Augmented Reality Supported Group Communication in Mobile Ad Hoc Networks

Ji-Sun Kim, Mohamed Eltoweissy
Virginia Polytechnic Institute
and State University
{hideaway, toweissy}@vt.edu

ABSTRACT

The application domains of Augmented Reality (AR) are becoming increasingly wide to use in various aspects from the private areas like tour guidance [29] or entertainment [30] to the public areas like manufacturing [31] or medical [32] since AR can enhance a user's perception of the real world by superimposing virtual objects onto the user's view. In the domain of group communication an augmented view can assist members of the group to exchange information and accomplish tasks effectively. Moreover, when using group communication in wireless ad hoc networks, features of AR system can help interaction of mobile users by providing enhanced interface. We propose an approach to using AR system to support the group communication in wireless mobile ad hoc networks where members move around, and they appear and disappear randomly. We outline the conceptual framework to help understand the approach. Our framework consists of three subsystems of data management, AR and communication management subsystem. We describe functionality of each subsystem, and then how to implement it.

Keywords

Wireless Ad Hoc Networks, Group Communication, Augmented Reality.

1. INTRODUCTION

There are many researches in order to improve group communication in distributed networks [1], and most of them are based on fixed networks where a device does not change its location, context or network connection, once set up for the cooperative work. They are not suitable for situations where collaborative mobile ad hoc computing systems are needed while traditional fixed networks are not available or not desirable to be used. Mobile devices should be self-organized for the communication needs in these cases, and Mobile Ad hoc Network (MANET) offers this type of network. Its easiness of deployment makes MANET an attractive choice for a variety of situation, such for emergency/rescue operations, disaster relief efforts, and military networks. Many existing literature of group communication in MANET focuses on routing protocols which feature network performance, energy conservation, reliability, security, and QoS support in different situations due to characteristics of MANET [2]. By the way, there is little research to consider the user interface to raise the group communication effect in MANET.

AR is growing as an important application area, which enhances a user's perception, so that efficiently improves human performance. Unlike immersive Virtual Reality (VR), AR superimposes computer-generated objects like images, sound or text on the real scene augmenting specific aspects of the real world. Early researchers working with AR systems suggests that virtual annotations registered to the real scenes provide a substantial advantage for users to understand communicating task details, and many AR applications in various areas, such as medical, entertainment, military training, engineering design and so on, for guiding user tasks available are proposed. We will describe AR with more detail in Section 2.2.

In this paper, on the base of MANET, we describe the conceptual framework integrated with the AR technology so that it provides an effective means to build up applications for the group's communication and collaboration.

We show how the proposed framework is organized to support a battlefield scenario, and also describe how the mobile AR system is used in MANET environment with the framework. Even though this framework is built based on the specific scenario, it can be applied to the various situations that have common assumptions as follows:

1. There is a manager for the network management of the group.
2. There are group members who can communicate one-to-one or one-to-many.
3. Group members get information or objects from the real world or create data like reports by resulting from communication.
4. Each group member store new information or objects to the database self-contained.
5. Environment objects are less changed. (such as street, building or parks)
6. Group members can join or leave the group dynamically and freely.

7. There are subgroups in a single environment. For example, one disaster response team can have a few teams such as fire team, police team, transportation team and etc.

The conceptual framework using AR technology is built with three subsystems based on these assumptions.

- Data Management subsystem, using a local database and a common data model,
- AR subsystem, including AR key technologies and responsible for transformation between original data and presented data,
- Communication Management subsystem, consisting of group management and network management system.

1.1 Contribution

We explore the availabilities of group communication using mobile AR system for the battlefield scenario in MANET. Our work is characterized by the following properties:

- When we combine AR with MANET, issues generated from each subsystem are described in detail.
- The proposed framework relies on the concrete scenario description which presents utilization of AR system within a group and how the underlying network manages to support relevant operations. This allows us to figure out what functionality each subsystem has and how group communication is accomplished.
- The section 6 includes key improvements made to the scenario when we communicate with the proposed framework, which indicates the direction for advance of the framework.

In Section 2, we first describe the general characteristics of MANET, and the underlying AR system and how it enhances collaboration among users. We then summarize the related works on both MANET for group communications and mobile AR because we will not consider the MANET environment without having a group and a stationary AR system. To help understand the features of using AR systems in MANET, we introduce a simple battlefield scenario without using AR in Section 3, and then revisit the scenario after the framework is presented in Section 6. In Section 4 and 5, we address design issues and the conceptual frame respectively. Finally, Section 7 presents the conclusion and future work.

2. BACKGROUND

This work is about two emerging areas, Mobile Ad hoc Network and Augmented Reality, demanded for various situations. While two areas have many potential problems, actively relevant researches have showed their effectiveness to overcome constraints in many environments. In the following, we first give a brief overview of two areas, and then discuss related work.

2.1 Mobile Ad hoc Network (MANET)

In recent years, wireless communication has been recognized useful to construct large networks, especially which include the telephone system and the Internet. For example, the cellular telephone network shows how large numbers of mobile nodes communicate over wireless link. However, this kind of network requires fixed infrastructure – central offices, trunks, radio towers and so forth before it is used. Furthermore, the cost for changing this network to meet requirements like increasing bandwidth has known expensive and slow. Even though fixed network infrastructure exists, cannot be available, such as during disaster relief operations. Thus, existing services may not be responsible for those situations, or may be too expensive. The fact that large fixed communication infrastructure is used for specific temporal situations such as military operations or emergent places seems to be undesirable and restricted in its usefulness. To establish survivable, efficient and dynamic communication during the temporal period, there will be a need for the rapid deployment of independent mobile users.

An ad hoc network as a wireless networking paradigm for self-organizing networks, is of interest these days because little effort is needed to deploy them and any prior investment for fixed infrastructure is not required; there are two major types, a mobile ad hoc network and a smart sensor network. The latter will not be considered in this paper. Since wireless links impact on the communication, the nodes have to suffer the effects of radio communication, such as noise, fading, and interference and the network topology may change rapidly and dynamically over time. A mobile ad hoc network is a collection of autonomous nodes or terminals that communicate with each other by connectivity in a decentralized manner. The network is partitioned, where all network activity like path discovery or message delivery must be achieved by each node itself, i.e., all mobile nodes attending the communication must implement routing functionality. Since this fact is not well-defined problem, the design of the network protocols is a big issue, and the network should be able to adapt the alternative routing paths with multi-hop to mitigate any of effects over wireless links. General packet forwarding, although, works well in the case of small network, as and when the network size increases the network may need different routing schemes such as hierarchical ones instead of flat routing protocols. Sometimes, the network may need to support multimedia traffic such as voice, video and data. Moreover, in a military network, secure communication, timeliness, reliability, limited power, automatic repair from failure are significant concerns.

Another problem with Mobile Ad hoc Networks is to deal with the node density due to dynamic movement of the nodes. If nodes become close to each other, bandwidth shared for the communication will decrease and workload on each node will increase because the number of packets to forward increases and network updates will be frequently done.

We can sum up the characteristics of MANET as follows:

- Mobile nodes can join and leave the network any time so that communication connectivity is fairly weak.
- Mobile nodes have a limited amount of energy because they run on mobile devices with battery packs.
- Mobile nodes operate with restricted bandwidth.
- Each mobile host acts as a router, forwarding packets from one mobile to another.
- MANET is often vulnerable to security attacks due to its features of open medium, dynamic changing topology, lack of centralized monitoring and management point.

2.2 Augmented Reality(AR)

Immersive VR allows the user to experience a completely synthetic virtual environment, but the environments created is still much simpler than the real world since it is difficult to realize the real world in a computer as it stands. Moreover, the more realistic environment, the higher cost is required to create the virtual environment. The application domain of VR is limited to entertainment or simulation because the space of VR is still in an artificial world. Unlike VR, AR enables the user to interact with virtual objects in a real environment in real time, and the user can feel more enhanced reality by superimposing the computer generated information such as visual graphics, sounds, smell or tactical sensations onto the real world. Therefore, the scope of applications using AR is widening from stationary to mobile, from standalone to collaborative and from personal to service environments.

A typical AR system contains common components with different technologies combined into a single system, which are display technologies to enable the combination of real and virtual objects into a single view, tracking the position and motions of the user, allowing real-time interaction and registration and implementing 3D Modeling and Calibration. The AR system with these display technologies is expected to enable the user interact with virtual objects seamlessly in a real world. For this goal, several key issues like update rate in real time and the accurate registration of the virtual object with the real scene should be considered. We describe these issues in Section 3 in detail.

A mobile AR is a combination of two promising fields, augmented reality and mobile computing. For example, using an HMD and backpack including devices such as laptop, GPS (Global Positioning System) and battery pack, the mobile AR system overlays 3D graphics over a real environment in real time, and changes those synthetic images to accommodate the movement of the head or eyes towards target so that the system always displays the proper view on the HMD while the user is moving physically. In this paper, we take into account both issues of mobile computing and AR.

2.3 Related Work

This paper highlights the combination of three areas:

- Computer Supported Collaborative Work (CSCW), allowing people to work together using computer technology. For the current work, we only concentrate on computer supported communication.
- Wireless Mobile Ad hoc Networks, providing mobility and flexibility for users to access and manipulate information and communicate altogether.
- Augmented Reality, enhancing users' perception by inserting virtual objects into real environment and providing users with the efficient interface to work on them.

Thanks to the recent progress in wireless networking technology, mobile collaborative systems are rapidly growing and impacting the large group communication.

It is expected by many researches that AR is an excellent user interface for mobile computing applications because the location information is displayed using AR technologies, and naturally browsed on the user's view. Nevertheless, a few existing systems combine AR and collaborative work. There is much less research with such combination in mobile ad hoc network environments where the fixed network is not available or undesirable.

In this section, we present some existing projects related to combined areas as described above, which have given idea and inspiration for various aspects of the framework that we suggest later in this paper.

2.3.1 Mobile Collaborative Augmented Reality

The combination of mobile computing and AR system over wireless links is very attractive in that interaction and communication enhanced using AR in the real world are available without any fixed infrastructure. Currently, the problem of this approach is that both mobile computing and AR realization have relatively many constraints [Section 5. Design Issues], limiting their combination to military or well-founded academic projects. We introduce the current mobile AR projects (or systems) in wireless networks. While these researches have different purposes, context and polices according to the application domain deployed, it is common that they have realized mobile AR system with client/server or Internet infrastructure in either wireless network or wired network. FLARE [3] and BARS [5][6] projects are very similar to our approach, except that ad-hoc specific group and network management are excluded in these projects.

- FLARE (Framework for Location-aware Augmented Reality Environments) [3] described a framework for building mobile AR applications in wireless ad hoc networks. FLARE focuses on a location service which can use a wide many sensors and collect data from various sensors by using tracking technologies. It also provides a group communication service handling network failures and partitions in wireless networks based on the application specific rule. Quazoom[4] is the first application using FLARE, which is a Doom-like game. While players move around in the real world and see a Doom-like game on their screen view, they shoot bots and pick up things like ammunition or medikits as in a normal Doom game. FLARE manages peer-to-peer communication in such a game environment and provides relevant algorithms based on the rule. FLARE seems to be a match for our approach, but dependent on a Doom-like game. FLARE is ongoing project and will support multiple group applications. It is a good reference model to develop our conceptual framework.
- The BARS (Battlefield Augmented Reality System) [5] [6] is developed to overcome difficulties which the battlefield is expected to face in the future. For example, when military operations in urban environment are performed by dismounted soldiers, situational awareness is required for their successful performance. However, this information represented to maps cannot be displayed with the 3D nature of the terrain. Like most mobile AR systems, BARS also use a wearable computer, a wireless network interface and HMD for hands-free, and soldiers with this equipment can exchange or deliver their situations or additional information. BARS focuses on User Interface, Capability for collaboration and Hardware, but network management issue. It could be a good concrete model for which our framework heads.
- Archeoguide [7] is system architecture for mobile outdoor augmented reality, and provides client/server architecture and multi-modal interaction. Its system environment consists of a site information server and mobile users like visitors. A wireless local network is also allowed the mobile user to communicate with the site information server. This project focuses on using multi-modal interfaces such as gesture and speech as well as 3D visualization, and using both a database of all information related to the site and a local database that stores only some parts of the site information related to a particular area for a particular user and visit profile. While the user moves around in the site, the mobile units worn by the user communicate with the database server to download information relevant to the new area of the site the user visits. Unlike our purpose, while this system does not provide communication between mobile users, but a mobile user and a stationary information server, it allows multi-modal user interfaces.
- DWARF (Distributed Wearable Augmented Reality Framework)[8] is a CORBA based framework that allows the rapid prototyping of distributed Augmented Reality applications. It is designed as a collection of software components that can be implemented on separate hardware connected by wired or wireless networks. Its first objective is to ensure the communication between components and to keep these components pluggable to the framework. The second is independent on hardware platforms, and the third is to arrange components that do not know each other, so that it allows them to be developed independently. DWARF allows communication with various modes such as event-based communication and remote procedure calls via interoperable interface (i.e. CORBA). DWARF could be a good starting point when we intend to develop application software using our framework.
- Augmented Stroll [9] is an example method to restore the picture in the context of the real environment and used in the MAGIC (Mobile Augmented Group Interaction in Context) project. By using this method, the user can interact with virtual objects in the real environment through *gateway window*, which is between the real and the virtual display, introduced in [9]. Besides, in [9], relevant terms are defined, i.e. *Augmented Reality and mobility*, *Augmented Reality and groupware* and *mobility and groupware in Augmented Reality*. These definitions are helpful when we first step up to mobile AR for group communication.

2.3.2 Mobile Ad hoc Networks for Group Communication

There are already several mobile AR systems as described in the before section, but less research address ad hoc network issues for communication using AR systems at the group level as well as the entity level. Our goal is to carefully consider MANET environment for the group communication. The following three works show how the group is managed in ad hoc networks environment.

- Proximity Groups and Group membership management [10] use location awareness to form a group and keep a group membership. Since the location of participants impacts on transferring messages in wireless communications, location awareness should be maintained by group communication system. In addition, their knowledge of the location information can improve the performance of the group communication itself. In [10], two reasons are presented. That is, we need group membership management in two aspects, functional and non-functional. The functional reason is for traffic management which defines a group corresponding to the situation around traffic-light or traffic-heavy area. The non-functional reason is to anticipate a group partition, and to ensure consistent group views when partitions happen. The approach is to use proactive routing protocol for location distribution to mobile members, but the transmission range is limited by the designated threshold (e.g. *n*-hop is a maximum number to transmit the message to manage group membership.). The coverage of an area is determined by the coverage estimation algorithm. In [10], general operations for group management such as creating a group or processing the node's request are not considered. Those issues are discussed in the following research.

- Group Integrity Management [11] proposes an ad hoc community group management scheme supporting policies for group integrity. This scheme allows for a hierarchy of groups and subgroups to be managed according to policies specified at runtime, using a tailored policy notation. These policies are adequate to the application context. Group Integrity Management presents the framework consisting of Integrity Specification and Group Management Architecture, including that the framework allows for basic group management operations such as join, leave or merging. This is applied to its relevant project, *multimedia multicast group integrity model*.
- ANMP (Ad hoc Network Management Protocol) [33] is built upon SNMP. Its architecture is based on hierarchical clustering of nodes into agents, cluster heads and managers. ANMP extends the MIB (Management Information Base)'s used in SNMP, which allows compatibility with other underlying networks when ad hoc networking system is connected to Internet infrastructure. ANMP also extensively supports secure multicast and the military security model as well as the unicast security of SNMPv3. we will adapt this protocol for the network management subsystem of the framework.

3. APPLICATION SCENARIO

We choose the battlefield in the urban as a scenario to explain the practical use of AR systems in mobile ad hoc networks because the battlefield is a typical domain for ad hoc networks and the dismounted soldiers are good examples to show how to utilize mobile AR systems. In this section, we provide simple military operations concentrating on the wireless mobile communication without using AR systems, and then in Section 6, we revisit the same scenario with the using AR systems.

Battlefield

The battlefield has a large numbers of mobile nodes (i.e. dismounted soldiers) deployed over an urban terrain. The same level radio frequency and channel resources are shared within the terrain. Establishing wired networks for military operations is not desirable or unavailable because the network configuration is dynamically changed according to the mission. Besides, the soldiers are continuously moving, thus the network topology for their communication is dynamically changing due to movement of soldiers. In our battlefield, the hierarchical structure is not considered. That is, there are only ground forces, not airborne. Different units may have different communication devices and capacities. For example, the wireless radios installed in military vehicles have a more ample energy supply and thus are more powerful than those carried by the dismounted soldiers. Generally, the battlefield is ruled by uncertainty and timely information for a moving soldier can be directly connected to his/her life or death. We have several assumptions and define military mission to make our scenario more specific, and then describe their operations based on the mission.

Assumptions [12]

Military forces have a well-organized command system. The soldiers are physically located according to the system.

- Military deployments are mission based which can lead to a certain amount of predictability in a unit's movement.
- Military deployments are bounded in that they operate in a fixed area for a predefined period of time. But, dismounted soldiers with the exception of various situations can move randomly.

Operations based on Mission, "Finding enemies and their weapons"

- Each deployed soldier has to identify his associates, and then set up checkpoints and observation posts throughout the city.
- The soldier conducts interviews with local citizens and arrested enemies to obtain additional information.
- When the soldier finds the weapon, he should transfer to other members its detailed information as well as its location.
- When the soldier finds a suspect, he has to keep surveiling the suspected person. He also sends observations of suspicious activity to the commander.
- The team's actions are coordinated in response to a dynamically changing situation.
- The commander has to take care to monitor the status of deployed soldiers. This status could only be periodically checked over wireless links.

Underlying problems and expectation

- The network connectivity among team members should be maintained by each mobile member, even if they are moving rapidly or are spread out across a wide area.

- Transmitting information from the soldier to other deployed members via radio would cause heavy traffic at the shared radio channel.
- The bigger terrain, it is more problematic to continuously monitor an overview of deployed units and soldiers, and command them synchronously.
- The display device should be hands-free since it is very difficult for soldiers to use handheld devices, and the implementation minimizes cognitive workload and training.
- It is difficult to distinguish where each soldier is deployed in the terrain at once look, and for the commander to monitor all status including soldiers' dangerous situations or movement of enemies or soldiers.
- It is difficult to transfer the detailed information about objects obtained during the operation.
- It is difficult to keep track of moving objects friendly or not.

We will revisit to the same scenario in Section 6, and describe how to mitigate problems as addressed above when we use AR system.

4. THE CONCEPTUAL FRAMEWORK

The term "The Conceptual Framework" is used because this framework is proposed based on only existing researches and ongoing projects without any relevant experiment or evaluation. We suggest the conceptual framework consisting of data management, AR and communication management subsystem, and discuss characteristics required of each component in the rest of this section.

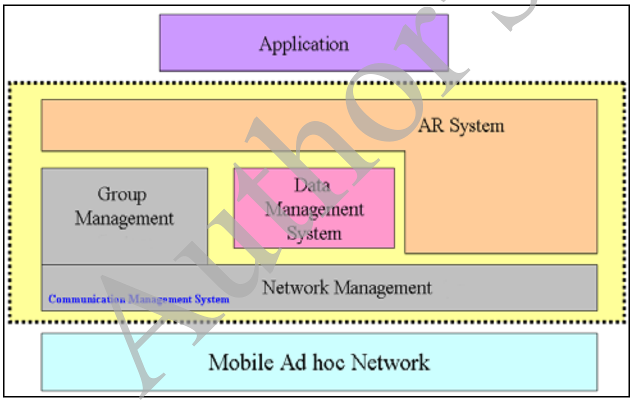

Figure 1: The framework outline. The components inside the dotted rectangle show subsystems of the framework. Group management and network management are handled within the communication subsystem.

4.1 Data Management subsystem

An application for the scenario described in Section 3 requires three kinds of data, critical mission information such as inventories and tactical information, a detailed model data of the user's environment which concentrates on visual fidelity and new data such as virtual objects annotated to the real scene, reports from each soldier or position data of mobile nodes created by performing military operations. The first two of data kinds (i.e. mission based data and environment data) are already installed in each member's system and may be extracted and transformed to be useful for the AR applications.
In AR, geometrical data of real objects are used for computation of occlusion, rendering of shadows, and tracking. In a distributed environment, all members of a group need to share the same environmental and their mission specific data. Applications supporting this network environment should be based on a common database to which allows to access for modification and updates. Since MANET does not have any fixed infrastructure like a central database server, all mobile nodes should have self-contained database. Characteristics of the distribution of information and events are as follows:

- Maintaining Database: Users have the ability to create reports and update entities in the database.
- Simplicity: The objective is to deliver information, not a consistent virtual world. That is, all consistent data are installed in all mobile nodes before they perform their operations in the real field.
- Compatibility: Data distribution between users can be heterogeneous. Commander, dismounted soldiers and the ground vehicle can carry different devices, but the implementation of data exchanged should be compatible.
- Various contexts: In addition to environmental data, data distribution management system must support the propagation of meta-data such as task assignments, objectives and messages.
- Replication: Unreliable network connectivity should be considered and shared data is consistently kept in whole or in part.

For data management, we have still potential problems dependent on MANET such as limitation of the environment (i.e. wireless link, limited bandwidth and battery powered) and transmission range. For example, we have to consider query processing time and data integrity regarding either full replication or partial replication when network is partitioned. For another problem, when broadcasting, listening nodes are consumed nearly half as much power as by the broadcaster. For one way to mitigate this problem the broadcaster can only send index instead of the whole data, so power consumption can be decreased. Too frequent broadcasting data use power unnecessarily, while less frequent broadcasting leads to increased client requests [19]. Besides, if several nodes attempt to broadcast simultaneously, there will be a collision and the broadcast of all will be discarded. Data management component to control these issues should work with network management component.

4.2 Augmented Reality subsystem

When we develop typical software applications, using MVC pattern is a great choice because this pattern separates interactive systems into subsystems for data model, control logic and user's view. In [20], it is showed that MVC pattern can be extended to AR systems such as application (Model), interaction (control), presentation (view), tracking, world model and context. This pattern stored on a subsystem level is made from an analysis of existing systems [20]. That is, AR pattern is generated from common several techniques and building blocks extracted from existing systems to implement the subsystems. We use this pattern for AR subsystem design as a part of the framework. In this section, we have only considered the layer of subsystems with using this pattern, but it would be needed to establish building blocks more detailed.
As the figure 2 shows, AR system has many complex factors to deal with various data and display virtual objects to the output device. In [21], the reference architecture model for AR is presented at an abstract level, meaning that this model does not give us any solution, instead a kind of means to help understand AR system at a higher level.

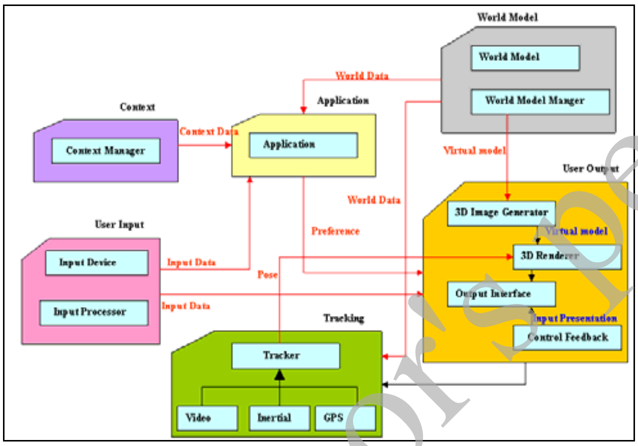

Figure 2: AR subsystem decomposition presented in [21]

4.3 Communication Management

In this section, we address roles and relevant existing protocols for managing mobile wireless ad hoc networks. We have divided communication management into group management for group membership and network management for physical networking.

4.3.1 Group management

It is difficult to maintain the group communication in MANET environments due to its characteristics such as unreliable links (i.e. multihop), nodes mobility and limited computation power of nodes. Military MANET [12] has a different mobility pattern from pure MANET [12]. According to characteristics of movements in a battlefield, we should not only consider entity mobility patterns, but also group mobility patterns [27]. However, we put this consideration work to the future work.

The group communication can be performed one-to-one or one-to-many, but most communication style might be one-to-many. In this case, accessing the data stream multicast by the source node should be allowed to only nodes authorized. Especially, in the battlefield the secure multicast protocol is a big issue. We are not going to consider how to authorize the user as a group member in this work because the issue is over the subject of this paper. Instead, we present the operations of the group management and the group manager, and then introduce relevant existing researches to apply to our framework part.

Operations Required

All groups and their subgroups are administered by a manager, who can create and maintain groups. Two kinds of manager are chosen, a primary manager and a backup manager just in case the original manager leaves the group by accident or on purpose[23][24]. Since all users dynamically come and go, the node with manager functions might also disappear unexpectedly. Provision (e.g. election of backup manager) must be made to survive the loss of the current manager. A group manager is not a commander or director in the real world, but mobile device with manager functions. The group manager is responsible of location updates for the group, and the distance between the group manager and the other members of the group should not exceed a designated threshold. Whenever users request to join the group or subgroups, group manager should evaluate users' requests, then accept or reject them. Group manager also establishes group membership and maintain a member fluctuation. That is, group membership should be known at all times, even in unreliable or unsteady communication environments. Non-members should not be able to participate in group communication. For this purpose, the group manager continuously expresses special conditions [26]. Besides, the group manager consumes more energy than other terminals because it has to perform the operations to manage the group. As mentioned above, backup managers carry the duty to step in as manager when necessary. These group management operations automatically is accomplished to support states and state transitions, i.e. changes in membership set, member roles, rights and duties, and topology.

4.3.2 Network Management

By definition, "network management is a process of controlling a complex data network so as to maximize its efficiency and productivity" [27]. This includes data collection, data processing, data analysis, and problem fixing on the network. Network management functionally consist of five areas defined by the International Standards Organization (ISO) [27]: fault management, configuration management, security management, performance management, and accounting management. Ad hoc network management is a significantly different from managing wired networks with ad hoc network characteristics and a diverse set of applications demanding different security requirements or different routing protocols. In [25], ad hoc network specific management is suggested, called ANMP (ad hoc network management protocol). It has flexibility, and can dynamically adapt different routing protocols and security mechanism based on simple network management protocol version 3(SNMP3). We present the operations required of network management for MANET.

Operations Required

A network management protocol recognizes awareness of the presence of node and message. Hence, nodes' connections including different modes like discoverable or non-discoverable are always maintained. One objective of network management keeps the network overhead to a minimum, i.e. reduces the number of packets transmitted/ received/ processed at each node. The partitioned networks are reconfigured without too much of an overhead when the network becomes divided due to energy constraints or mobility. A network management protocol also provides the route maintenance and recovery. Multiple route detection protocols can be adapted in order to reduce the frequency of route discovery, and for reliable communication.

5. DESIGN ISSUE

As described in Section 2.2, a typical AR system is a system blended with different technologies. For the practical implementation of communication in the battlefield with using AR system, we need to consider hardware and software issues, and then take into account augmented reality techniques relying on several network issues.

5.1 Hardware

Although current mobile computers are useful in many respects, their processing capabilities fall far short of what is required to properly realize augmented reality. The hardware used must be small size, light weight, and easily portable. Especially, in the battlefield scenario, dismounted soldiers might have weapons so that heavy and bulky systems are not desirable to be carried around. It might also be fast and have the ability to display detailed high resolution graphics. Battery power is one of major concerns. Batteries on present devices such as laptops are only maintained for a few hours. The most important hardware issue is that the system must have accurate and timely tracking capabilities of the user's position and orientation. Without this capability, many of the most applications such as the ability to display 3D graphics in real scene or browse location based information become useless.

Computer weapon systems worn by the soldier are required to meet the tactical battlefield characteristics. They must be self-contained since efficiency without outside help is maximized. In the rest of this section, we will not mention the exact specification for computer hardware; instead describe available device types and their requirements.

Figure 3: self-contained soldier

User-Input Devices

Since all mobile users move freely carrying their weapons, typical input devices such as mice or keyboards may not desirable. Input devices should provide users with full freedom of movements so that they are used to select, move and modify virtual objects. For example, wrist-worn keyboard, Chording pads, Voice Recognition or tiny handheld devices can be used as a user input device.

Figure 4: The interaction. The gloves are equipped with 3 markers to be able to track the hands in a wide range of orientations. [13]

Figure 5: Wrist-worn keyboard

Display Devices

Since Head Mounted Display (HMD) has been widely used in virtual reality systems, AR researchers also have been working with HMD. This display system is called "see-through", which allows the user to see the real world view as well as computer generated objects. Moreover, an advantage of this device is that the image generated by the camera is to provide tracking information to the system. When we use HMD, there are some performance issues, one of which is that there is a forced delay of up to one frame time to perform the video merging operation with a video camera to view the real world. However, compensation for this delay could be made possibly since everything that the user sees is under the system control. Headset incorporates two small CRT or LCD for visualization and includes a head tracker. It places a small video in front of each eye, and gives a good sense of immersion. Besides, handheld worn to the belt can be used.

Figure 6: Handheld display worn by belt (http://www.handsfreemobile.com/ebelt.com)

Figure 7: HMD

Tracking Devices

Tracking is defined as the measurement of object position and orientation in a scene coordination system. Tracking information of moving objects in real-time is the important part of mobile AR system, but every tracking technology has its drawbacks. For example of possible problems, tracker outputs don't match, area may not be covered by trackers or there can be varying accuracy. Since no tracking technology is perfect, the combination of many trackers can be used to help provide more precise tracking information. For example, the combination of camera and inertial tracker for compensation of drift, GPS and inertial tracker for orientation from inertial, GPS and optical tracker for orientation value from optical sensor, and GPS and any indoor tracker for extended operation range exist.

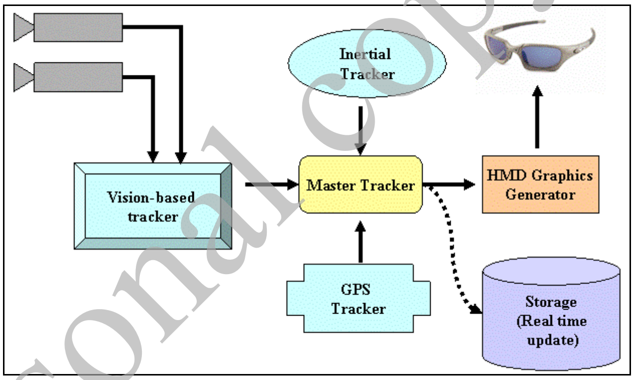

Figure 8: This diagram shows that master tracker computes more precise tracking information gathered from various trackers, and then the result information by Graphics generator is viewed on HMD.

Battery Power

Each soldier has battery-powered packs since using outside power energy is not available. These packs can be attached to the shoes or the belt.

Figure 9: Battery packs worn to shoes

Sound and GPS Devices

Directional Head Mounted Microphone and Earphone are used to communicate among soldiers or annotate sound information to the real scene. Moreover, GPS receivers can report position data over its RS-232 link once per second, and this position data is automatically broadcasted to other soldiers using radio frequency.

Figure 10: Head mounted microphone and earphone

The user's shape carrying these all devices as described above is becoming slimmer and smarter as two pictures below. For example, the typical shape is a backpack mounted system, but the newer shape can have the whole system carried in the vest. The pictures below show the comparison.

Figure 11(a): Old type [14]

Figure 11(b): New type [14]

Besides of size and weight of the system, its performance and accurate information will be efficiently advanced.

5.2 Software

The software is generally responsible for collecting data from all these sensors, processing data and generating images based on display devices. There are several basic tasks which AR system must commonly accomplish. That is, the system obtain the information or graphic data to augment the user's perceptions, and then filter these data in such a way that only relevant information is remained while useless or irrelevant data is discarded. At last, useful information will be displayed to the user conveniently and the user can easily interact with it. However, the implementation of interaction of virtual objects and an active real environment does demand extensive software challenges besides basic tasks.

There are some of the emerging issues related to software challenges. In [15], four issues are presented for wearable computers. These issues are also found in mobile AR computing since these are not unique to wearable computing. We address here two issues from them for our software issues.

"*Adaptability*" [15] Mobile computing operates in a highly dynamic situation. Services offered to the mobile system may rapidly adapt to those dynamic environments. Those mobile computers can not be considered to have servers' capabilities or strong network connectivity. As relevant environments change, appropriate adaptability is demanded in all distributed software layers. Moreover, the user should recognize those system services at all time.

"*Extensible and Configurable Systems*" [15] Mobile computers has the ability to configure the attributes in all software component and application structure. This is accomplished both on the operating system and application level. For the battlefield, wearable computers using add-ons devices need to be reconfigured at run time. This allows for attaching and detaching the devices on the fly without affecting computer operations.

5.3 Augmented Reality issues

AR technology can overlay computer mediated information on top of that reality through a wearable computer, a see-through and head mounted display as described in section 5.1. With all of those devices we can see multimedia presentations within the real world. For example, when we look at a building, we can overlay some information onto what we are seeing. It could be a piece of text. It may say something about that building, maybe something from the past or something current. We can show video about something that might have happened there in the past. We have sound that would allow them to hear something that had happened before. However, for performing these all functions, there are still some technical issues we have to resolve. We present key issues of AR in this section.

Performance AR system has proper update rate for generating the augmenting image without any visible jumps. Although this works well within the current graphics systems to moderate graphics scenes, in mobile systems update rate greatly impact on the power consumption. [28] Moreover, we need to scale the image resolution to transfer the image over wireless links.

Display Presenting the combination of virtual objects and real world within a single view is a complex challenge for AR system designers. For this realization, we need information filtering technique for context part as well as technical parts (i.e. using HMD). For example, advances in communication system, computer systems and sensors have dramatically increased the data available to the military operations. If the burden of integrating the information from disparate sources is not filtered, the commander or soldiers may miss the important target behind less useful information. We already put the technical parts to the section 5.1. “Display devices”

Tracking It reports the locations and orientations of the user and the target objects in the environment. This technique should continuously match with the real world and the computer generated objects. We already described this technique in the section 2.1 “Tracking devices”

Registration This is that virtual and real worlds must be properly aligned. If the registration is not accurate, the AR system compromises illusion that the two coexist. Thus, failures for the registration are caused by two possibilities. One is raised by system noise, and another is made by time delays. Visual system is very sensitive to visual errors, so the system design should expect these errors and response with the proper operations.

5.4 Network issues

One of the most critical requirements for future military network is to reduce the network configuration works at a battlefield so that rapid deployment of forces or mission changes can be made quickly and flexibly. This fact forces the battlefield network to be ad hoc to the extent possible. Thus, mobile ad hoc networking (MANET) research has received a considerable attention in recent years, but we have to consider ad hoc network constraints. In this section, we discuss several ad hoc network issues for the group communication, but not pure ad hoc network environment which each node moves around without any target.

Membership management

In the battlefield each force requires reliability and timeliness of the group communication. Group communication applications generally provide group membership management services as well as multicast protocols for reliable, ordered, and timely delivery of messages to the members of a group[10]. However, anticipation of when a network partition occurs may become limited since soldiers might always move around according to their mission. They can communicate each other in their partition, but not outside of their partition. Traditional communication protocols such as medium access control, routing and etc are inadequate in this kind of network. Some existing researches support to maintain group membership when the network is partitioned. [16][17][18]

Bandwidth for Multimedia Data

When we use mobile AR system in the scenario, we can assume that all mobile nodes additionally exchange video images. Since wireless networking supports higher data rates, it is adequate to exchange multimedia data in this network environment. However, exchanging multimedia data generally requires high bandwidth and real time transmission, so that data rate selection for the transmission of multicast packets might be more important than reliable transmission. On the contrary, military communication should support reliability and timeliness, so that a new algorithm is necessary to dynamically select the data rate of the multicast according to the traffic load of the wireless networking.

Light-Weight Communication Protocol

Mobile users continuously move in and out the communication range over time. This leads several issues such as reliability, the lifetime of communication or partition and merge of a group. We need protocols for light-weight communication links that can easily be established and broken down without affecting either communication partner. Light-weight communication protocol is central to power consumption of the mobile device running on the battery pack.

6. APPLICATION SCENARIO WITH USING AR SYSTEM

We have figured out issues required to implement mobile AR application in MANET through Section 5. Although those issues have not been perfectly resolved yet, relevant ongoing researches and technologies are becoming increasingly advanced. In the future work, we will show through hands-on experiments how to resolve the potential problems of each component of the framework. In this section, we represent the scenario mentioned in Section 3 sufficiently using the proposed framework.

Each soldier is equipped with a wearable computer which can communicate over the wireless link, GPS and a helmet with display screen (HMD), trackers, sound device(i.e. microphone and earphone) and video camera. Based on digital terrain plans which are already stored in self-contained database, digital arrows are projected into the HMD to provide the soldier the right direction. In addition, location information like positions of enemies or weapons friendly or not can be displayed as picture on HMD. This enhances the soldier's perception compared to using compass and 2D maps. These visual systems would allow digital mapping in real time if there is no existing plans stored in the database, and the structure of buildings would be recorded while the soldier moves and sees around. Even if a few soldiers are searching the targets in a same building, they can avoid redundancies like a couple of soldiers moving the same area without knowing each other's location because all operation messages are generated automatically and transferred to all soldiers involved in the mission. Continuously wireless communication among all members within a team would be able to monitor the status of each member during accomplishing the mission. If needed like in very dangerous environments, with health data like pulse rate or breathing frequency based on the specific sensors, the commander can monitor and check the soldier's status through data transmitted digitally, and then he can command stopping some dangerous operation on time. When the soldier should manipulate difficult operations like bomb-disposal, he/she can carry out precisely with the aid of a schematic diagram displayed on HMD or the voice of an expert. This communication system also supports to transfer further information data to a certain soldier while talking to each other. Besides, the overview of operations for the mission is displayed to the commander's view and he can be responsible for relevant operations via wireless communication.

Using mobile AR system in our scenario, expected focal point is that wireless and freehand communication systems with acoustical and optical interaction can not only enhance the users' perception, but also improve their operations for the purpose.

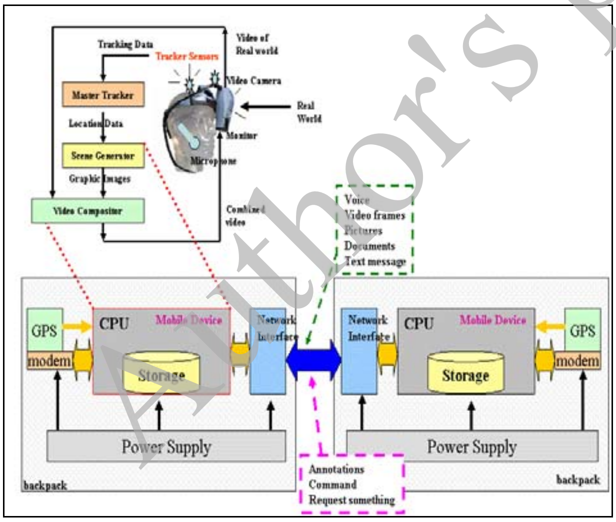

Figure 12: Mobile AR system diagram using the framework. Two boxes mean two wearable systems containing the computer, network interface card, GPS having modem with RS-232 port and battery pack. Through trackers attached to the helmet, Master Tracker gathers tracking data. The data is combined with the scene graph via Scene Generator, and then graphic image is generated, which is displayed to the user's HMD. The type of data exchanged can be voice, video frames, pictures, documents or text message, and then responsible information can be annotation to the virtual objects, command or request message.

7. CONCLUSION AND FUTURE WORK

We have presented two scenarios of the battlefield with and without using AR system, the conceptual framework to implement the scenario and related issues. Through the second scenario, we can encounter that military operations are improved when we sufficiently use AR system, and the soldiers are rapidly deployed in the battlefield when we appropriately configure wireless mobile ad hoc network.

The goal of this paper is to present an ideal framework in order to offer researchers more informed decision when they are considering upon using AR system for cooperative work in ad hoc mobile network. The framework we have seen through our scenario features:

- *Discovery of shortest path to the target object.* Once a user selects a target location, the system computes the shortest path, and then it can be continuously recomputed while the user moves.
- *User's current status & transmission range perception.* The commander or chief of the group can see all users' current status such as dangerous situation, battery usage or movement on the screen view. Visual display can help the user to recognize the current location and transmission range. These days, the combination device of GPS and modem is used and the modem has a RS-232 port. This means, the user can get the signal of own location information from the satellite, and also the information can be sent to other users via radio frequency modulating the digital location data to analog data. Therefore, the user can see the other's as well as own location.
- *Automatic response to the change* If environmental data is changed (e.g. building explosion), automatically event-based update occurs, and new data is applied to all self-contained database of each mobile node.
- *Information browsing* The user can visually browse all data that the user wants to know with just one touching the menu on the user's input device.

The conceptual framework proposed in this paper does not contain precise description of implementation and user interface that features the practical use of AR system. There is necessary work to reduce amount of a self- contained local database that we need in order to interact with the real world.

For the future work, we need to develop the framework further. That is, we will develop the prototype of the framework through hands-on experiment of each subsystem. With this prototype, we can continue to progress each subsystem.

The first, we would like to investigate an advanced user interface (UI) management. Unlike UI management proposed in [34], we will take into account haptic interface [35] as well as visual interface. Immersion and rich sensory interaction using haptic interface as well as visualization is notably increasing in all kinds of human-computer interaction, including medical and scientific visualization, games and even artistic area. So far, we believe that this interface is not applied to mobile computing yet, however, if we can feel haptic feedback or force feedback from generated virtual object, our perception will be greatly enhanced.

The second part we shall consider is to reduce burden of a local database of each mobile user. One of related approaches is to use mobile code [36]. The real world object (e.g. walls) has active tags that the AR system uses to obtain the information like location or additional data that the tag has, but this data should be very tiny. In other words, huge environmental data is already distributed to a large number of tags, and mobile AR system can download or upload the information, which is called *mobile code*, whenever it is needed. Communication between the active tag and the AR system is made using wireless protocol like Bluetooth. This approach is especially useful in case of that mobile users operate a fixed area for predefined period of time (e.g. since military deployment is mission based, which can lead to a certain amount of predictability in a unit's movement, this approach can be useful.)

Finally, we would like to implement simulation models for the framework application and run tests in the real worlds to compare against other mobile AR system.

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