Designing a Self-contained Group Area Network for Ubiquitous Learning

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ABSTRACT

A number of studies have evidenced that handheld devices are appropriate tools to facilitate face-to-face collaborative learning effectively because of the possibility of ample social interactions. Group Area Network, or GroupNet, proposed in this paper, uses handheld devices to fill the gap between Local Area Network and Body Area Network. GroupNet is an independent network where all members are located at the same place and all handheld devices involved in it are interconnected by peer-to-peer wireless technologies. The GroupNet concept proposed in our study is more focus on how to design a mobile learning management system which can better support mobile learning for a small group of learners with effective social interaction within proximity. This paper describes the architecture of GroupNet and demonstrates its functionality in the specific area of mobile learning. GroupNet uses handheld devices as the main hardware and GroupNet architecture consists of four layers. Various mobile learning scenarios are also described in detail to give guidance to instructors. These scenarios apply GroupNet to collaborative learning activities and situated learning activities. With rapid growth of mobile technology and global business context, many more possible scenarios of using GroupNet are expected to emerge in the future.

Keywords

Group area network, Mobile learning management system, Mobile learning, Ubiquitous learning

Introduction

The recent advancements in electronics engineering and manufacturing technology have resulted in handheld devices, such as cellular smart phones, personal digital assistants (PDAs), pocket personal computers and tablet personal computers, getting wireless enabled, cheaper and more powerful. The characteristics of small size, light weight and easy operation allow users to take their most important data and software applications with them almost everywhere. Thus handheld devices are becoming increasingly popular. Meanwhile these appliances have also been used for educational purposes and a number of studies have focused on related issues (Liu, 2007; Massey, Ramesh & Khatri, 2006; Peters & ben Allouch, 2005; Pownell & Bailey, 2000).

Let us consider the situation where four Bridge lovers meet together on a special occasion. They want to play Bridge, but nobody has playing cards. However, they do have handheld devices with themselves. Thus they could somehow interconnect these handheld devices and play Bridge immediately. They may have several choices for connecting to each other: 2G, 3G or wireless local area networks (WLAN). In many places, these services are usually provided for a charge, but even then, they are not always available everywhere, for example, field trip to rural areas, higher up in mountains or sailing on the sea. Some places still lack sufficient information and communication technology (ICT) infrastructure. In such scenario (or in any scenario, for that matter), it would be good to play Bridge without paying any costs for network connections, if their handheld devices could be connected through peer-to-peer (P2P) wireless network connection. In a P2P wireless network, each peer's handheld device can act both as a client and as a server, and allow peers to interact with each other directly (Morikawa & Aoyama, 2004). In this study, Group Area Network, called GroupNet for short, is proposed based on P2P wireless network connection to fit with this type of mobile scenario. GroupNet consists of a set of interconnecting handheld devices with wireless access, carried by a group of people within proximity.

GroupNet works with wireless modules of the handheld devices to achieve the best of ubiquitous networking. Ubiquitous networks enable secure access to data from everywhere on multiple devices (Tarasewich & Warkentin, 2002; Weiser, 1994) to achieve the ubiquitous learning environment. The ubiquitous learning environment can connect, integrate and share learning resources in the right place at the right time by an interoperable, pervasive and

seamless learning architecture (Yang, 2006). P2P networking used in GroupNet is one approach of creating ubiquitous networks (Morikawa & Aoyama, 2004) for supporting ubiquitous learning. The main advantages of GroupNet are as follows:

- Additional infrastructure such as cables, wireless access point and hubs are not necessary for creating a GroupNet, making it possible to create GroupNet dynamically.
- It supports a small number of group members who meet at the same time and at the same place to communicate and collaborate with each other smoothly using handheld devices.
- It can ensure both the privacy and security of information because there is no need to connect to Internet for establishing interconnection among all handheld devices in a GroupNet.

GroupNet can be applied widely in many areas such as learning, training, communication, teamwork and entertainment. Various applications can be developed based on GroupNet for specific purposes. This paper first reviews the related works on using handheld devices for learning, and then describes the basic concepts and the architecture of GroupNet. Moreover, the functionality is demonstrated in the specific area of mobile learning. Finally, two scenarios are also described in detail to explain the benefits of GroupNet.

Related works

Handheld devices are seen as having potential to achieve a great positive impact on learning because of small size, light weight, portability, low cost, easy operating and wireless communication features (Pownell & Bailey, 2000; Roschelle, 2003). Patten, Sánchez & Tangney (2006) proposed a framework of seven distinct categories of application specific for handheld devices: administrative, referential, interactive, microworld, data collection, location aware and collaborative. We argue that GroupNet is more suitable for collaborative category of the framework, to improve learning from both context-aware and situated environment perspectives. Collaborative category of applications in this framework undertakes to establish a learning environment of knowledge sharing by utilizing the features of handheld devices (Patten, Sánchez & Tangney, 2006). Moreover, Roschelle (2003) illustrated three important classroom applications supported by handheld devices: classroom response systems, participatory simulations and collaborative data gathering. These issues have attracted researchers' attention for a long time. However, new applications have potential to be developed for pedagogical purpose (Roschelle, 2003). The GroupNet proposed in this study can help to realize this aim.

A number of studies have evidenced that handheld devices are appropriate tools to facilitate face-to-face collaborative learning effectively because of possibility of ample social interactions (Wessels, Fries, Horz, Scheele & Effelsberg, 2007; Zurita & Nussbaum, 2004a, 2004b). For example, in the study of mathematics and language, researchers found that learners worked collaboratively with the support of handheld devices, and performed better in terms of test scores than those who worked together without the support of handheld devices (Zurita & Nussbaum, 2004a, 2004b). In another study, the interaction of the learners could be enhanced in a physical classroom via a quiz service which was implemented on mobile devices, and the aspects of attention, activity and perceived learning success were also improved (Wessels et al., 2007). Norris & Soloway (2004) advocated the handheld-centric classroom where project-based learning is uniquely supported and learners can engage in collaborative efforts. Teachers can also instantly collect the questions, answers and discussions of all students, and give feedback to students during a lesson through a network of handheld devices (Davis, 2003; Siau, Sheng & Nah, 2006).

The above research efforts have indicated that handheld devices can support collaborative learning and interaction of participants. However, these experimental systems were designed for some specific study purposes. There is still lack of a clear architecture for rapid deployment of appropriate interaction systems to assist instructors and learners. Therefore, GroupNet is proposed in this study as a general purpose rapid interaction mechanism to support mobile learning via handheld devices.

Recently the wireless ad hoc networks using wireless technologies have drawn considerable attention in the liertature. A wireless ad hoc network is a collection of mobile devices to form an arbitrary topology by wireless links, such a network can be constructed rapidly without the use of an existing network infrastructure or centralized administration (Ishibashi & Boutaba, 2005; Kiess & Mauve, 2007; Mauve, Widmer & Hartenstein, 2001). Due to its flexible nature, wireless ad hoc networks have been applied to many fields, such as disaster relief, emergency operations, military service, maritime communications, vehicle networks, casual meetings, campus networks, robot

networks and so on (Kannhavong, Nakayama, Nemoto, Kato & Jamalipour, 2007). However, most previous studies focus more on the networking issues like how to improve dynamic routing protocols to overcome the problems of wireless ad hoc networks caused by node mobility (Huang & Chen, 2006) not the application platform issues. The GroupNet concept proposed in our study is more focus on how to design a mobile learning management system (m-LMS) which can better support mobile learning for a small group of learners with effective social interaction within proximity.

Basic concepts of GroupNet

Before describing the application of GroupNet for learning and other areas of applications, the core concepts and characteristics of GroupNet are described in this section.

What is GroupNet

Before introducing *Group Area Network* (GAN), or GroupNet, two well-known terms needs to be mentioned: wide area network (WAN) and local area network (LAN). A *Wide Area Network* is a computer network that covers a broad area, crossing metropolitan, regional or national boundaries. A *Local Area Network* is a computer network covering a small geographic area, such as a home, office or group of buildings (Comer, 2004). Recently, a new type of network has emerged, called *Body Area Network* (BAN), which consists of a set of mobile and compact intercommunicating sensors, either wearable or implanted into the human body, which monitor vital body parameters and movements (Goulianos & Stavrou, 2007). The coverage of BAN is even smaller, only around a person's body.

Group Area Network or GroupNet fills the gap between *Local Area Network* and *Body Area Network*. It consists of a set of interconnected handheld devices with wireless access, carried by a group of people within proximity. From the distance of coverage point of view, the relation among them is like WAN > LAN > GAN > BAN.

GroupNet is a standalone independent network where all members are located at the same place and all handheld devices involved in it are interconnected by wireless technology in P2P manner. The independent network is ad hoc and is started on the desire of the members. All devices in the network remain completely dynamic, and can leave or join the network on demand. Figure 1 shows an example of GroupNet.

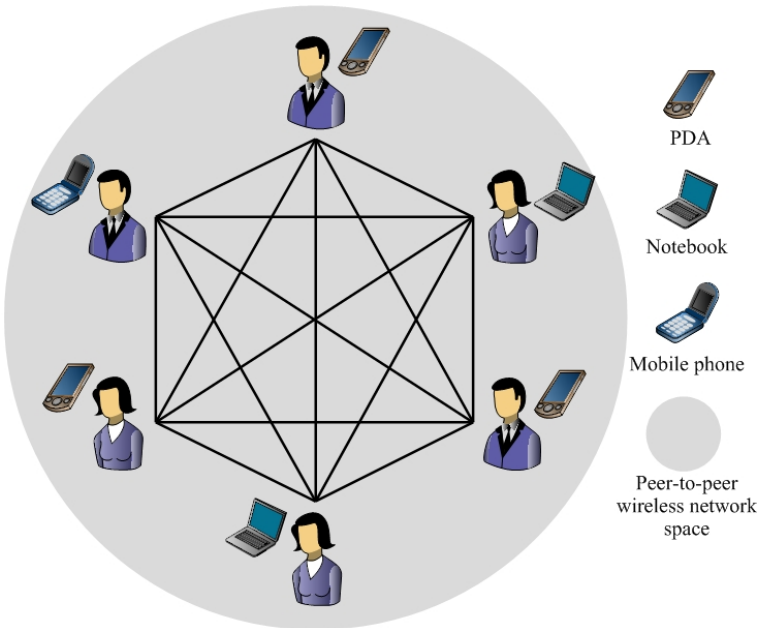

Figure 1. An example of GroupNet

Characteristics of GroupNet

A GroupNet has several important characteristics that make it suitable for various kinds of applications in the context of different people meeting physically in groups from time to time and from place to place while doing collaborative tasks with the support of networked handheld devices:

- A GroupNet's coverage is only a very small area. All members in a GroupNet are located at the same place. They can see each other and retrieve direct gestures to do social interactions. Therefore, the optimal number of members in one GroupNet is less than 10 persons. However, many GroupNets can be established and concurrently running at the same physical location.
- Every member can be a host or a guest. Individual users can start a new GroupNet or join an existing GroupNet as they wish. When a GroupNet has been established, the initiator can switch the host role to other members as needed.
- GroupNet is completely P2P wireless communication. The wireless standards have been around for a long time and they are used very commonly nowadays. Thus, the handheld devices in GroupNet use ad hoc wireless connectivity to connect to each other on the go.
- Mobility is perhaps the most distinct characteristic of GroupNet. Because of the high portability of all devices in a GroupNet and the inherent characteristic of P2P wireless technology, the GroupNet obtains high mobility compared to other networks.
- GroupNet has dynamic composition and decomposition capabilities. The portability of handheld devices and the characteristics of wireless technology help in making it possible to dynamically compose and decompose the GroupNet. When users want to establish a new GroupNet, they can start it easily at anytime and any place. On the other hand, if members desire to join, leave or terminate an existing GroupNet, they can do it easily, too.
- GroupNet behaves as an independent network. The members of a GroupNet are located at the same place and the devices are interconnected using P2P wireless technology. Thus, every GroupNet is an independent and standalone network and every involved handheld device can efficiently use the full bandwidth.
- GroupNet does not require any additional infrastructure. Users connect to each other's handheld devices by P2P wireless technology. That means no outside Internet connection is needed. However, users can connect their handheld devices to the Internet for downloading GroupNet application software or any other data before hand.
- GroupNet does not need connectivity to Internet. Members access data on each other's devices directly using P2P wireless technology. In fact, the architecture of GroupNet itself does not provide any mechanism to connect to Internet (however, individual devices in a GroupNet may be connected to Internet using different networking means).
- GroupNet provides less security threats compared to those computers always connected to the Internet. This is especially useful for those situations where data security or transmission through the Internet is a concern. Since GroupNet applications does not need to connect to Internet for its operation, the data transmission and content stored within GroupNet is more secure. GroupNet is also immune to other Internet related problems, such as fake access points, hacker attack, spam mail, phishing and so on.

Architecture design of GroupNet

After describing the core concepts of GroupNet, this section discusses the architecture of GroupNet for actual implementation. The GroupNet architecture is introduced first, followed by the description of various components.

GroupNet uses handheld devices as the main hardware. These handheld devices are located in the same ad hoc network. Every device could act as either a server or a client. Overall, the GroupNet architecture consists of four layers, from the lowest to highest: Network, GroupNet kernel, GroupNet applications and GroupNet application user interface, as shown in table 1.

Handheld devices

Handheld devices are main equipment in GroupNet. These devices must possess mobility and software expandability. There are many devices in the market that are suitable for GroupNet architecture, for example, smart phones, personal digital assistants (PDAs) and portable personal computers. Recently, a number of manufactures have started producing much smaller notebook computers and tablet personal computers to form the ultra-mobile

personal computers (UMPC) market. For example, notebook computers are now available with 8.9 inches, 7 inches and even 4.5 inches screen size. Therefore, more and more devices are emerging that could be used in GroupNet.

Table 1. GroupNet architecture

Layers	Functions
GroupNet application user interface	Integrated user interface of functions for application development
GroupNet applications	Whiteboard, chat room, voting, instant message, game, groupware, collaborative learning systems and other specific applications
GroupNet kernel	Activity control, online status, files sharing, message passing and session recording
Network	Wireless protocols (IEEE 802.11x, IEEE 802.15) and TCP/IP protocol suite

Network layer

In order to achieve the mobility of GroupNet, appropriate wireless standards are required. At present, there are two wireless standards, IEEE 802.11 (Wi-Fi) and IEEE 802.15 (Bluetooth), which can interconnect handheld devices using P2P connection. There is another factor, limitations in the standard for the number of connections, which is important during the selection of appropriate wireless standard. For example, Bluetooth can interconnect only seven devices at a time. TCP/IP protocol suite is employed to develop GroupNet kernel functions.

GroupNet kernel layer

Based on the Network layer, data can be transmitted within the GroupNet. The GroupNet application server and client control GroupNet activities by GroupNet kernel. The five main functions of GroupNet kernel are activity control, online status, file sharing, message passing and session recording. Activity control is the core of GroupNet kernel. It deals with session establishment, member management, participation, token passing and session termination. Online status can be used to check session and member status in any GroupNet application. Users can share various types of files to other members by file sharing function. Message passing function supports real-time message exchange, such as chat text, handwriting, drawing and annotation. Members can enable the session recording function to record all activities in a GroupNet session. GroupNet kernel could be called to develop applications for education, communication, entertainment and other matters.

A possible example of activity control is shown in figure 2.

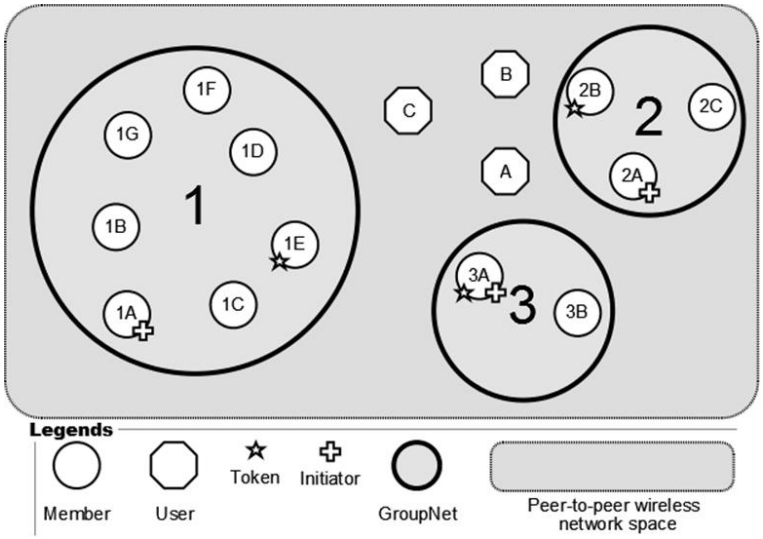

Figure 2. The activity control view of several GroupNet

Various terminologies related to GroupNet kernel are as follows:

- User: A person who has a handheld device with GroupNet software application installed, but not yet involved in any active GroupNet, e.g. A, B and C shown in figure 2.
- Member: A user who is involved in an active GroupNet.
- Initiator: A member who initiated an instance of GroupNet, e.g. 1A, 2A and 3A shown in figure 2. This person acts as a moderator and has the authority to pass on to or retrieve token from others in the GroupNet.
- Token: A virtual token represents the authority of activity operations which can enable particular actions, e.g. starting an application, conducting a voting and message broadcasting. The token can be passed among members.
- Host: A member who is holding the token, e.g. 1E, 2B and 3A shown in figure 2.
- Guest: A member who is not holding the token.

The GroupNet kernel provides the necessary software functions for operating GroupNet management and supporting upper level GroupNet applications. These functions could be classified into three types, including functions for everyone, for GroupNet members and for initiator.

Functions for everyone

- Detect the local device information: This function detects the device ID of a local device. The device ID is used in listing all devices in range using GroupNet application.
- Listing service: This function lists all devices that are running GroupNet application on an existing GroupNet. The detailed information of each device involved in GroupNet is listed, including the device ID, name of GroupNet application being used and name of current GroupNet.
- Establish a new GroupNet: This function establishes a new GroupNet for any device to join in. The device establishing the GroupNet acts as a host and announces itself as a host to other devices that are within range.
- Join an existing GroupNet: This function allows a device to join an existing GroupNet.

Functions for all GroupNet members

- List members in the same GroupNet: This function lists all members in the present GroupNet.
- Switch token to the other members: The member who holds the token can undertake particular tasks. Sometimes, the host role has to be given to another member for some purpose. This function allows the token holder to switch the token to another member.
- Leave the GroupNet: This function allows a member to leave the current GroupNet.

Particular functions for members with initiator role

- Kick member(s): This function enables initiators to make one or more members leave the current GroupNet.
- Terminate the GroupNet: This function allows initiators to terminate the present GroupNet. As a result of this function, all members will leave the GroupNet and become users.
- Pass token to a specific member: When the GroupNet has been established, the initiator gets the token. The initiator could then pass the token to another member in the GroupNet if needed. The member who is assigned the token becomes the host and has possibility to carry out certain tasks that a host can undertake.

An example of GroupNet flow is shown in figure 3. There are some GroupNet users located at the same place. One possible flow of GroupNet experienced by these users could be explained by the GroupNet kernel functions:

(a) There are three GroupNet users within the range of P2P wireless network at the same place. The user A wants to establish a new GroupNet for doing some collaborative tasks.
(b) User A established the new GroupNet, named “4” and user A got a name “4A” in this GroupNet. At the same time, 4A becomes the initiator of the GroupNet and gets the token. Then user B and user C want to join this GroupNet 4 (called “GN4” from now on).
(c) After users B and C joined GN4, they got their names “4B” and “4C” respectively. At that moment, 4A passes the token to 4C.

(d) 4C received the token, so 4C now has the host role. At that moment, two GroupNet users "D" and "E" come in the P2P wireless network and they wish to join GN4. The member 4B leaves GN4 at the same time.
(e) Since 4B has left GN4, 4B becomes a GroupNet user until s/he exits the GroupNet application or joins a GroupNet again. The users D and E get their names "4D" and "4E" respectively. Unfortunately, the member 4A who is the initiator of GN4 thinks that the member 4D is not suitable to take part in the GN4 activities. Therefore, 4A wants to kick member 4D to make him/her leave GN4. The member 4C passes the token to 4E.
(f) The user B had exited the GroupNet application and has now disappeared from the P2P wireless network. The member 4D had left GN4. The member 4E gets the token. Then GN4 operates for a period of time where members 4A, 4C and 4E conduct their collaborative activities. GN4 could be closed now. The member 4A who was the initiator of GN4 has the right to terminate GN4 and he wants to terminate GN4.
(g) The user D had exited the GroupNet application and has now disappeared from the P2P wireless network. The GN4 has been terminated forcing all members to exit GN4. They all become GroupNet users who have not yet joined any GroupNet.
(h) After all users have exited their GroupNet application, the space reverts to the original environment for without wireless network.

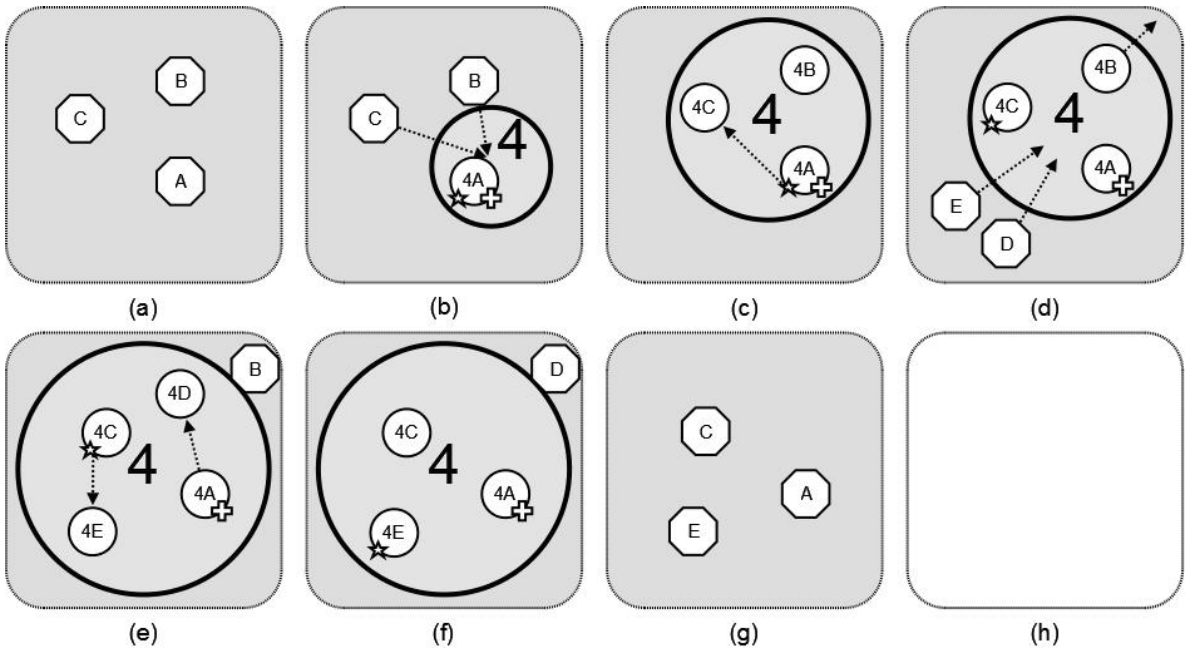

Figure 3. An example of GroupNet flow

GroupNet applications layer

GroupNet concept is designed to support group tasks, thus the GroupNet applications are also designed and implemented according to the nature of group tasks. GroupNet applications are based on the corresponding theories that govern the tasks facilitated by the applications. For instance, GroupNet applications developed for collaborative learning activities are based on collaborative learning theories.

GroupNet applications are based on the corresponding operating platform and GroupNet kernel, and associated client/server or P2P of session layer connections. Thus there are server side functions and client side functions to fulfill various tasks of GroupNet applications. The GroupNet application server is for the use of GroupNet initiators who are in charge of the coordination logic and rules for the corresponding GroupNet applications. It could be used to manage the whole GroupNet flow. With regard to the GroupNet application client, it is for the use of GroupNet users and members.

GroupNet application user interface layer

Since all users have possibility to either establish a new GroupNet or join an existing GroupNet at their will, the GroupNet application must have both the user interface (UI) of server functions and the UI of client functions within one application. Through the integrated UI, GroupNet users can use all functions that GroupNet kernel provides. The designers of GroupNet applications have to consider in what form they should develop the GroupNet applications. For example, the GroupNet applications could be implemented in the form of Java applications that will run in the Java runtime environment (JRE), or in the form of handheld devices software that has to be installed first.

Two scenarios for mobile learning using GroupNet

Now that the system architecture of GroupNet has been described in the above section, we want to describe what scenarios could apply GroupNet to solve group collaborative tasks. In addition, we demonstrate application of GroupNet for learning activities. These scenarios are aimed to provide more practical view of GroupNet.

Collaborative learning activities

Various collaborative learning activities are used by teachers to promote the learning performance of students. Through the use of computers, whole discipline of computer supported collaborative learning (CSCL) emerged. Later, researchers and educators started to use mobile technology to support collaborative learning with more social interactions between learners, named mobile CSCL (MCSCL) (Zurita & Nussbaum, 2004a; Zurita, Nussbaum & Salinas, 2005). Now it is possible for teachers and students to use GroupNet to support their collaborative learning activities. We argue that the GroupNet supported collaborative learning is also one kind of MCSCL. The group size in GroupNet is small, which is also one requirement of collaborative learning activities (Prichard, Stratford & Bizo, 2006). The ad hoc wireless technologies enable students to have better social interaction with each other. The mobility characteristic of GroupNet is helpful for doing collaborative learning anywhere. The handheld devices can be used to record the data that is produced during the whole learning process in a more intuitive and effective manner. This data can be a valuable feedback for both teachers and students.

Here is a scenario of using GroupNet for collaborative learning activities. Student A in a remote working community is using handheld device to learn certain topic. The handheld device is WiFi, Bluetooth and global positioning system (GPS) enabled. The content is being transferred to the handheld device via WiFi through an access point from a local server, which also contains student's personal profile. The personal profile includes information about student's previous learning history, competence levels in different subject areas and so on. On this particular occasion, system monitors student A's current progress and infers that A is finding it difficult to progress in current subject content. Using GPS tracking, system identifies student's position and then checks to see if it can track any other students nearby who could join this student to make an ad hoc GroupNet based study group. If it finds any other students nearby who are also studying at similar level in the subject content, the system goes back to student A and with a window pop-up, asks whether the student would like the system to help in creating a study group with other students for better learning experience. If student agrees, the system informs other students about the possibility to create a study group and asks whether they would like to join it. If those students agree, then by giving directions through GPS tracking, the system brings all these students together at one place. Once the students are near enough to each other that they are within the Bluetooth range of each other, GPS tracking is switched off and the local server pushes out an ad hoc GroupNet based client-server module to one of the handheld devices via WiFi connection. Once the client-server module is downloaded to the device, it tracks which other devices within GroupNet range are willing to join GroupNet and pushes out client module to those devices.

In this manner, a GroupNet is established. Then the GroupNet server module on the handheld device requests a subject related problem from the server. Based on the profiles of all students in the current GroupNet, local server sends a problem to the GroupNet server module that is divided into as many pieces as there are students in the current GroupNet. The GroupNet server module pushes out appropriate pieces of problem to the client modules on other handheld devices. Students then discuss the problem face-to-face and by watching the problem pieces on others' handhelds, try to solve their own pieces, transfer intermediate solutions to other devices for further problem solving and try to reach to a conclusion through intensive dialog and collaborative learning approach. Once they

have solved the problem, GroupNet server module notifies the local server and sends the archive of interaction. Based on this information, local server updates the profiles of students and pushes out content to everyone's device for further learning process.

Situated learning activities

Lave & Wenger (1990) introduced situated learning that asserts that learning happens in authentic context. Learners obtain knowledge not only from other individuals, but also from the social interactions with other individuals. The situated learning activities could be categorized into several types: problem-based learning (PBL), case-based learning (CBL) and context-aware learning (Lave & Wenger, 1990). In order to provide learners with the authentic context and to apply the obtained knowledge to the real world, tutors create scenarios for learners with real world settings. We argue that situated learning activities, especially context-aware learning activities, are other possible activities that could be supported by GroupNet. Situated learning can now happen in any place because of the mobility characteristic of GroupNet. Meanwhile, it is especially suitable for small groups to learn collaboratively in situated learning activities. Learners and tutors could be interconnected very easily through establishing a GroupNet because of the GroupNet's high composing and decomposing abilities.

Conclusion

This investigation introduced a new mobile network concept named GroupNet that could be used to support group collaborative tasks. A small number of people could get together anywhere and any time, and handle collaborative tasks together supported by wirelessly interconnected handheld devices within GroupNet environment. The mobility is perhaps the most distinct characteristic of GroupNet that enables GroupNet to be established and operated anywhere. We argue that GroupNet is applicable for various types of learning activities. The GroupNet concept proposed in our study is more focus on how to design a mobile learning management system (m-LMS) which can better support mobile learning for a small group of learners with effective social interaction within proximity. This study demonstrated two scenarios for applying GroupNet to learning activities. Overall, we argue that GroupNet could be used in various areas with various applications.

A promising area of GroupNet's application is multi-player games. The example of playing Bridge by multiple players in introduction section of this paper highlights this aspect. With recent emergence of game-based learning and edutainment, GroupNet can be instrumental in bringing educational research closer to the needs and preferences of today's learners who grew up playing with multiplayer online games, X-Box and Nintendo play-stations.

Even though GroupNet looks useful so far, further research is required on several issues for enhancement. Since GroupNet is a new concept, all application dimensions have not yet been identified. Various implementations of GroupNet will be needed before further scenarios for GroupNet applicability could be established. Also, it should be possible for the GroupNet kernel to implement the applications by P2P system architecture instead of client/server architecture. Applying P2P architecture to GroupNet applications provide more freedom to the GroupNet initiator and make the GroupNet more flexible. The initiator will not always have to stay in the GroupNet (currently, only initiator has the possibility to dissolve a GroupNet, which also means that a GroupNet has to dissolve if the initiator wishes to leave). Thus the GroupNet will obtain more complete composing and decomposing abilities.

The development of appropriate applications to support mobile learning through GroupNet concept is also a crucial dimension. GroupNet can be successful only up to the extent the applications running on it are useful for the learning tasks. The evolution of GroupNet and the development of learning applications particularly suited to GroupNet environment, therefore, have to go hand in hand.

As mentioned earlier, GroupNet is also an attempt to fill the gap that currently exists between local area network and recent research work on body area network. We hope that GroupNet will also be able to act as a bridge between these two networks, providing secure data transfer, and will lead to more cohesive and seamless applications spanning from individuals to wider communities.

Acknowledgement

This research was supported by the National Science Council, Taiwan (NSC 95 -2520 -S -110 -001 -MY2).

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