices, the designs of the HMI's interfaces also require accepting the technological changes and modify thereby. Since the computational capability of the mobile devices income mode distributed, static interfaces of HMI are losing the popularity, rather adopting the dynamic style of designing the interfaces. As an example, dynamically designed HMI interfaces for mobile applications does not constantly produce inherent interfaces. Static interaction style is commonly now not adequate to fulfill the advanced task and knowledge desires of current systems. Recent Upsurge in computing power and the look of additional omnipresent, distributed capabilities can build the tasks and knowledge that users want even additional unpredictable, greatly increasing the issue of providing sensible interaction style. Because of the nondeterministic properties of an omnipresent computing surroundings with an outsized variety of process and users, stationary style can now not be adequate to supply helpful and serviceable interfaces amongst the users and this might be impossible to forecast the interactions which will be needed for a selected system and user, the knowledge which will be necessary, or perhaps the knowledge which will be obtainable. it'll even be not probable to forecast or management the hardware and code

capabilities which will exist in native and distributed forms or the expertise and capabilities of the human and code participants.

2.2.3 Ontologies

Information system has significant role in the sector of management and operation of production which is emergent process as this is becoming more flexible but complicated due to dynamic market and consumer demands. For the automated decision making and adaptation to context-based application, information system must provide more optimized functionality instead of just being the simple repositories of data. Specifically, for our case, the dynamic feature of HMI is essential, where the interface can adapt itself according to the user or system needs, i.e. monitoring along with response to queries with adaptive representation of information visualization without compromising its performance. This may require users to model representation, context sharing and semantic operability of various heterogeneous systems. Ontology has numerous benefits which includes machine readable knowledge about users, context and device semantically, facilitation of model integration by providing better comprehension and management of complexity of the models as well.

The perception of ontology is defined by a communal conceptualization of an explicit and proper specification [29]. An ontology is also defined as the representation of knowledge of any certain field of concentration: the sets of ideas, their descriptions and different relations to relate different idea individuals [30]. An ontology can be developed using five most basic and essential modeling parts: Classes, Relations, Functions, Axioms and Instances.

- **Classes** are defined as the main concepts of different domains. For example, a domain of Football team the classes will be players, coach, manager etc.
- **Relationships** defined as the properties that interrelate the classes or concepts. For example: Players listen to managers, Coaches guides the players etc.
- **Functions** are generic type of concept acts as property. As example: is-mother-of (a, b) denotes that a is the mother of b.
- **Axioms** are mainly used to limit the possible relations between the values of classes. According to this, axiom can be defined as the properties of relations [31]. Axioms also some general rules. For Example: every instance of foot is considered as the instance of leg as well.

- **Instances** are defined as the basic objects that usually belong to different classes. For Example: Alice is a dancer means she belongs to dancer class.

The use of an ontology brings some benefits over using general database for storing the data. Firstly, Ontology has the functionality of sharing the knowledge of general understandings of information structure among the users or application api. Again, the ontology can have the general understandings by using axioms and functions which generalizes and classifies the data stored. Another important use of ontology is the possibility of using semantic rules. Semantic rules are the real beauty as they transform the data as the smart information keep by using generic rule [32]. Applying one single rule, will direct all similar relations and instance to follow the same methodology.

3. APPROACH

Collaborative Supply networks are becoming more competitive and proper flow of information is an essential requirement for this network. The goal is to attain a comprehensive global and optimized local manufacturing assistance through advanced developed algorithms and respond to the changes promptly as per requirements.

To achieve the goals, promptness and responsiveness of a system in mobile tool is very essential. The mobile tool is very handy way to monitor the changes and response quickly despite of the situations of the users. Decision making ability and adaptive interface can attain the goal of a smart mobile tool. Using knowledgebase for data storage can avail the intelligent feature of decision making and optimization. To develop adaptive interfaces, selection and development of adaptive patterns are also important.

3.1 Adopting Reference architecture Approach

ASTUTE has been a successful EU funded integrative-technology based project that offers implementation for developing interactive, responsive and adaptive HMI (Human Machine Interface) for information collection and representation depending on situational context, information content, services and user state information. The design of ASTUTE architecture is designed in such a way that the device catches the intensions' of the user and optimize the options available for the users.

Since the goal is to develop and implement adaptive and interactive mobile interface for collaborative networks, ASTUTE can be a set of reference architecture. ASTUTE visualization model can be adopted as reference for developing the visualization model for the collaborative supply network. To implement the visualization model for the collaborative networks following ASTUTE visualization model, firstly the architecture of ASTUTE HMI engine is needed to be understand.

ASTUTE adaptive HMI engine has been developed with the combination of HMI Definer and HMI Builder [33]. These two parts plays the main role in generating and visualizing the information in the interfaces. One of the main role of HMI Definer is to record and organize the modality of inputs and outputs for generating the HMI layouts and the design characteristics of UI. This also states the preferences features of the device and collects the information of the tasks to be performed by the user. HMI Definer forms package with all the required information to be displayed and sends to the HMI Builder. HMI

builder analyze the information package and process with required information and instructions to generate interfaces for the user in the mobile device [34]. Figure 5 represents typical ASTUTE architecture in Adaptive HMI level.

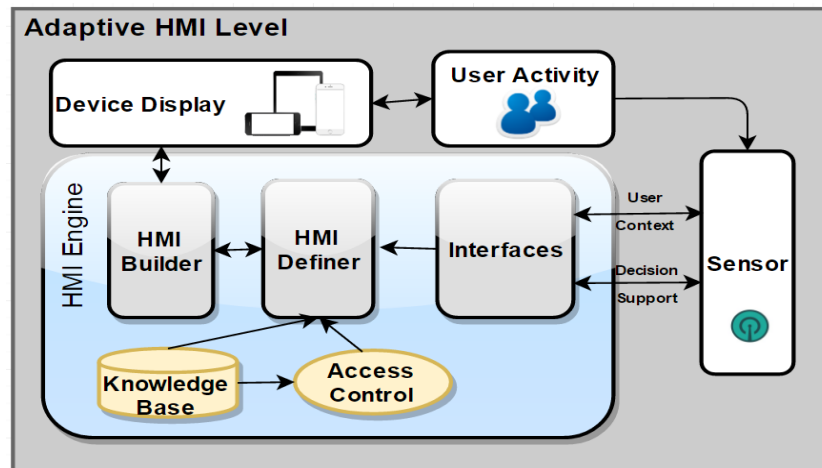


Figure 5: ASTUTE architecture in General Adaptive HMI level [34]

In HMI Builder, the package holds that HMI design specifications used for generating different part of user interface in terms of HTML elements parts or different Java objects for developing web interfaces for ASTUTE which can be displayed to any web browser. A very important and necessary characteristic of HMI Builder is to establish a clear communication channel with HMI Definer and subsequently communication with the user interfaces in different platforms and HMI Definer focuses on the design and development of the layouts of the interface, choose the visualization methods and technologies.

HMI builder recovers data from framework which is one of the most practicality of HMI Builder and helps to generate adaptive Interfaces. The general perspective of the HMI Builder of ASTUTE is shown in Figure 6 represents the general overview of HMI builder and demonstrates its relationship inside HMI engine. A communication structure that supported P2P (Peer to Peer) model of client/server is coordinated by the HMI Builder architecture.

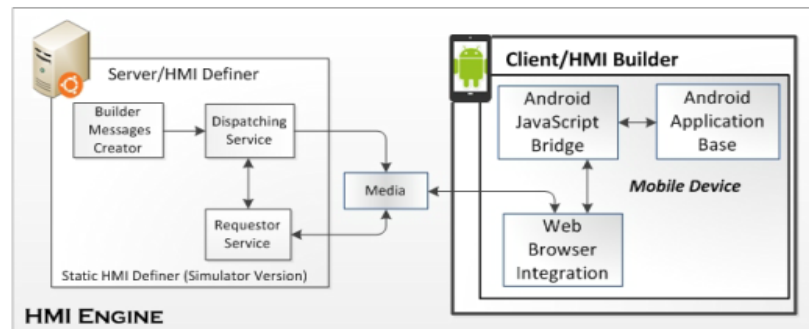


Figure 6: ASTUTE HMI Builder general overview [33]

The REST (Representational State Transfer) web service builds the HMI definer with different related servlets which also performs as context manager and collects user context data from the android. Over time of usage the ontology model is continuously updated by the context manager using auto generated SPARQL (Simple Protocol and RDF (Resource Description Framework) Query Language) updates and at the same time different SPARQL queries are made to induce updated HMI layout data from the ontology. The layout data is then formed as JSON data packet and sent to the HMI builder in android device using JavaScript Bridge. [33]

The customer side is secured by an application that is actualized over Android OS. The Android OS is the base of the customer element that conveys interior layers in the gadget and furthermore sets up the correspondence with arrange gadgets by means of wireless network. The customer side is formed by three general modules: Web Browser Integration, the Android application base and the Android/ JavaScript Extension. [33]

Figure 7 demonstrates the framework integration with the activities performed by every component, keeping in mind the end goal to quickly depict how the HMI Builder functions. The framework builds up an association with the web application which relates to the corresponding the server. Initially, the web-server starts the communication with specific destinations containing esteems related to the user interfaces. After that, web-application receives the information contained message. As soon as the server dissects the message using the JavaScript Extension (specified in past segments), the server directs the message composed with the Web-View (WV) parts which are to be presented in the Android interface. [33]



Figure 7: Integration of ASTUTE Application [33]

The user model of ASTUTE generated by the ontology is basically explained into two main knowledge concepts: Domain Knowledge and Application Knowledge [33], [34]. Domain knowledge is introduced by addition of generic database, which is a requirement for development of user model. These basic data are mainly obtained from various sources: user-context, user-environment data, user-tasks and the device modalities, are essential elements for domain knowledge. Device Domain, Environment Domain, Task Domain, User Domain and Interface Domain are the five sub-categories of abstract concept domain concept.

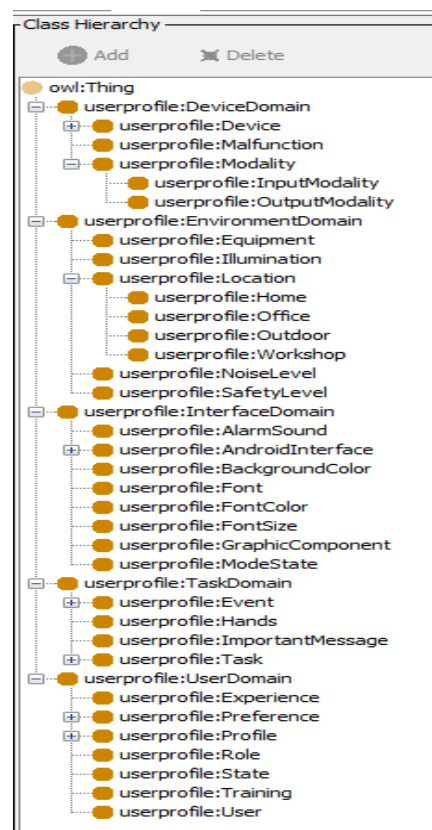


Figure 8: Snapshot of ASTUTE user model Class Hierarchy

Device domain class represents the modalities of the connected devices and malfunctions. The sub-class malfunction holds the possible malfunctions status of the devices and modality sub-class holds possible supported I/O modules. These three subclasses have been

characterized since device is the most fundamental bearer of the UI application, and the framework will bolster multimodalities of the device.

The EnvironmentDomain comprises of the components and different features of the workplaces like areas, Light, noise Level and Security levels. Equipment subclass is for adding distinctive sort of gear in various circumstances. Area subclass is for expressing the area of the user like home, office, meeting or workshops. Enlightenment, Noise level and Safety level subclasses are for enrolling alternate constraints for depicting nature.

Interface Domain is developed with different UI related component subclasses: Alarm Sound, AndroidInterface, BackgroundColor, Font, FontSize, FontColor, GraphicComponent and ModeState. The subclass ModeState represents states of possible modes of the interfaces. The rest of the subclasses stores other related information of UI.

TaskDomain class organizes different instances of the user model that are responsible for handling user interface related tasks and messages. Few of the major subclasses of this class are Event, Task and Urgent Messages. Different situational context and their records are mainly handled inside the Event subclass. Task subclass holds data about client errands. Important Message subclass holds the definitions of different type of potential alarms and warnings.

The UserDomain class consists of the subclasses of the different type user differentiating properties. This domain basically distinguishes various users in different situation. The users can be distinguished by the User Profile, User Preference, Experience and Role in the system, user state, User Training and user name.

Application knowledge has been outlined by including diverse associated Domain data and generating application-particular thoughts, occurrences and semantic web Rule Language (SWRL) rules [35]. These example and principles are not specific and fluctuate in various situational case.

Enabling and supporting a collaborative Supply chain network implemented inside of a cloud-based platform has been the main aim of C2NET project. The development of the project has been implemented by adopting the idea of anything as a service (XaaS) [30] paradigm. A cloud based XaaS paradigm may consist of three main layers and a user interface layer on top of them [36]. These simplified layers are Software as a Service (SaaS), Infrastructure as a Service (IaaS) and Platform as a Service (PaaS) [34]. SaaS as top layer of paradigm provides application support. PaaS stays between SaaS and IaaS and act as middleware through hosting some basic services that does not require human support. Lastly, IaaS does all the fundamental computing related supports like processing,

storing and networking [36]. User interface lies over all these layers maintain support for human interactions.

The execution of the XaaS paradigm for C2NET architecture is illustrated in Figure 9.

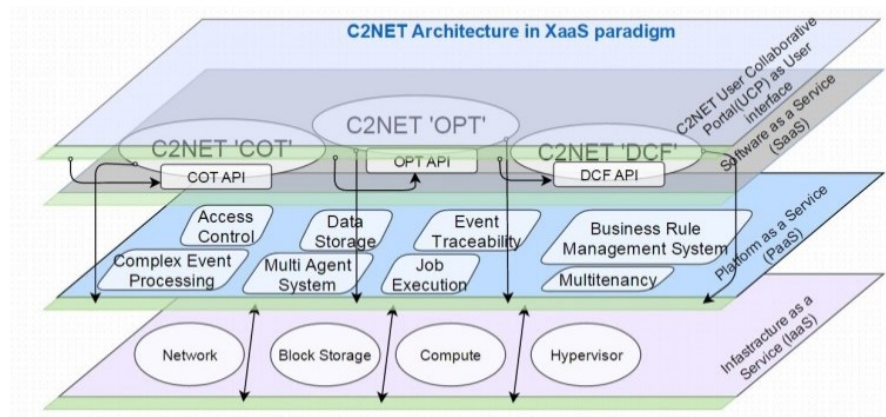


Figure 9: XaaS paradigm for C2NET architecture [34]

As illustrated in the earlier Figure 9, on the top of upper layer (SaaS), C2NET User Collaborative Portal (UCP) works. This UCP is the main User Interface (UI) of C2NET which a web-based application portal is. User interrelates with different components of SaaS layer by generating and presenting proper visual interfaces. This must be mentioned that the approach has been built on plugin design pattern [37]. Thus, UCP of C2NET stands as a common medium to integrate different plugins of C2NET visualization.

According to the functional necessities of C2NET and the architecture developed for C2NET UCP can be met by ASTUTE architecture and ASTUTE visualization model, ASTUTE can be a good reference for implementing User Interface for a Collaborative Supply network. The benefits for adopting ASTUTE architecture for building C2NET UCP are as follows:

C2NET UCP can use the similar methodology of architecture of ASTUTE project that is composed of HMI Engine and HMI definer, which is proved to be effective and advanced with the possibility of integration of C2NET-UCP to mobile application.

Like ASTUTE C2NET can also use the idea of HMI engine which can obtain user context (preferences, user profile, device characteristics, situation, light and sound) through different third-party API, internal and external applications.

C2NET UCP is proposed to be developed using a container-based visualization model following the ASTUTE user model. The data received from HMI definer will be passed and recorded in that container as a user-visualization model data.

HMI builder determines the requirement of information for visualization and makes request to the user model data container.

ASTUTE architecture provides reference architecture for user modeling for dynamic information storage and processing as well as refers to a set of adaptive patterns for development of adaptive HMI for C2NET.

Moreover, the implementation and adoption of extension of ASTUTE architecture can be used to develop the Visualization Engine for C2NET. The possible extensions are as follows:

- a) Inclusion of new type of users and task in the visualization model adopted from ASTUTE.
- b) Implementation of HMI for mobile devices based on user needs.
- c) Introduction of planning adaptation through the UCP. [3]

The earlier discussion explains and validates the requirement of implementation of ASTUTE methodology for C2NET UCP development. Amongst the different steps to implement such methodology, first step is to design an ontology for C2NET visualization model like ASTUTE that is defined as user model is ASTUTE. From the Figure 8 of ASTUTE ontology explains five basic domain classes.

ASTUTE ontology user model is designed based on domain concept and the domain are designed is such a way that they remain generic. The domains: Device Domain, Environment domain, Interface domain, Task Domain and User domain are quite generic for every case of HMI development whether it is for a manufacturing system or a collaborative network. So, adopting the ASTUTE user model is basically adopting the idea of domain concept of ASTUTE user model. While designing the user model of C2NET from ASTUTE domain concept, the only changes will be the subclasses of these domain classes.

The next stage of adopting ASTUTE methodology is adopting the adaptive interface development methodology and adaptive patterns that are applicable. Adaptive patterns are the definition of the effects on UI and description of their design and implementation ways. The adopted possible adaptive patterns from ASTUTE will be presented and explained along with other new adaptive patterns idea and definitions in the later part of this chapter.

3.2 Knowledgebase Design within ontology:

Since the first step of adopting ASTUTE methodology is adopting the methodology of development of user model for visualization. For development of user model consist of information resource, identification of the events and classes of them and relationships among the events are needed to be identified. This knowledgebase will be designed inside C2NET ontology and over time enriched with information of different situation and events. In [12] paper, an extensive study on different ontologies and meta-models which are related to collaborative systems and supply chain management has been summarized with a reference meta-model for C2NET. Form the meta model, a clear picture about related low-level classes and basic relationship between classes and events can be understood. Thus, a reference set of low level classes and basic properties of them are identified. The goal is to design the ontology in such a way so that the classes and their events will be populated inside the ontology following the ASTUTE domain base classification.

The domain concept of ASTUTE is very generic that different identified classes can be divided into different domain class according to their applicability. The meta-model for C2NET [12] although has its owns classifications for its subclasses and the events, this domain based classification is required for development of user model visualization. The basic properties can also be grouped in several groups based on their action.

Amongst these five domain classes, EnvironmentDomain and TaskDomain classes are mainly hold the knowledgebase of the collaborative supply networks. Rest three classes: DeviceDomain, UserDomain and InterfaceDomain will hold the information to build adaptive HMI for perspective user.

3.3 Patterns selection and development

As adaptive user interface, an attractive and efficient option for viewing information now-a-days, can used in C2NET for its UCP, the patterns regarding adaptation effects come to discussion. Adaptation effects refer to behavior of the system which shows different responses for different users, context and intention. These major features help to achieve the visualization effects in the user interface. C2NET mapping with ASTUTE also includes adopting the required patterns that been used in ASTUTE with proper modification if required. 18 different patterns were selected and used in ASTUTE. They are also categorized into different situational domain: user domain, environment domain, Device Domain, Task Domain, User Domain and Planning Domain.

3.3.1 ASTUTE used patterns

a. **Pattern Name: Context Adaptation.**

ASTUTE used Domain: User Domain & Environment Domain.

Proposed Domain for C2NET: User Domain & Environment Domain.

General Description and Adaptation Effects:

This pattern will adapt with user context and environment. User context means understanding user behavior and intention. This pattern will use some input modality and get the context data.

Changing font and background depending on the user's preferences. While using the interface for long time and activity of user gradually decreases, means when user is exhausted, the system font will enlarge and contrast of the display will increase. If the user activity is normal, means user is active, and then fluctuating the font size gradually to detect the effective case for that user and gradually go to an optimum level to obtain the maximum efficiency from the user.

Change of Background depending on lighting condition of the user. Adjust brightness depending on environment lighting. When the user is in bright environment use set bright background and dark font color. When the user is in dark environment use set dark background and bright font color.

b. **Pattern name: Non-disruptive Notifications**

ASTUTE used Domain: User Domain.

Proposed Domain for C2NET: User Domain.

General Description and adaptation Effects:

This pattern differentiates notifications smartly and identifies the important ones. Depending on the classification of notification based on user and task on that session, less important notifications will not be triggered and will not disrupt users.

Depending on the user and his/her task event notifications are categorized and only the primary task related event notifications are triggered and display the number of un-triggered notification. Important primary task related notifications will disrupt the users and

user will have to decide if the user desires to modify the main task or endure previous task by choosing “Accept” or “Remind later”. These notifications of sound can be used. Sound notifications are optional based on device, but they will be triggered with primary task related notifications and block the user from ignoring it.

c. Pattern name: Multiple ways of input

ASTUTE used Domain: Device Domain.

Proposed Domain for C2NET: Device domain

General Description and Adaptation Effects:

This pattern provides the users to choose the input option available in the device. The maximum possible modalities will be provided for certain devices which have been used by the user.

d. Pattern name: Composed Command/ Multimodal instruction.

ASTUTE used Domain: Task domain.

Proposed Domain for C2NET: Task Domain.

General Description and Adaptation effects:

Instructions are being created and visualized in multiple mode based on the user, his role of action in that session and task to be done in that session.

Define the possible task for certain user depending of the role of user and then list the steps of that task.

Multimodal instructions will be used while listing the steps to help the user become familiar if he is doing this task for the first time.

e. Pattern name: Audio visual presentation.

ASTUTE used Domain: User domain.

Proposed Domain for C2NET: User Domain.

General Description and Adaptation Effects:

This pattern provides optional animation-based visualization to understand and complete the task by the user. Depending on the task and user, different audio-visual representations are visualized, and this event only occurred at users relax time.

This pattern will provide some dynamic visualization of different plans with different type of charts related to the task of the user when user is present but not busy.

f. Pattern name: Multiple Alerts dissemination.

ASTUTE used Domain: Task domain.

Proposed Domain for C2NET: Task Domain.

General Description and Adaptation Effects:

Categorize the alerts and notifications in groups and disseminate in numbers. This pattern gets the alert notifications and list them in a list of alerts hidden in the screen and displays just the number of total notifications.

During multiple alerts or notification, categorizing them into different groups and showing the numbers. When user clicks on the alert icon, it will extend and show the summery of each alert. User can acknowledge the alert from this drop-down menu.

g. Pattern name: Spatial representation.

ASTUTE used Domain: Environment domain.

Proposed Domain for C2NET: Environment Domain.

General Description and Adaptation Effects:

This pattern will get the user location from input modality and contribute building the interface for the user.

User's location information will be obtained to use them in decision making and notification showing. For example, if the user is outside office, only the urgent notifications will appear.

h. **Pattern name: Warnings.**

ASTUTE used Domain: Task domain.

Proposed Domain for C2NET: Task Domain.

General Description and Adaptation Effects:

A group of notifications which has potential threat on the future will be moved to another list and will display the notifications as Warning but will not hamper the user task. This Pop-Up appearance without disruption of the user is the main functionality of this pattern.

A non-disruptive message which are not urgent but has a potential for future crisis will be moved to warnings as well and will show small notification text or light sound to attract the user without interruption.

i. **Pattern name: Mode switch**

ASTUTE used Domain: User domain.

Proposed Domain for C2NET: User Domain.

General Description and Adaptation effects:

The adaptive patterns will be built on the basic interface. So, this pattern will give the authority to the user to disable all the patterns and use the basic interface. User can switch between Adaptive interface to Basic interface without effects.

j. **Pattern name: Detail levels/ Abstract simplification**

ASTUTE used Domain: User domain.

Proposed Domain for C2NET: User Domain.

General Description and Adaptation effects:

The role of action of the users defines the operation accessibility of the user in certain task. Depending on the user accessibility, un-accessible task portion will be made invisible to the certain user by this pattern.

Different level of detail for different level of user although the task category is same. For example, a planning manager planning interface is different from the planning interface

of Production manager or sales manager. Depending on the hierarchy of the team the details visibility is restricted.

This Pattern provides detailed information in different layers. The user will have the option to choose a suitable level of detailed information he/she wants to access and achieve. In production management, the team leaders usually have different (lower) level of detailed information about the system and specially about the robot to detect any living problem, as the maintenance engineer will be taking care of repairing that same robot.

k. Pattern name: Layer

ASTUTE used Domain: Task domain.

Proposed Domain for C2NET: Task Domain.

General Description and Adaptation effects:

Different type of layers will be used for different type of task. Rather than accumulating large amount of information in a single layer, they will be displayed in more number of layers.

l. Pattern name: Task management

ASTUTE used Domain: Environment domain.

Proposed Domain for C2NET: Environment Domain

General Description and Adaptation effects:

User specific tasks will appear as hint in the interface. This pattern presents tasks in such a way so that they are well-organized and ranked and that helps the user to understand the needs to be performed first.

A planning manager may need to prepare several plans in a day. Prioritizing the task will ease the manager to plan accordingly. It will promote the users to do certain tasks depending on time.

m. Pattern name: Log

ASTUTE used Domain: Task domain.

Proposed Domain for C2NET: Task Domain.

General Description and Adaptation effects:

This pattern will export event data to a text file to generate a log. This pattern creates event history log.

n. Pattern name: Alert/Important message

ASTUTE used Domain: Task domain.

Proposed Domain for C2NET: Task Domain.

General Description and Adaptation effects:

This pattern identifies the important task notification for the user and disrupts the user. The main function of this pattern is to provoke the user to respond the important Alerts immediately and revoke to do other work. Alert/important messages will obtain the highest precedence and will interrupt users with Different sounds.

3.3.2 Unused patterns from ASTUTE Documentations

Table 1: List of unused patterns proposed for ASTUTE

No.	Pattern Name	Proposed Domain for C2NET	General Description
i.	Global channel configuration	Environment Domain	This pattern provides several interaction profiles combined with different I/O channels formations personalized to the context respectively. Thus, the users can select different interaction profiles using this pattern with an additional interaction step. [38] [39]
ii.	Redundant input	Device Domain	This Pattern combines several interaction channels to practice of redundancy. This is required

			to ensure safe and undistorted inputs. To lessen the liability of errors different channels can be combined for clarification of different Inputs coming from numerous channels. [39]
iii.	Redundant output	Device Domain	This Pattern avails the use of redundancy in output level through the combination of several output channels. This is required to ensure a backup output channel during overflow. [39]
iv.	Multimodal Form	Device Domain	<p>This pattern enables the users to enter data into different slots. The system uses voice command for quick initiation of further inputs while user chooses an item from the available list. The graphical menu item has been also selected instantly during selection by voice command. This pattern enables the users to enter data into different slots.</p> <p>While using a pointing device as input, speech selection processes are circumvented. Whenever the voice recognizer fails to interpret the input, this will be considered as mistake and must be informed via speech. Authentication and disambiguation will be completed multi-modal, using both voice command and popup notes if the voice recognition fails or becomes low level of authentication and thus, giving the user the chance to shift to an additional strong modality for error rectification. [38]</p>
v.	Form Filling	Task Domain	This pattern collects information from the user in a structured way to categorize a least description and prepare a variable with entered information stored inside. This short description is presented to the user with the options of extra inputs and silence while filling out a form by the users. [40]

vi.	Perspective Information Detailing	User Domain	<p>Based on the user vicinity of the user goal or critical steps, this pattern avails the adaptation of the system while interpreting the level of information features and viewpoints are carried to the user at the suitable time.</p> <p>In visual modality, the effect of this pattern can be compared as a magnification of an important information with rectification of the level of information details and complementary information. [41]</p>
vii.	Modality Combination in enriched information	Device Domain	<p>This pattern combines different modalities to create a more clear, detailed and meaningful information. The combination is being done with the help of complementary modalities considering the user perception and the efficiency of the modality.</p> <p>Visual modality that are compound and condensed can be combined with less directive modalities which are short and have direct perception. For example, clear Visual input with short duration with clear audio is enough. Usage of simple visuals to support long and complex audio instructions. [39]</p>
viii.	States transition	Environment Domain	<p>This Pattern can be in use for representing consecutively the same information but with a scale or position change without user confusion.</p> <p>Keeping consistency in elements visibility allows the user to recognize and recall those elements. [41]</p>
ix.	Information and Solution presentation	User Domain	<p>This pattern is related with information presentation in user convenient or understandable way. Based on the user situation, the information can be presented in different ways in</p>

			The same information (meaning the core of the message) can be transmitted in different and more efficient ways. [41]
x.	Metaphor	User Domain	This pattern uses metaphoric illustrations to generate affordance. The users of any system can have different level of expertise. This pattern also sustenance Voice instructions and interactions comparing with the availability in real life. [41]
xi.	Abstract simplification	Task Domain	This pattern can reduce the complexity and quantity of information in most possible ways by representing the information in most simple and understandable format. [41]
xii.	Trend	Task Domain	This pattern combines information with time and make this relationship explicit in the information display. [41]

3.3.3 New Proposed Patterns:

a. Pattern name: Collaboration Notification.

Proposed Domain for C2NET: Task Domain

General Description and Adaptation Effects:

This pattern deals with the notifications of collaborative types. It processes the notifications due to collaborative contribution in the network and display in non-disruptive way.

When another user modifies or contributes to some work, the main planner or contributor will get a notification. Every user will get a notification about the work history of that certain task. Every user will see who else is online and what he/she is doing in that task.

b. Pattern name: Plan Scheduler

Proposed Domain for C2NET: Planning Domain

General Description and Adaptation Effects:

This pattern creates and suggest plans which are related with the users based on the previous history of usage of that user. This pattern gets information during the session and saves the information if the session is success. Later generates a template of plan and shift by analyzing the historical data. User can choose or reject the suggestion.

New production shift planning alert depending on the history of production shifts. Generate Plan Templet. For example, this pattern suggests some purchasing options to purchase manager by automatic searching based on previous searching history.

c. Pattern name: Recipe Generator

Proposed Domain for C2NET: Planning Domain

General Description and Adaptation Effects: This pattern prepares a basic templet of the recipe dynamically.it analyses previous several recipes generate by this portal and assist user to develop new recipe. It also exports data to graphical form to visualize the business process and forecast.

Production Recipe will be suggested depending on previous history of production to the manager. Obtain production data and generate graph and forecast production plans.

d. Pattern name: Cloud status

Proposed Domain for C2NET: Environment Domain

General Description and Adaptation Effects:

Create optional notification about the link status and storage. Provide real time cloud status, both link status and storage. Notify network manager if user faces communication problem

e. Pattern name: Email/SMS Notification

Proposed Domain for C2NET: Task Domain

General Description and Adaptation Effects:

This pattern sends some most important notification to the user my push SMS or POP-mail. This pattern also works as an interface to obtain some input from the user by this SMS or email.

User will be notified for urgent notification by email or SMS, if he is not connected with the portal that time. Interface can also receive special inputs from SMS or Email.

f. Pattern name: Easy Training

Proposed Domain for C2NET: Task Domain

General Description and Adaptation Effects:

This pattern generates training steps by means user task history. The pattern captures repeated steps and suggest the user while missing or overriding the steps.

Generate training of steps by highlighting on tools in the interface for new users. If the new user wants to go on different approach, give alerts. The system will try to push the user to its known best optimized approach.

g. Pattern Name: Option Identification

Proposed Domain for C2NET: Planning Domain

General Description and Adaptation Effects:

Provides possible support and tools suggestions for specifics. Suggest to user other options while selecting a tool or storage.

h. Pattern Name: Choice adaptation.

Proposed Domain for C2NET: User Domain

General Description and Adaptation Effects:

This pattern remembers the options the user is taking in certain task and get that option first to the user in later.

Adopt user choice by obtaining the information of usage of the user. For example, if the user is comfortable with Pie chart for visualization, further statistical information will be displayed in Pie Chart to him.

4. IMPLEMENTATION

The implementation of the research work has basically three stages of research and development. The first stage is to research and development of Visualization ontology-based user model by adopting the architecture of ASTUTE user modeling. The second stage is to develop an application for the Collaborative supply network that has a solid backend for establishing secure and uninterrupted communication channel with low overhead and can generate the user models through updates and query to knowledgebase Ontology. The mobile application should have a front end that demonstrate some adaptation effect and general functionality of the whole collaborative system. The third and final stage is to accumulate all the components: Visualization ontology-based model, Mobile application backend-frontend and different plugins and ensuring seamless interactions.

4.1 Environment of Development and Tools:

The first thing to explain the implementation is introducing the environment of each development stage. In different stage, different tools are used for developments along with environments.

a. Visualization ontology-based model:

For the development of ontology-based visualization model, Olingvo ontology manager has been used for managing and developing the basic structure of the model. Since the application Olingvo is platform independent, the only environment required is Java JDK (Java Development Kit). It is worth to mention that Olingvo Ontology manager is a successful application developed in Tampere University of Technology at FAST Lab.

b. Mobile Application Backend:

To develop the mobile application backend Java EE (Enterprise Edition) has been chosen as the Environment of development. Java EE has been chosen because of its versatile and vast source of libraries and for future extension to User Collaborative Portal. Eclipse IDE has been used as to tool for the development of the backend. For hosting the web application Apache Tomcat 7 has been used. Since the ontology will be updated via the backend Jena library has been used as environment.

c. Mobile Application Frontend:

Since the mobile application front end has been developed for the android client only, Java and android libraries are required for the environment of development. The tool used for development of frontend (Android app) in Android Studio. The android app has the compatibility of android version 4.2 and above.

d. Visualization model Hosting and Update:

Apache Fuseki is well known for hosting ontology-based model and can provide good performance while update and query to the model. In this research work, Apache Fuseki has widely been used for ontology hosting and communication via the application backend.

4.2 Ontology-based Visualization Model

The concept for development of Visualization model has been adopted from ASTUTE visualization model. The methodology of Domain concept of classes and events and application knowledge for description of the system has been well adopted for the design and development of C2NET Visualization Model Ontology. According to the ASTUTE methodology, the total knowledgebase has been distributed in two level of abstractions: Domain Knowledge and Application Knowledge. Domain knowledge consists of the events and classes of different levels of components and activities of Collaborative Supply networks. The reference Collaborative meta-model [12] suggests an excellent resource of different possible classes of collaborative supply networks. These include Network Characteristics, Components of supply chain, Resource Capacity, Different Risks and Goods, Transportation, KPI (Key Performance Indicator), Goals etc. This study has been conducted exclusively for C2NET project [42]. In order to arrange these classes and events of different situation, domain concept can be applicable through dividing all the classes into sub class of two main domain class: EnvironmentDomain and TaskDomain. EnvironmentDomain is dedicated for hosting all the subclasses that are related with supplements and property of supply Chain network flow. TaskDomain is related to direct actions that are required by the user to ensure effective and efficient Collaborative supply network.

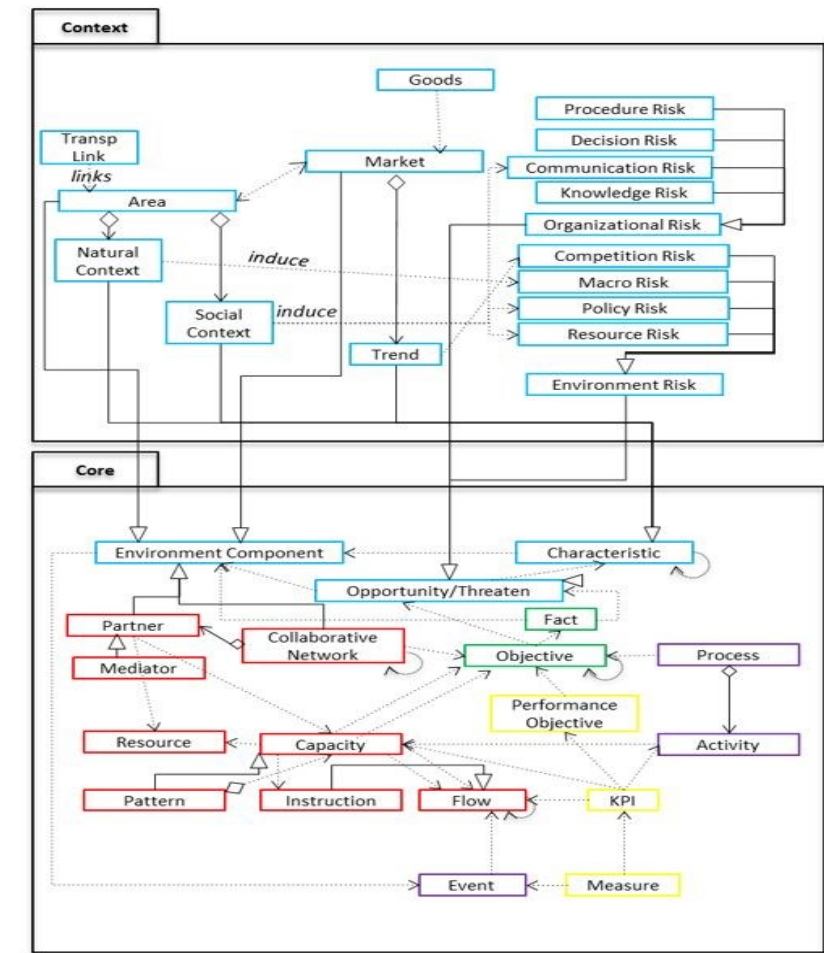


Figure 10: Context View of Reference Collaborative Meta-model [12]

Figure 10 shows the part of Reference collaborative meta-model that are related with the context View of Collaborative network. The uniqueness of this view is that this view represents the Characteristics and Risks of Collaborative Supply Networks. From the figures we can obtain different classes and its subclasses for the EnvironmentDomain like Characteristics, Components, Locations, Risks, Safety and Transportation. Figure 11 illustrates the representation of these classes organized properly as a part of the Ontology model inside EnvironmentDomain.

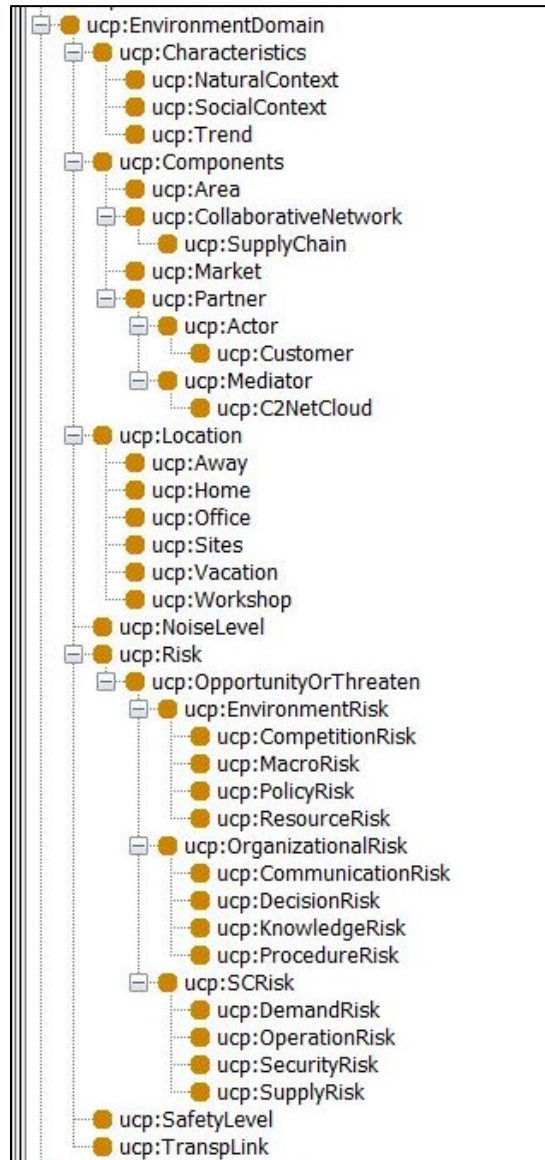


Figure 11: Subclasses of Environment Domain of Ontology for C2NET Visualization

While EnvironmentDomain hosts all the Collaboration and Supply chain related characteristics and components as well as Risks, TaskDomain is organized with different subclasses of actions and planning for executions and performance of collaborative network. Figure 12 and Figure 13 demonstrate objective view and partner view of collaborative meta-model respectively where the classes are illustrated with relations.

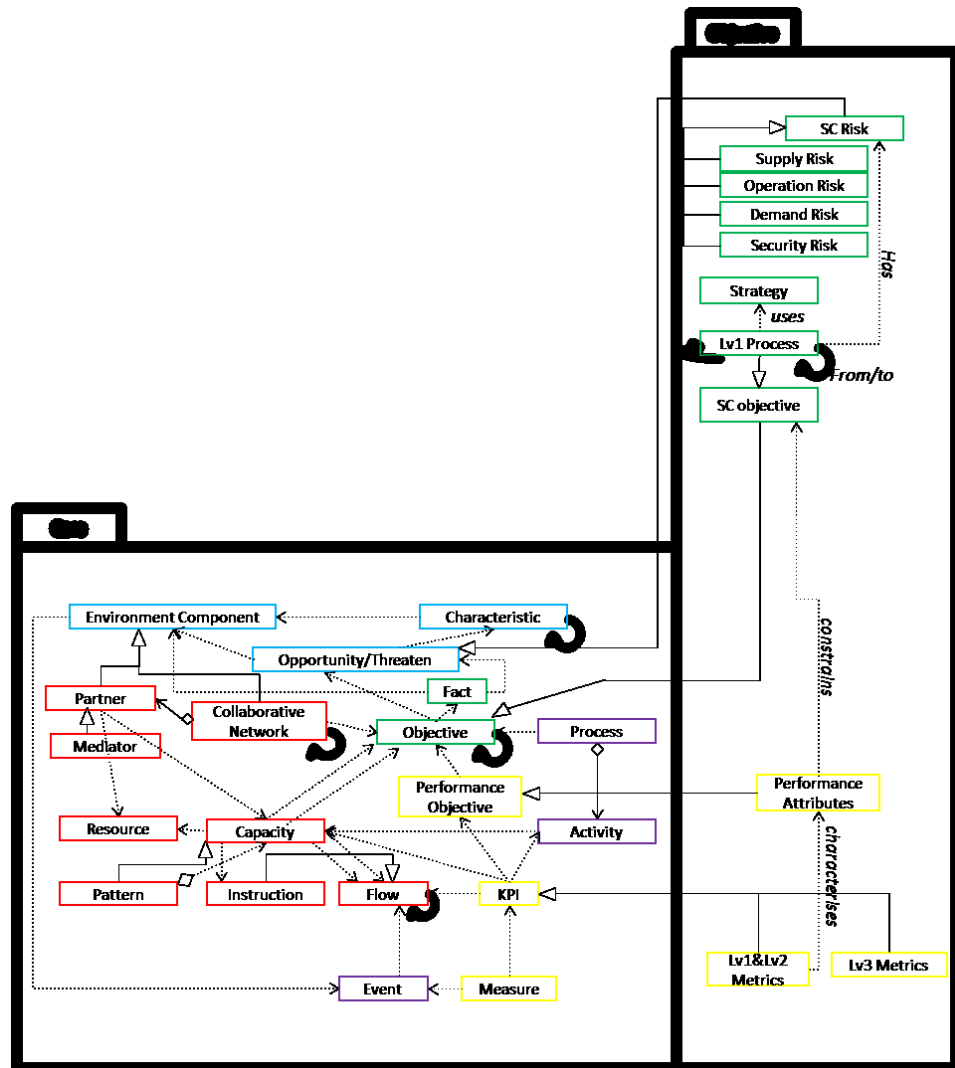


Figure 12: Objective View of Reference Collaborative Meta-mode [12]

The Objective view of the meta-model represents standardization of the collaborative network objectives for supply chains and developing relationships among them. On the other hand, the partner view shows an in-depth ontology model for supply chain components and expresses the relationship among them.

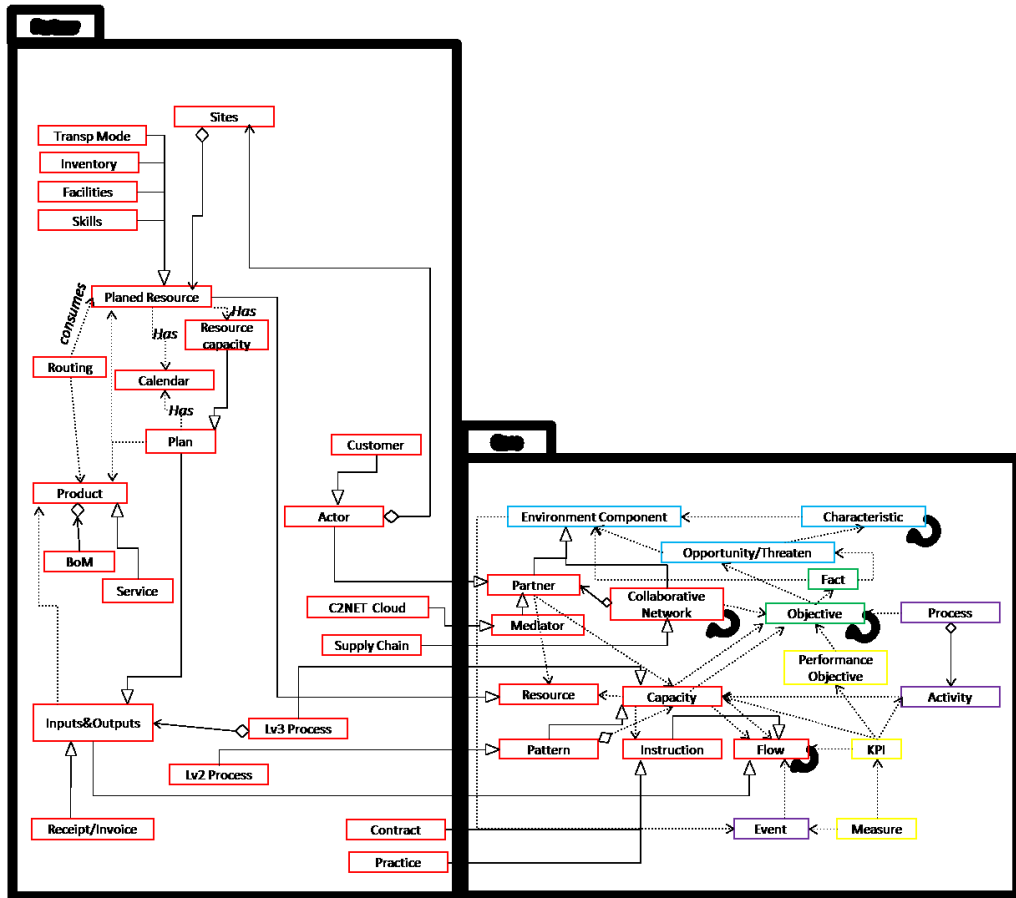


Figure 13: Partner View of Collaborative Meta-Model [12]

From both the Figure 12 and Figure 14 we can obtain different classes and events for TaskDomain, as they are more involved with execution and planning. Figure 14 demonstrates the subclasses organization of Task domain inside the ontology.

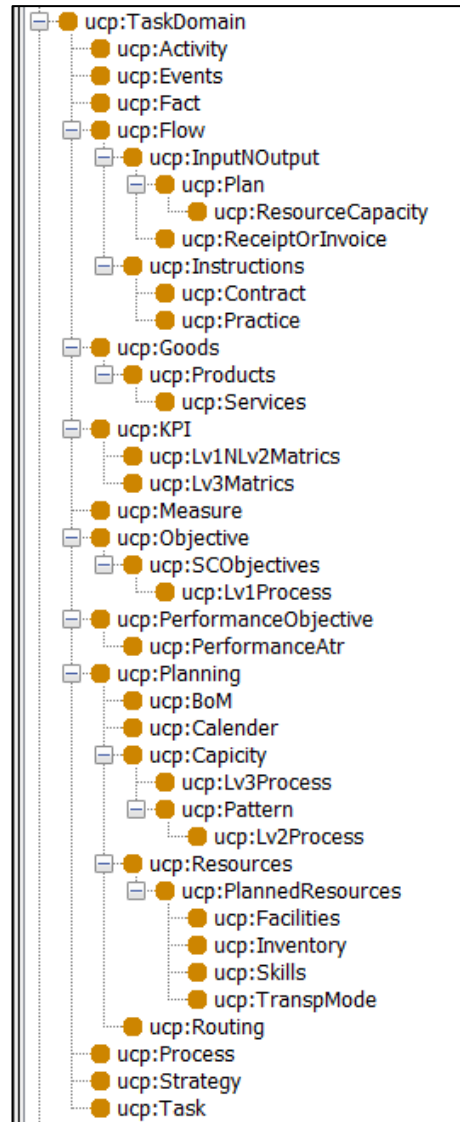


Figure 14: Subclasses of TaskDomain of Ontology for C2NET Visualization

The collaborative meta-model [12] only represents the components and events of Collaborative supply chain. To implement a HMI following ASTUTE methodology [33], DeviceDomain, UserDomain and InterfaceDomain classes have been introduced to enlist corresponding processes for visual representation. Thus, the general structure of the ontology-based visualization model has been developed. A typical view of the visualization model for C2NET is presented in Figure 15.

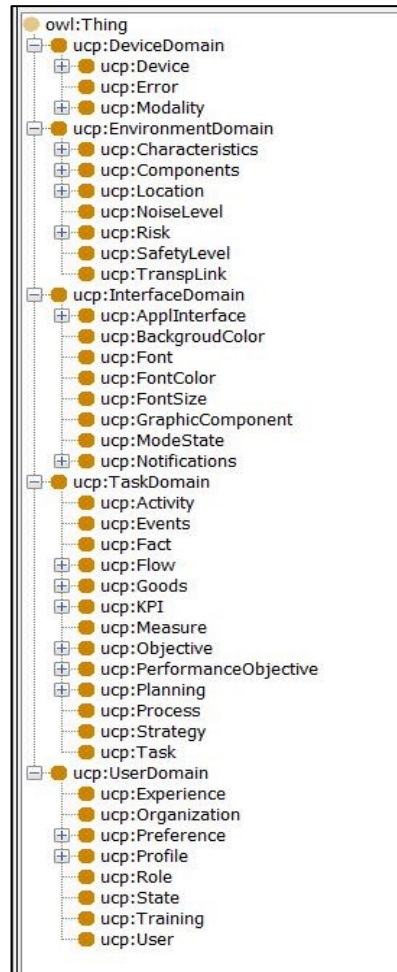


Figure 15: C2NET UCP ontology

Here the UserDomain defines the classes of the users of the HMI and can be differentiated with different characteristics like Experience, organization, Preference, Role, State etc. Basically, the idea of this domain class is to distinguish different users by their different abilities. Similarly, the interface domain represents different components and characteristics of possible interfaces. Device domain mainly, represents the device information and its modalities of I/O. This class also holds different error messages and events.

From the Figure 10, Figure 12 and Figure 13 the general idea of different properties to relate the events of different classes can be obtained. A thorough study of different ontology models of different supply network and collaborative systems that has been studied to generate the reference meta-model for C2NET [12], a detailed list of properties can be obtained. These properties include both object property and data type property. A typical view of enlisted properties in the C2NET UCP ontology is illustrated in Figure 15. These properties are also categorized in few main Object and Data Type Property.

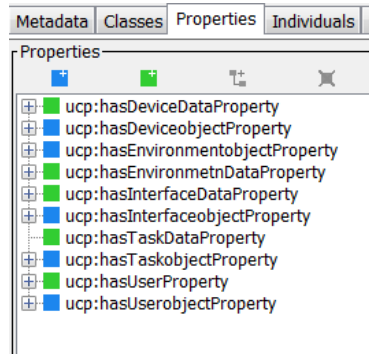


Figure 16: Main properties types

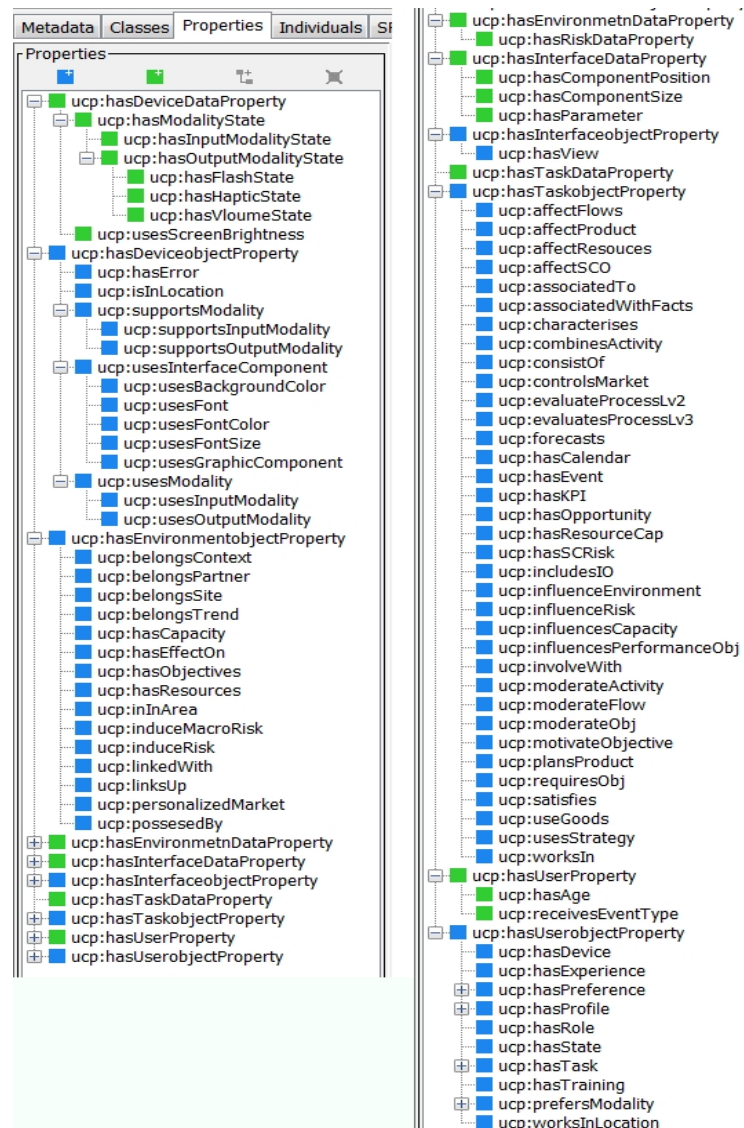


Figure 17: Detailed Property list representation of C2NET UCP

4.3 Mobile application Development:

Development of mobile tool for a collaborative supply network generally consist of two parts: development of a web application to support the server side and development of android application as client-side support. Here the server-side application act as HMI Builder and Android application acts as HMI definer. During the developments of these applications, several important technologies and tools have been used for development which are briefly presented below:

- i. REST: REST is Representational State Transfer which is basically a framework for establishing sets of constraints and properties over HTTP (Hypertext Transfer Protocol). A Web services based on REST or in other words, a RESTful Web service provides a proper communication channel and interoperability of client or Server with internet. There are six constraints of a RESTful service: Uniform Interface, Stateless, Cacheable, Client-Server, Layered-system and Code on demand. [43]

In this development, REST act as the preliminary communication framework for establishing communication between Server and Client.

- ii. WebSocket: WebSocket is a communication protocol for devices for establishing full-duplex and secure communication over a single TCP (Transmission Control Protocol) connection. WebSocket is a W3C standard. Although WebSocket runs over TCP, it is different than HTTP. The WebSocket protocol enables interaction between a browser and a web server with lower overheads, facilitating real-time data transfer from and to the server.

During the development of the thesis work, WebSocket has been used as second stage secured communication protocol for sending and receiving messages to and from the server. This is a streaming communication with low overhead. User context and situational update and HMI definer messages are transferred between server and clients.

- iii. Apache Jena: Jena is a popular framework for development of Java based semantic Web Application development. Jena is rich with a wide variety and number of reference libraries to handle RDF, RDFS, RDFa, OWL and SPARQL following W3C recommendations. Jena is also combined with an inference engine that uses SWRL rules for establishing strong relations and develop which includes a rule-based inference engine to perform reasoning based on OWL and RDFS ontologies.

- iv. JSON message: JSON stands for JavaScript Object Notation. JSON is a syntax of messaging and JSON messages are specially formatted messages where messages are sent as object.
- v. Apache Fuseki: Apache Jena Fuseki is a SPARQL server which can run in different mode: as a standalone server or as a OS or as a Java web Application. Fuseki server is good platform for holding the semantic models like ontology and execute different query sent from different services.

4.3.1 Development of Server-side application (HMI Definer):

The server-side application has been developed with Java EE following Spring framework. There are two major classes dealing with the main functionalities of communication and messaging techniques. The classes are “Login_main” and “SocketServ”. The other classes SocketHandler, JSONUtils etc. are for helping with different functionality of the major classes.

In Login_main class, there are two main functionalities: Respond to the Authentication request by checking from a database and checking the user Role from the ontology and combine result with the response of authentication request to the client. Basically, Client sends a login request for each login attempt. The is a HTTP request using RESTful web-service. The codes look as follows:

Program 1.

```
public String doLogin(@QueryParam("username") String uname, @QueryParam("password") String pwd) throws Exception {

    String response = "";
    String userrole = "";

    if (checkLogin(uname, pwd)) {
        // initiate checkRole
        userrole = Login_main.CheckRole(uname);
        response = Utility.constructJSON(userrole, true);
        System.out.println("logged on");
        System.out.println(response);
    } else {
        response = Utility.constructJSON("login", false, "Incorrect Username or Password");
    }
    return response;
}
```

Upon receiving the authentication information as header of the request in the form of QueryParams. These parameters are then stored in a local string and compared with the database of username-password sets. The codes look as follows:

When the login attempt is positive, the server checks the username inside the connected ontology and obtain the user Role from the ontology to send it back combined inside the response of the HTTP login request. The user Role is very important in customization of the interfaces based on permission of each type of user as defined according to the collaborative network meta model. The codes are as follows:

Program 2.

***public static** String CheckRole(String uname) **throws** ParserConfigurationException, SAXException, IOException {*

```
String Query = "PREFIX ucp: <http://www.ontologies.com/Ontology8588.owl#> SE-
LECT ?Role WHERE {" + "ucp:" + uname + " ucp:hasRole ?Role }";
    System.out.println("query ready");
    String Qdist = "http://localhost:3030/ds/query";
    QueryExecution qe = QueryExecutionFactory.sparqlService(Qdist,
Query);
    System.out.println("query sent");
    ResultSet results = qe.execSelect();
    System.out.println("query success");
    String w = ResultSetFormatter.asXMLString(results);

    // code for parsing XML to a single string
    DocumentBuilder builder = DocumentBuilderFactory.newIn-
stance().newDocumentBuilder();
    InputSource src = new InputSource();
    src.setCharacterStream(new StringReader(w));
    Document doc = builder.parse(src);

    String role = doc.getElementsByTagName("uri").item(0).getTextCon-
tent();
    System.out.println(role);
    return role;
}
```

Upon success response from the Server, the android client will start preparing the first interface for the user based on his/her role in the network. In the meantime, a secure and continuous communication is required for the user to continue participating and monitoring different processes of the CN. WebSocket communication has been initiated for the establishment of the secure and streaming communication. As soon as the client gets the authentication confirmation, it initiates webSocket communication request and send that

to server. Here **SocketServ** class comes into act. Upon receiving the request of establishing the socket communication between server and client, the class first accept the connection and add the client to its Hashmap by providing a unique id. The codes are as follows:

Program 3.

```
private static final Set<Session> sessions = Collections.synchronizedSet(new HashSet<Session>());

// Introducing the Hashmap for linking the sessions and username as a hashmap

private static final HashMap<String, String> nameSessionPair
= new HashMap<String, String>();
```

There are basically four methods inside the class that acts upon establishing the communications. They are: `@onOpen`, `@onClose`, `@onMessage` and `@onError`. All type of communication will be classified in any of the methods. `@onOpen` has been used only when a new client sends a connection request. During the event of joining a new client in the network, this method notifies also to all other clients through notification. This method also adds new clients into the hashmap with unique ID.

`@onMessage` method is only called when server receives any kind of message from any clients after successful initiation. Usually these messages are combined with different tags explaining the priorities and sender clients. The messages also get the id from the hash-map. Based on the type of message, they are processed accordingly. After processing the messages, the information that are needed to be stored in ontology has been stored inside the ontology through update queries. This information will be used to create adaptive patterns and produce information package for HMI interfaces of the users. Messages are sent in json format.

`@onClose` method is called when the user signs out from the network from that session. This method disconnects the secure websocket communication and removes the session id. `@onError` method trigger when there are some error situations. This method does not totally disconnect the user, but the communication goes into hold and sends a message with error name and description to the clients.

The class `JSONUtils` is basically used for formatting the messages in JSON format with different tags that are used for communication. These tags are analyzed both in server-side and client-side when new messages are received. All the message communications are occurred following the same format.

4.3.2 Development of client-side application (HMI Builder- Mobile tool):

The client-side application is developed in android platform. The android application works with support from the server-side one. The server provides information package over times and the android application works as HMI builder by creating user interfaces with the information provided by the HMI engine.

The process starts with sending the user name and password to the server after obtaining them from the Login interface. Since the project only allow network managers to add new users, the login screen is the initial page of the application. The login request has been transmitted to the server-side application using RESTful service.

The method invokeWS does the calling of RESTful webservice by using the link of the server. Inside this method, the response from the server is also received with some parameter which determines the type of the user. Basically, the role of the user in the Supply network system determines the class of user and defines set of permissions in the user interface. There are four sets of permissions based on the role of the user.

4.3.3 Patterns selection and design for mobile tools

A through study has been conducted while selection of the patterns for a Collaborative Supply Chain system. The patterns have been selected mainly for the development of C2NET UCP (user Collaborative Portal). Table 4.1 reflects the selected patterns and their properties briefly.

Table 2: Selected Patterns for C2NET UCP

Pattern Name	Behavioral Description
Context Ad-aptation [44]	This pattern generates the effects using the user-context and user-environment data by receiving the data using the input modalities and makes the interface more adaptable for the user by matching the received data.
Non-disruptive Notifica-tion [45]	This pattern mainly organizes the received notifications and moderates the appearance of these notification by identifying the priority. Based on the type of user and assigned task description to him/her, less prioritized notifications will be omitted from triggering so that users are not disrupted.
Multiple ways of In-put [44]	This pattern avails the users the more options of available input mediums.

Multimodal instruction [44], [45], [46]	This pattern applies the adaptation effects by generating instructions based on the information of user identity, user-role during the session and (3) the user assigned task that are to be accomplished during in that session. These instructions are then represented in the user interface.
Audio-visual presentation [44]	The pattern generates different audio-visual combination representations by the way of optional animation or static graphics with voice commands to understand and complete user's tasks. He demonstration of these animations are only presented to the user while user is not busy with other activities.
Multiple Alerts dissemination [21], [30]	The pattern works with different alerts and notifications and broadcasts several alerts after categorizing in different types. Notifications are only presented as the increment of number in displayed.
SpatialRepresentation [21], [30]	This pattern detects user locations via input modality and helps in generating the interfaces based on the permissions of the user role.
Warnings [44], [47]	This patterns also works with a type of alerts with moderate priorities. They are categorized as warnings in different user interfaces. Warnings are presented in such a manner that they will not hamper user activity but only notify to the user about the presence of such warning notifications.
Mode switch [21], [30]	The pattern helps in switching the interface type. The main criteria for switching is the user role, location and device size. If the device is more than 7" of size the interfaces will be switched to Full UCP mode unless the user is outside office and have the permissions.

For the development of the thesis work, only few of the selected patterns have been implemented for mobile tool only for the testing of the functionality of the mobile tool. The implemented selected patterns are described below:

a. Spatial Representation:

This pattern works with the user location obtained from the mobile device. The location of the mobile devices can be obtained by calling a built-in function of Android coding interface. For obtaining the location of the user google offers dedicated api android.location. The locations are obtained in the form of longitude and latitude. A range of 500m has been set to be considered from certain set point of user office. The user must be inside the range to obtain the full features of the application, otherwise the user will be prompted to a separate basic interface with limited access.

b. Warnings:

Warning pattern basically works with the notifications by measuring the level of importance. The level of importance is set by the HMI definer. If the level of importance is more than seven (in the scale of 1 to 10, where 1 is least important

and 10 as the most important), the message pop up over any user interface running during that time. The user can only continue working after acknowledging the warning and taking actions.

- c. Mode Switch: The pattern work with device data. With a simple Function of google for android called `getWindowManager()`, device information about the size of screen can be obtained. If the device screen is more that 6inch of diagonal length, then the user will be prompted to use the UCP instead of the mobile interface. The user can decline and remains in the mobile interface.

4.3.4 Interaction of Components

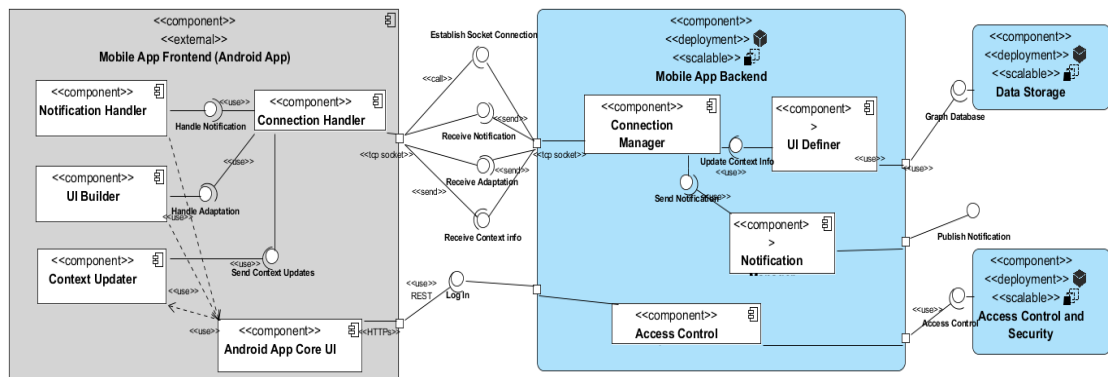


Figure 18: C2NET mobile application UML diagram [34]

Figure 18 shows a typical UML (Unified Modeling Language) diagram of the development of the mobile tools. The figure also shows the interactions among the components. As it is already explained the components of this full stack development, it is worth to mention again that the back end is developed in Java EE and front end is developed in Android. There are basically two type of communication happening throughout the process: Secure HTTP communication using RESTful service and Secure WebSocket communication between front-ends and back end. A tomcat apache server has been used for hosting the server-side application.

The interaction starts when front end sends access request with login credentials. The request comes in the form of HTTP post and after checking the access rights, server responds accordingly. If the server responds positive, then front end moves ahead to the next stage of communication by WebSocket communication initiation request. Here it is worth to mention that Websocket communication is a streaming communication and after

establishment of the websocket communication, there is no longer use of request and response over HTTP. Server always communicate with Fuseki server by HTTP get/post. Figure 19 shows a sequence diagram of interaction of components.

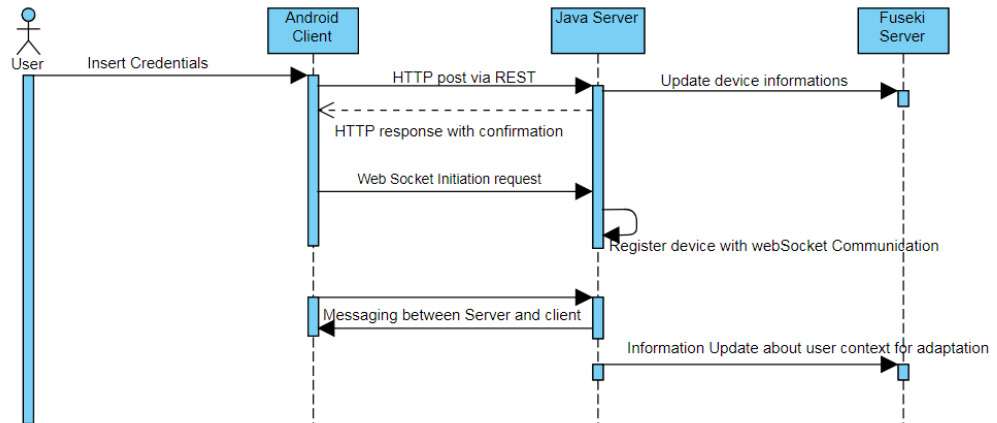


Figure 19: Sequence Diagram: interaction of Components

5. TESTING AND RESULTS

The testing of the application operation and adaptive interface has been conducted with a testing environment and considering a use case of C2NET project.

5.1 Test Environment

The testing environment has been set up in two parts. First part is for the set-up of the server-side application. The server-side application has been hosted by Apache tomcat server run by a computer. There is another reasoning server (apache Fuseki) stored in the same computer. The client application has been tested in 2 android devices and in the emulator of Android Studio IDE (Integrated Development Environment).

For testing the adaptive patterns, different situational context has been used for testing the functionalities of the patterns. Since the implemented patterns are based on location and device size, few different locations have been used for testing the Spatial Representation and two different size of devices has been used for testing the mode switch pattern. Two different devices used for testing the mobile applications are: Google nexus 5 and Samsung galaxy tab S (10.1”)

5.2 The Use Case

The design of use case is based on the case scenarios of C2NET project. The level of information in the test case has been made limited and designed exclusively for testing this thesis work.

There are two actors in this use case who belongs to two different organization but collaborating on a single supply chain process. Due to privacy issue, the name of the companies is presented as Company#A and Company#1. In the screenshots of the mobile app, the name of the companies is whitened because of same reason. Actor 1: Company Manager of Company#A has the authority of taking decisions of procurement and acquisition for his company. Actor 2: Production Manager of Company#1, is responsible for meeting the production demand based on the customer demand. Here, Company#A add a requirement for a certain part and Company#1 produce that part and supply accordingly. Figure 20 briefly explain the use case in the form of Use Case UML diagram.

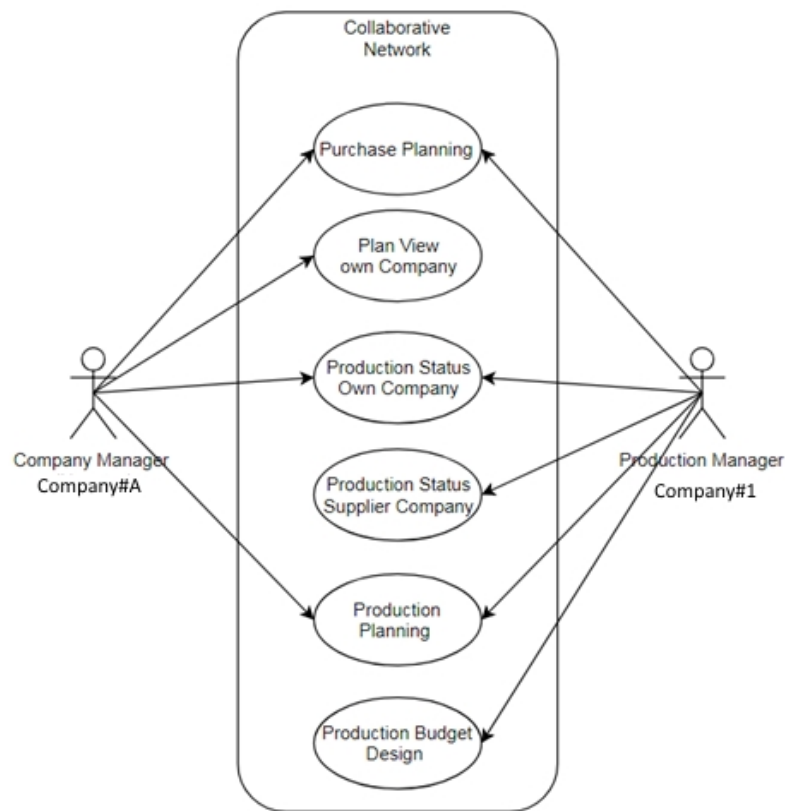


Figure 20: Typical Use Case Diagram of Collaborative Network

As mentioned before, the mobile application is exclusively developed for the monitoring purpose only. Thus, adding a new order is not possible from mobile application. C2NET UCP is the only tool for making modifications in the ordering systems. So, after the order has been placed from UCP, Company#A Company Manager will be able to see all related postings and progress related to this order. As soon as the new order is placed, Company#1 Production manager will get the notification of producing the order of its customer.

Since Company#A Company manager is a top-level user of the collaboration system, he/she will have the maximum options of monitoring in the application. Figure 21 shows a typical home screen in the android platform for Company#A Company manager.

The Company#1 Production manager is responsible for only the production of certain demand. Thus, this actor is only related to production related views. Although he/she will have to make his/her own plan of production, thus he/she will be related with such planning networks. Figure 23 illustrates a typical Home interface for a production manager.

To test the adaptive patterns, the use case has been tested in different locations. One certain location is considered as office environment (TUT Kampus arena) and others are considered as outside office. Different Devices are used for testing another adaptive pattern. Different warning messages are manually created for testing warning related adaptive pattern.

5.3 Test cases and Results

5.3.1 Test Case 1:

Both users try to log in to the mobile application from their Android mobiles. The Users are welcomed to put the credentials in the welcome page. Upon pressing the Log In button, the credentials are sent to the server using REST and Server Checks the credential first. The Authentication has been done in two levels of security. Firstly, the username and the password are checked. They are both unique and username is uniquely known to the knowledgebase. Upon confirmation of authentication in the first level, username has been checked in the knowledgebase and further information about the user has been obtained (User Role). The server sends confirmation to the mobile application about authentication success as HTTP response along with user role and information for building the home screen of the certain user.

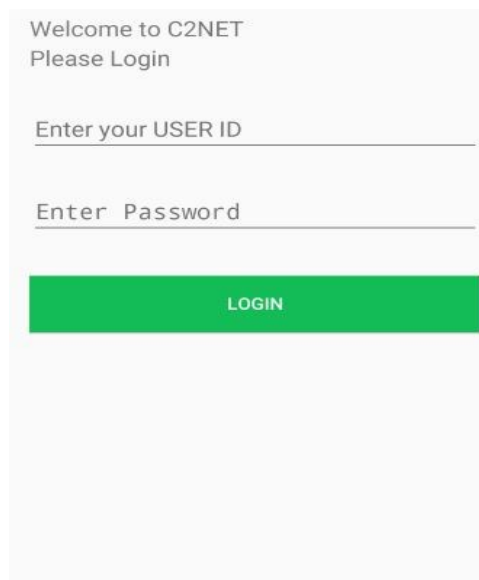


Figure 21: General Login Screen of C2NET

Figure 21 represents a generalized log in screen for C2NET mobile application users. and represent the home Screen of the two users of the system based on their role in the system. Figure 24 and Figure 25 shows the role information of the users stored in knowledgebase.

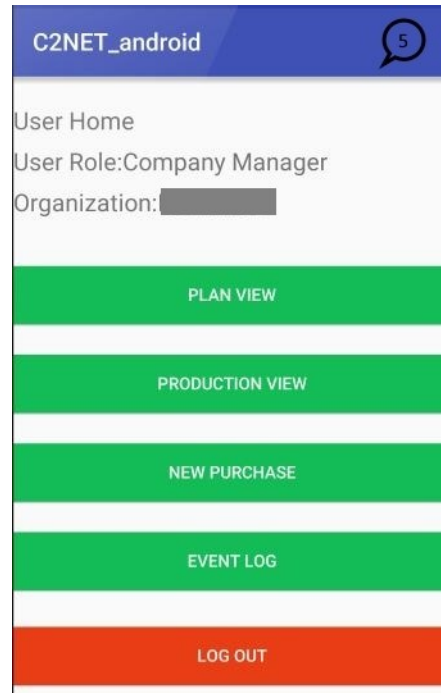


Figure 22: Company Manager (Company#A) Home Screen

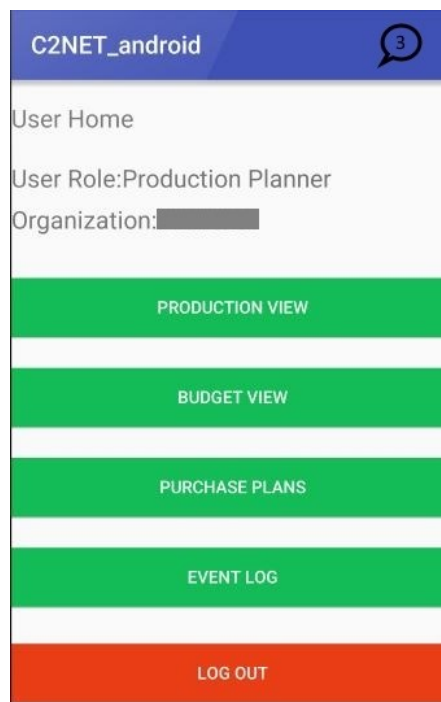


Figure 23: Production Manager (Company#1) Home Screen

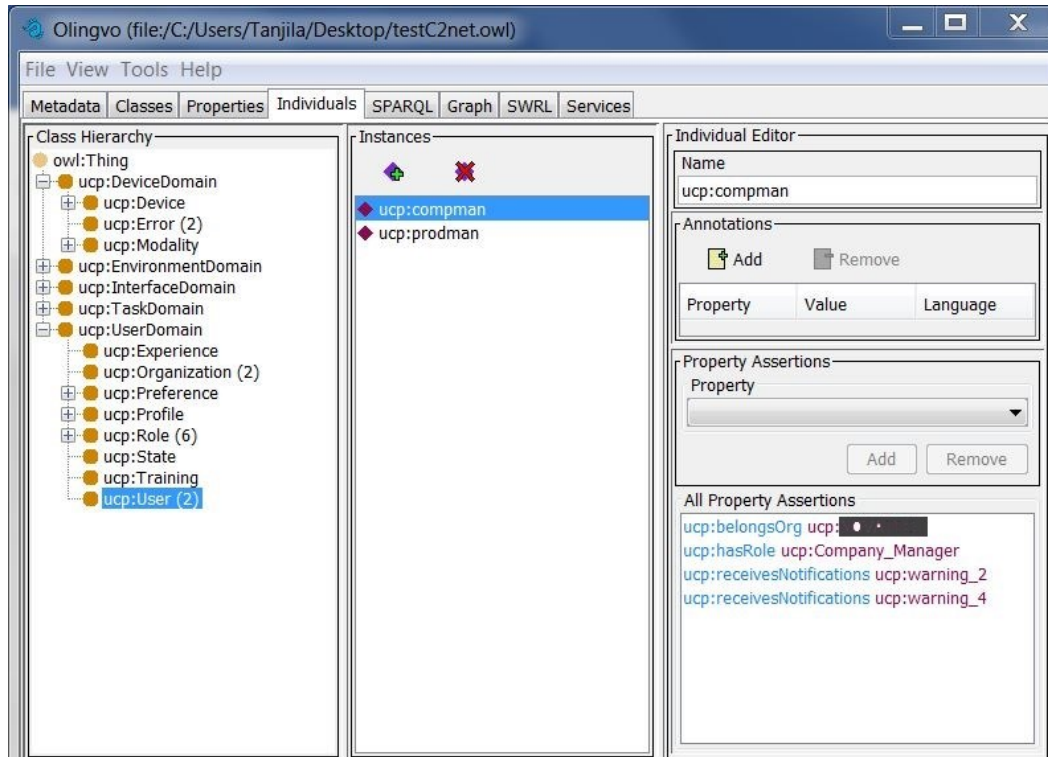


Figure 24: User Role in Ontology of Company Manager at Company#A

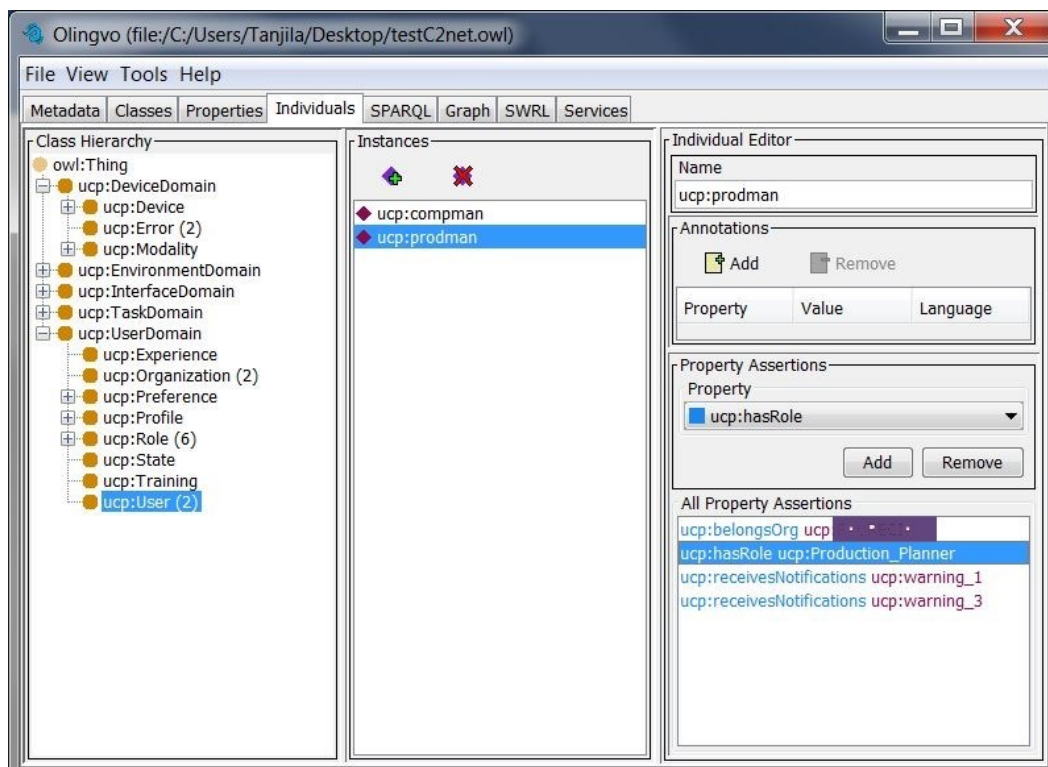


Figure 25: User Role in Ontology of Production Manager at Company#1

5.3.2 Test Case 2:

This Test Case is for testing the mobile application adaptive pattern Spatial Representation. As explained before, User Company#A Company Manager's office is considered as TUT Kampus Arena. Thus, considering the Kampus arena as the center, 500m are will be considered as the office zone. Kaleva Prisma, Tampere is considered as the home of the user. The user is supposed to obtain different home screen for each different location.

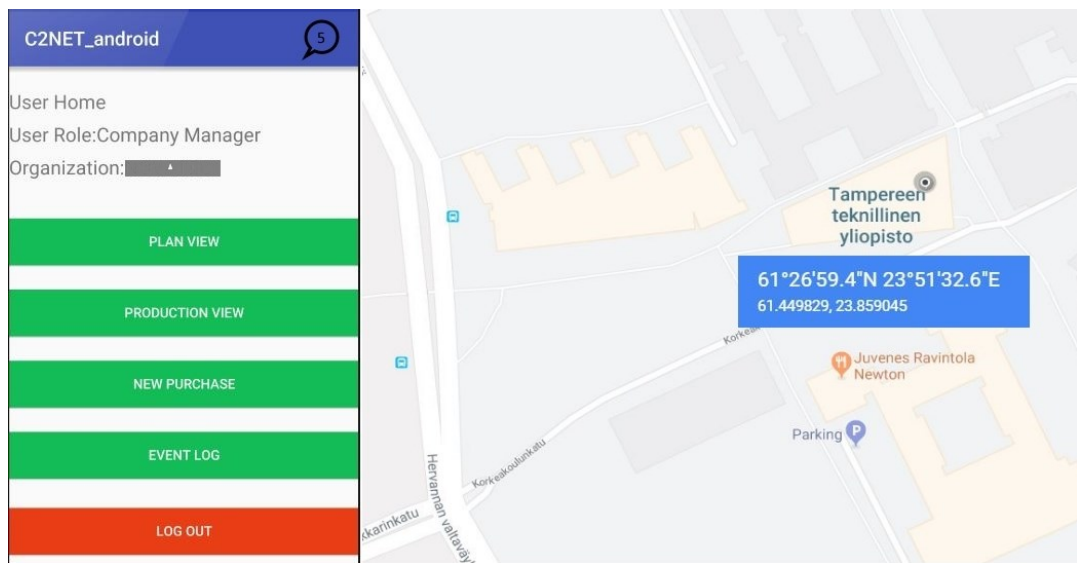


Figure 26: Company#A Company Manager Home Screen from Office Location

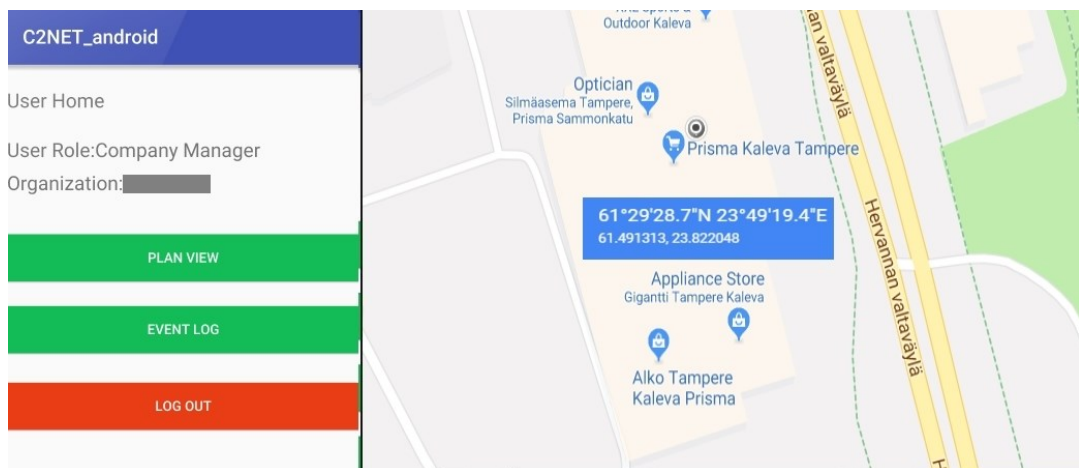


Figure 27: Company#A Company Manager Home Screen from Home Location

Figure 26 represent the home interface of Company#A Company manager at office and Figure 27 represents the home interface of the user from his/her home. Figure 28 shows the stored office data in the knowledge base. The data has been set up by the network admin.

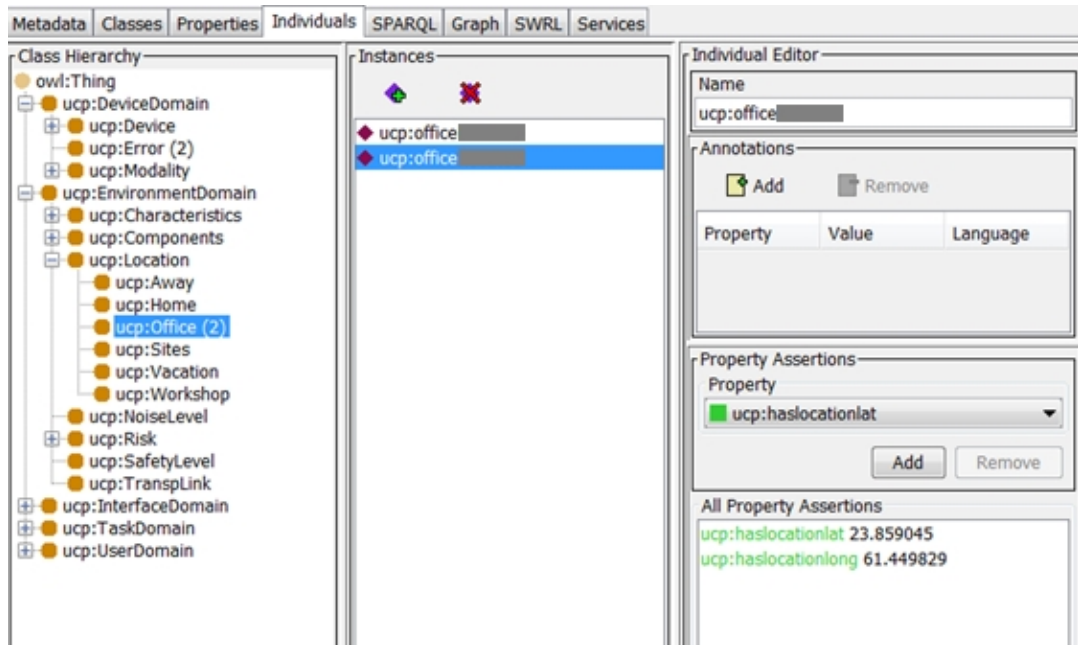


Figure 28: Knowledgebase Company#A office location

5.3.3 Test Case 3:

This test case will test the adaptive pattern Warnings. The idea has been that the user will be prompted to see the warnings which are urgent. The level of urgency is set by the warning generator. Every type of warnings is assigned with certain level of urgency.

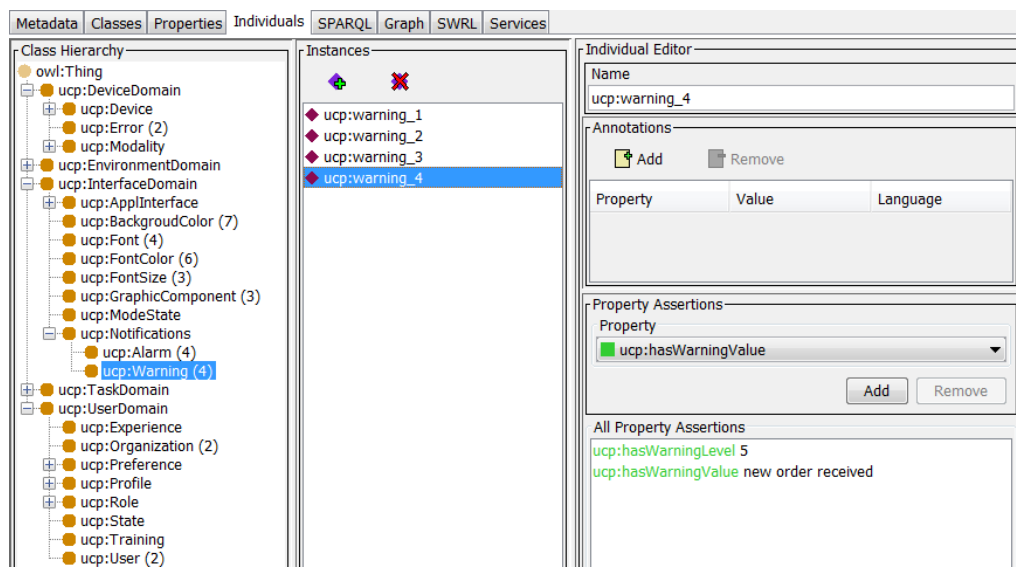


Figure 29: Warning message updated to knowledgebase with level

Figure 29 represents some warning information updated in the knowledgebase with certain level of urgency. This warning message will not have any effect on interface due to low level of urgency of that message. Figure 30 shows another warning message with urgency level 9 and thus the new urgent message invokes a new layout in the client user interface.

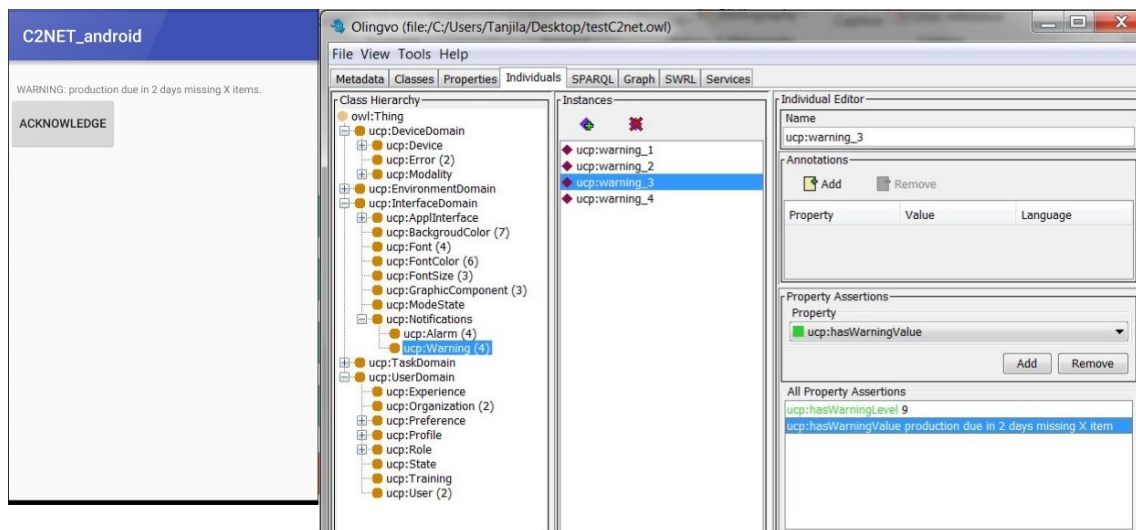


Figure 30: warning message pop up on urgent situation

5.3.4 Test Case 4:

The adaptive pattern Mode switch is described and tested in this test case. The test case is developed with two different android devices with different size of screen.

Both devices are used to log in again in office environment. The screen size is measured with an internal function while log in. Thus, Screen Greater Than 6" diagonally will put the effect of this pattern on and redirect this device to C2NET UCP interface. Figure 31 shows the case of log in attempt with bigger screen.

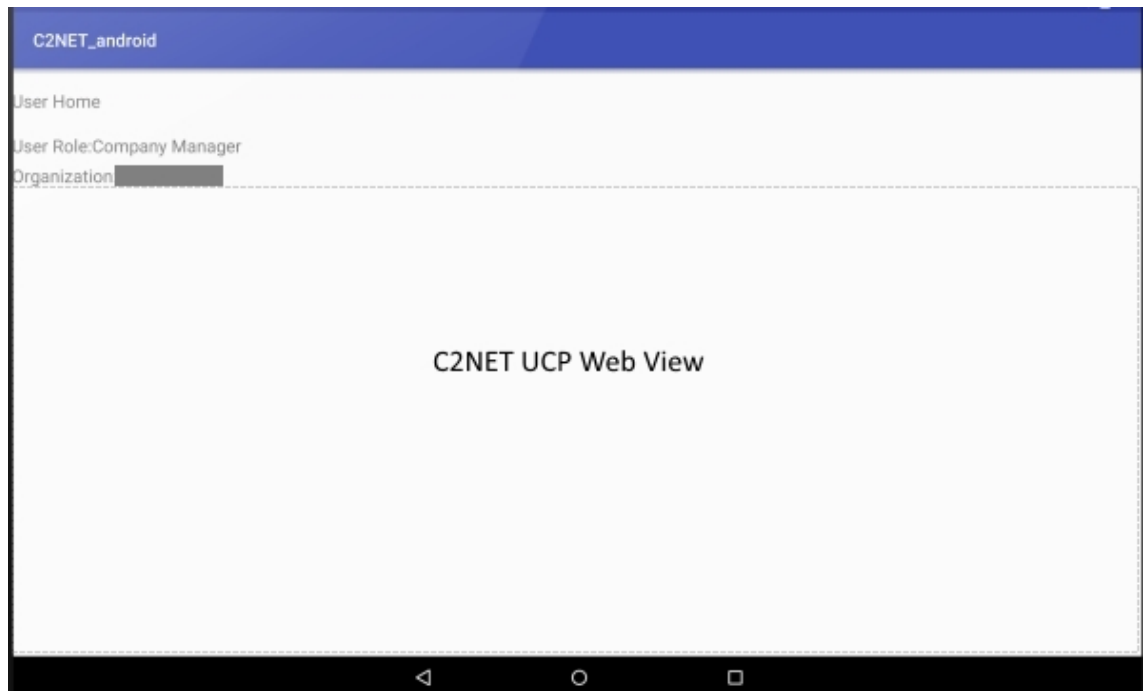


Figure 31: C2NET UCP Web-View - Pattern mode switched

6. CONCLUSION AND FUTURE WORK

The research work for the thesis has been an excellent orientation of Collaboration, Collaborative Networks, Supply Chain and full stack software development. Though one of the major objective was the reusability of a successful solution architecture concept used in different application domain, development of software for server and android client has been quite interesting and knowledgeable. Again, the use of adaptive patterns and development of ontology provided another dimension of this research work.

Development of the Ontology for a collaborative Network was very challenging, though some reference information about the structure of Collaborative Supply network has been provided. Still extraction of the information from different type of Collaboration model was quite challenging. The ontology has been developed in such a way that there are possibilities of using the ontology in other use cases of CN. A generic ontology development was also a requirement for this thesis work and that is successfully achieved.

This research work also sums up with a proposal of some concepts of adaptive patterns that can be used for collaborative systems and its associated HMI. The concepts were presented with possible application area and its adaptive effects. They were designed in such a way that they have good applicability with developed user model for collaborative Supply Networks.

The main development of Server-side application is a combination of HMI definer and User Context Updater. The client end is an android mobile tool where basic adaptive features have been implemented and suggests the possibility of another adaptive patterns application.

Though this development can be called as a standard of development of adaptive mobile interfaces for collaborative supply networks, they can at least be marked as a strong start point for such developments. This thesis work has been an attempt of presenting a demo tool for visualization of Collaborative Supply Networks Assets with some shortcomings which have possibilities of improvements.

Since the design of user model have been attempted to be generic in most possible ways, but still there can be more ideas and more inclusions of classes and relations inside different domains marked. Application of strong rules inside the ontology will create a more compact and smart tool for adaptation.

During the implementation of client application, the development has been intentionally kept simple. More features can be added including advanced security for the users. The interfaces for client can be more decorative and responsive. There is also possibility to use of other libraries and frameworks for development that has not been used in this research. The back-end in this research is developed with Java EE. Now-a-days, JavaScript is taking over Java everywhere and have JS have a quite latest and popular set of tools. Thus, development of the same back end in JS would be an excellent and interesting future work.

Throughout the thesis work, a lot of adaptive patterns have been studied and researched. Amongst them a potential list of patterns has been presented in this thesis. And only few of them have been developed and tested. Thus, there is always possibilities of development of other patterns. An interesting way could be the development of concept patterns for adaptation of collaborative supply network assets. Another possible branch of further work can be research on planning adaptation which can be very useful and helpful for collaborative networks and supply chains.

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