A Study on Characteristics of Ad hoc Network Applications

Masato Hayashi* and Christian Bonnet**

* Corporate Technology Group
Hitachi Europe, Ltd.
Masato.Hayashi@hitachi-eu.com

**Mobile communication department
Institut Eurecom
Christian.Bonnet@eurecom.fr

Abstract : **Mobile ad hoc network becomes very popular in terms of research and development to have much potential of useful applications and services because it makes it possible that anytime, anywhere , with anybody, network is established on demand for certain purpose without any support of existing network. In this paper we approach ad hoc network from the application point of view and propose new communication stack architecture for realization of ad hoc applications. The new architecture includes application group management that controls membership of application and session management which assures the logical connection among application members.**

Keywords: **Mobile Computing, Ad hoc network, Group communication, Application**

1. Introduction

With rapid advance of device technology and radio access technology, the mobile terminal (Pocket PC, PDA etc) as well as mobile telephone becomes indispensable not only in business scene but also in our daily life.

"Anytime anywhere, anybody can exchange information". In fact people can access Internet anytime and anywhere at this moment. But that is not enough for daily life. Because whenever people want to send messages, they must use existing network even if they are just within face-to-face distance. In this present way, communication among people sometimes suffers the influence of conventional network (traffic congestion etc.) that causes deterioration of service level: throughput, longer delay of message and so on. Of course people have to pay for message transfer service. The demand that people want to communicate each other directly to exchange information when they meet on the public space is increasing.

On the other hand, new business concept "Peer-to-Peer (abbreviated as P2P)", which is person to person communication, becomes keyword towards future IT(Information Technology). In P2P, every peer is equal to others. In another words, a peer can be server or client to the others. A peer can create, store and advertise information as server, while it asks and gets information from other peer as client [1].

Having considered the above background, ad hoc networking technology that realizes direct communication between mobile terminals on the scene has been attracting considerable attention lately for the infrastructure of direct communication from daily life to P2P business in mobile environment.

Mobile ad hoc network (MANET) is an autonomous system of mobile node connected by wireless link [2]. MANET is a group of wireless nodes which cooperatively forms an instant network that operates without support of any fixed infrastructure. Direct communication between nodes is possible when adequate radio propagation conditions and network channel assignment exist. Otherwise nodes communicate through multi-hop routing [3]. In this sense MANET node functions as both a router and host [4]. MANET offers unique benefits and versatility for certain applications.

Most of efforts in this area so far have been done in the area of routing issue and MAC protocol. There are a lot of routing protocols proposed for IETF. There are two types of routing; unicast routing [5-10] and multicast routing [11-15]. Concerning MAC issue, the adaptability of MAC protocol of IEEE802.11 [16], the reliable MAC broadcasting for ad hoc networking [17], high speed and efficient MAC protocol for multi-hop routing [18]etc. have been worked on. However, there isn't much study targeting on higher layer than IP layer including application layer. "Spontaneous Network"[19] is defined from the point of group application, which paper has just introduced the potential technology challenges.

Those routing and MAC protocols are affected by parameters as the number of terminals, the way of multi-hopping, traffic distribution, mobility pattern and so on. Those parameters also are influenced by applications and services that run upon this type of network.

Our work starts from the application point of view to be able to derive a classification that gives the potential communication model of application. This classification may be used to identify the need of complementary protocols.

In this paper, firstly we make brief explanation of ad hoc networking in the next section. Then in Section 3, we show several potential application examples suited to ad hoc network and indicate the importance of group communication on MANET. In section 4, we identify the necessity of complementary protocols and propose new stack architecture for MANET. In section 5, we discuss the requirements of proposed complementary protocols. Lastly we conclude the discussion.

2.Characteristics of ad hoc network technology

In general ad hoc network is defined as having features as follows.

(1) Autonomous Instant networking on the spot for temporary purpose without help of fixed network

Mobile node searches in its proximity area to discover other nodes or checks radio signals from other nodes within radio-arm area. If any, the node contacts in direct mode each other to establish the connection. Each node repeats the discovery process to form local network without help of fixed infrastructure. Then application service in the nodes will start. In this way gathering nodes will construct a network on the scene for temporary purpose.

(2) All terminals can be mobile

MANET assumes nodes movable in any direction. Upon the movement of a node, its neighboring nodes change

and its connections are forced to change according to ad hoc routing protocol to maintain the IP connection. Physical and IP connection would be dynamic, however, from the application point of view, the relation among application group members does not change logically.

(3) The node has connection with others in direct or indirect (Multi-hopping) manner

MANET node functions not only as host but also as a mediator like a router to help connection between nodes that have no direct connection. Therefore IP connection can be taken over to plural terminals by means of multi-hopping (relay mechanism to other nodes outside direct radio zone). Ad hoc network is easy to extend with existence of mediator nodes.

The ad hoc network has much dynamic and could be accessed anywhere, whenever, with whomever. The ad hoc network is completely distributed system which is free from constraints that stem from other networks. Therefore this kind of network will appear for a while and disappear after its purpose. Sometimes it repeats. These features make realize new type of application different from that supported by existing network. What is the most important property is "Freedom" of communication in itself, in another words, its nature of ubiquity.

3.Application examples

We show in Table 1 the examples of potential ad hoc network application possessing some or all of those characteristics shown in previous section.

We pick up several points with regard to communication property: its model, reliability and scalability. Of course there are also other important properties: security, QoS and etc. but these are out of the sight of this paper. Reliability in this paper means that data is received without error. On the other hand, scalability is the number of participants and extension of networking area. Communication model are one-to-one, one-to-many and many-to-many. Many-to-many indicates that sender is changeable then every node can be sender. Of course this classification is not definite because the features classified here depend on the usage scene of each application.

The examples are categorized into consumer use, company use and public use. Gaming is one of typical application for consumer usage where several players gather and form game group somewhere. Concerning reliability, it requires high reliability. Otherwise gaming itself does not run efficiently. Gaming area and its participants could increase depending on the kind of game. Some game is more exciting with more players (horse race, car race etc.) On the contrary, by-word-of-mouth communication network does not need high reliability, for example, in case of spreading gossip.

Regarding company or commercial use, information is so valuable and sometimes confidential that high reliability is essential property. Scalability might be required in some applications. For example, conference support system where the number of participants can be more than hundreds and participants often change several conference room following the topic of their concerns. Shopping guide in big department store (on occasion of bargain sale) has to deal with a lot of guests. On the other hand, sale at client spot in Sales/Business support application does not need scalability.

With regard to public use, scalability is required to deal with many clients. ITS (Intelligent Transportation System)

Table 1 Classification of applications

	Application	Communication model	Reliability	Scalability	Grouping	Terminal device
Consumer use	**Gaming**	1:1 / 1: m / n: m	low	Small (～10)	Necessary	Mobile
	Chatting /messaging	1:1 / n : m	low	small	Necessary	Mobile
	Gambling	1: m	high	Very large (～10000)	Necessary	Stationary / Mobile
	PAN	1:1	low	Small	Necessary	Mobile
	Home-Net	1:1 / n: m	high	Small	Necessary	Stationary / Mobile
	By-word-of-Mouth net	1:1 / 1: m	low	Small	Necessary	Mobile
Company use	**Business Meeting**	1:1 / 1: m / n: m	high	Small / Large(～100)	Necessary	Stationary / Mobile
	Conference support	1:1 / 1: m / n: m	high	Small/large	Not Necessary	Stationary / Mobile
	Information sharing	1: m	high	Small/large	Necessary	Stationary / Mobile
	Sales/Business support	1:1 / 1: m	high	Small	Necessary	Stationary / Mobile
	Spot vending	1:1 / 1: m	high	Small	Necessary	Mobile
	Work(Load) allocation	1: m	high	Small/Large	Necessary	Stationary / Mobile
	Shopping guide	1:1 / 1: m	Low/high	Small	Not Necessary	Stationary / Mobile
Public use	**ITS**	1:1 / 1: m / n: m	Low/high	Very large	Necessary	Stationary / Mobile
	Leisure spot guide	1:1 / 1: m	low	Very large	Not Necessary	Stationary / Mobile
	Emergency net	1:1 / 1: m / n: m	high	Large	Necessary	Mobile
	Ticket-less system	1:1 / 1: m / n: m	high	Very large	Necessary	Stationary / Mobile
	Tourism Guide	1:1 / 1: m / n: m	high	Large	Necessary	Stationary / Mobile

where people in automobile can enjoy the service of auto-drive, route information (congestion guide, navigation etc.). Reliability depends on the served information, while it is definitely indispensable for emergency support system where rescue teams on the scene and rescue center are collaborated for rescue activities.

In terms of the kind of terminal device in use at exampled applications, it is found that application system might make use of not only mobile device but also stationary computing machine which functions as a server. For instance, to take up gambling application from mobile node, there is one gambling server that is stationary computing machine to define a service group. The person who wants to do gambling accesses the server, joins the service group and enjoys it. The ticket-less system, where one fixed server defines service group to which a person with authorized e-ticket in mobile device can access, is controlled by fixed server.

Concerning communication model, almost examples include one-to-many and many-to-many model, which indicates that grouping concept is essential for ad hoc network system from the application point of view. In particular, property of dynamic topology in space and time makes grouping control indispensable. In the next section, we discuss the grouping concept.

4. Grouping concept and its necessity

4.1 Grouping concept

Grouping communication technique has two levels in ad hoc network system. One of them is ad hoc network group dealt with on IP layer, which is defined by MANET in IETF. Ad hoc network group is related to routing control of IP packet. That is why mediating node also is one of members of ad hoc network group. We call this kind of group "ad hoc group" hereafter. The other is application group that deals with application workgroup. This kind of group is closely related to application. On this definition, the mediating node is excluded from application group. Hereafter we call the group "workgroup".

4.2 Issues in dealing with grouping for application

We explain by taking up one of examples that ad hoc group control (IP Multicast group control) does not handle for application. Here imagine the chatting with friends at a public recreation spot. Each friend enjoys one of spectacles according to his/her own preference. Mobile device with chatting function probably connects other devices nearby that may be a part of ad hoc network of the spot. When I want to chat with friend*X* through my device, the device tries to look for the device of friend*X* by means of MAC and some routing method. In the case that the friend's device is by chance a member of the ad hoc network that my device participates in, I could reach friend*X* then enjoy chatting. However, let's think about the opposite case; the case that the friend's device does not touch the ad hoc network of my device by chance. In this case, I cannot reach him. From this example, it can be realized that ad hoc group control does not care who is workgroup member. It only takes care of members that joined ad hoc network. The shown case that a pair of device does not always belong to the same MANET often occurs in ad hoc network because of its dynamic nature of topology.

Moreover, even if the path exists by chance between me and friend*X*, the session property -response delay, throughput, logical link quality etc.- does not always be secured during exchange of message under topology change. When chatting contains exchange of video clip, session throughput and link quality must be guaranteed to certain level for practical use although those somehow depend on what kind of device is used.

Therefore, the progressing efforts on research and development of MAC and IP routing (especially multicast routing protocols) does not deal with Workgroup control and its session control. Summarizing the issues;

MAC and IP routing protocol;

(1) do not provide assurance of workgroup membership management. As a result, it is likely that some members are out of service. In MANET, compared with existing mobile network system, there is high probability that workgroup member will often change owing to its dynamicity.
(2) do not take care of the session property requested by application. As a result, application suffers deteriorated quality, which sometimes makes service unrealizable.

4.3 Proposed new architecture

As shown in previous discussion, workgroup control protocol to solve above the first problem and session control protocol to solve the second problem should be involved in ad hoc device as communication function. Workgroup / session control protocol is closely related with multicast routing protocol as well as application participants. Therefore, we propose in Figure 1 the new stack architecture for ad hoc network communication. Workgroup control might not be necessary for some applications.

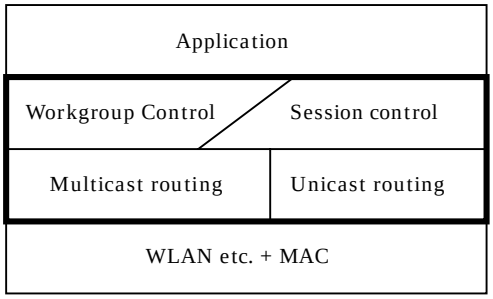

Figure 1 New stack architecture

5. Requirements of workgroup / session control protocol

5.1 Workgroup model tree

In considering of workgroup model, criteria for modeling are chosen through discussing examples of ad hoc network we showed in Table 1.

From the management point of view, the model is different from aspects of method of workgroup setup and the property of changeability of workgroup after its establishment which affects the way of maintaining it. Furthermore we study the aspect of workgroup setup by asking "Who and when defines the group?"

There are four criteria for workgroup modeling we selected; necessity of membership control (α), group formation timing (β), reusability of workgroup definition (γ) and changeability of network topology (ε). In the following how important these criteria are is explained through application scene.

Business meeting, for instance, has to be organized and proceeded by someone such as a chairman. In this

application, someone has to take care of participants in order to initiate and keep the group. Otherwise a meeting does not proceed properly in order. On the other hand, shopping guide service, which provides visitors information of goods, sales etc. to promote purchase, does not require the workgroup membership control. In this service, people voluntarily join and leave the shopping guide service group (area) freely. Nobody controls membership.

Concerning the timing of grouping, there are two ways; pre-definition and on-the-scene definition. Business meeting is often set up beforehand: its topic, participants, its place, its date etc. However, the group for chatting with friends or gambling is usually established on the spot.

The definition of workgroup membership shall be reused, for example, in case of periodical meeting. In the periodic meeting, participants hold the definition of workgroup name, its controller(organizer)'s name, other related participants etc. for the next meeting. At the next meeting, the process of group establishment shall be skipped. In this way, reusability of workgroup definition also influences the mechanism of workgroup setup.

With regard to workgroup changeability, it contains membership change by join/leave and spatial change of node, which result in topology dynamicity.

Figure 2 shows workgroup model tree from No.1 to No.16 classified by the selected four criteria. Each ad hoc application shall be identified to one or plural workgroup model tree.

5.2 Analysis of workgroup model

In this section, application examples of Table 1 are adapted to workgroup model tree of Figure 2 and we discuss which model could be feasible for ad hoc application.

Table 2 shows the classification of exampled applications of Table 1 by the four criteria for workgroup model considered on several possibilities. In this classification, Business Meeting application is identified as (α , β , γ , ε) = (Yes, Pre/Spot definition, Yes, Yes). Shopping or Leisure guide system is (α , β , γ , ε) = (No, Spot definition, No, Yes) since they are "hot spot service (broadcast)" type where people freely can join and receive information at special spot. People do not need to hold the definition of workgroup. The Tourism system, which supports the tourgroup connection and serves guide information or souvenir shop information etc., is usually one time temporary service, therefore, it is (α , β , γ , ε) = (Yes, Spot definition, No, Yes).

As a result of classification by those criteria, workgroup model that can be applied to each application is shown at Tree number in Table 2. Several applications correspond to plural models.

Accordingly, in Figure 2 more feasible models for ad hoc application workgroup are clarified. Namely, we can obtain the fact that the most potential Workgroup model are tree number 2, 3, 5, 6, 8 and 14, while tree number 9, 10, 11, 12, 13, 15, 16 has no corresponding application.

In case of the model No.14, MAC and IP multicasting protocol are enough to deal with this model because membership control is not necessary. Hence, this model is out of sight for our work.

Summarizing the model, there are three main models;

Model A (α , β , γ , ε) =
(Controlled member, predefined, reusable, changeable)

Model B (α , β , γ , ε) =
(Controlled member, spot-defined, no reuse, changeable)

Model C (α , β , γ , ε) =
(Controlled member, spot-defined, reuse, changeable)

We can say in other words that workgroup Model A is the group of family type, that Model B is the group of the persons with the first time meeting and that Model C is the group of friends.

5.3 Session control protocol

All workgroup models in the previous section contain a

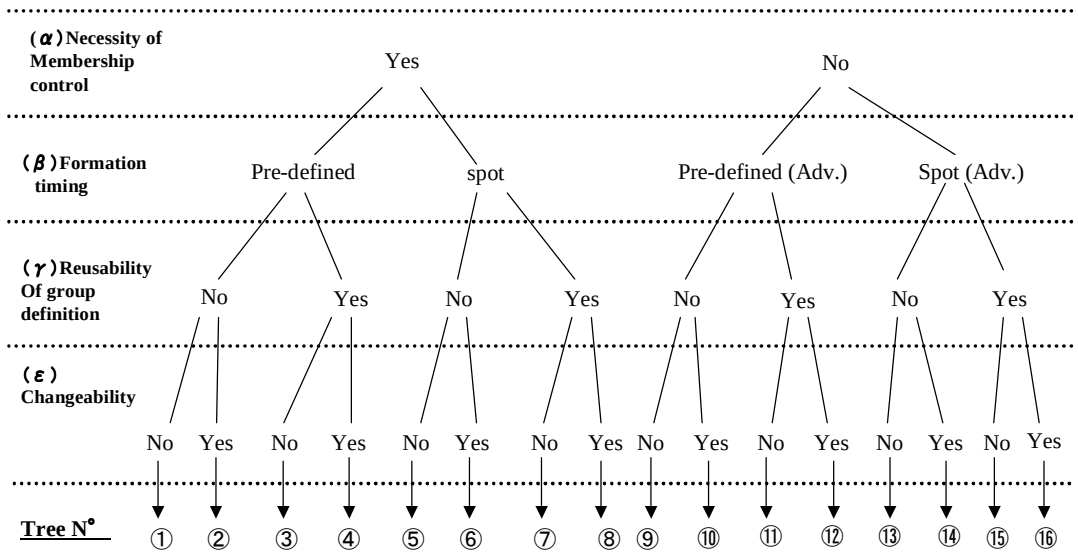

Figure 2 Workgroup model Tree

function of controlling workgroup member, which indicates the session control for workgroup is essential.

In MANET, session control is more important than that of existing network because its dynamicity affects easily the session link, which results into session break, instability of link and so on.

Its dynamicity of network topology makes the existing session protocol difficult to adapt to ad hoc network. SIP (Session Initiation Protocol) [20], for example, is regarded as one of elements for multimedia Internet infrastructure. Its flexibility with other Internet protocols and its easiness of function extension lead essential session protocol in particular for IP telephony.

SIP assumes two types of network server that are proxy server and redirect server. User client should know in advance the location of network server of destination. In order to deal with terminal mobility issue, SIP network server or location server (if any) has to hold location information of the sub-network where user client might move. However, in MANET, there isn't either fixed network server or location server. And user sometimes is unable to acquire the location information of a destination due to its arbitrary mobility.

So far there isn't session protocol that can handle the dynamic and vulnerable environment in session. Therefore a new session protocol is required for realization of MANET application targeted on workgroup models.

The main target of session control shall include the function of maintaining session link among workgroup members to gain session reliability under dynamic topology. For the purpose of reliability, session control must include the below functionality at least;

(1) Session monitoring and probing the session connection
Periodically session manager node keeps an eye on the session connection, while workgroup member node by itself also checks the group communication. Session manager which may trace session quality and performance may be initiator of application.

(2) Discovery of session service after break
After topology change, the breakdown of session to some members may occur. In this case, session manager and hanging members should try to search by any means the lost session that they have enjoyed previously.

(3) Recovery of the session and lost data
Upon discovery, sender or hanged members is to re-establish the session and rejoin the previous workgroup. In case of losing data during break, recovery of data has to be processed to gain consistency of application.

6. Conclusion

We showed the potential MANET applications and discussed protocols from the application point of view. As a result of discussion, many MANET applications would be served in the mode of group communication which has two aspects, ad hoc Group for IP routing and Workgroup for application. In this paper, we proposed new stack architecture for MANET application to be able to handle workgroup and session for topology dynamic, and then discussed the requirement for workgroup model and session control.

Table 2 Classification of Workgrouping

	Application	Workgrouping				Workgroup Model Tree #
		Necessity of Membership Control(α)	Formation Timing (β)	Reusability of group definition(γ)	Topology Changeability (ε)	
Consumer use	**Gaming**	Yes	On the spot	Yes	Yes	⑤⑥⑦⑧
	Chatting /messaging	Yes	On the spot	Yes	Yes	⑥⑧
	Gambling	No	On the spot	Yes	Yes	⑭
	PAN	Yes	Predefined	Yes	No	③
	Home-Net	Yes	Predefined	Yes	No	③
	By-word-of-Mouth net	Yes/No	On the spot	No	Yes	⑥⑭
Company use	**Business Meeting**	Yes	On the spot/ Predefined	Yes	Yes	①②③④ ⑤⑥⑦⑧
	Conference support	No	On the spot	No	Yes	⑭
	Information sharing	Yes	Predefined	Yes	No	②④
	Sales/Business support	Yes	On the spot/ Predefined	Yes	Yes	③⑥⑦⑧
	Spot vending	No	On the spot	No	Yes	⑤⑥
	Work(Load) allocation	Yes	Predefined	Yes	Yes	①②③④⑤⑥
	Shopping guide	No	On the spot	No	Yes	⑭
Public use	**ITS**	Yes	On the spot	No	Yes	⑥
	Leisure spot guide	No	On the spot	No	Yes	⑭
	Emergency net	Yes	On the spot	Yes	Yes	⑥⑧
	Ticket-less system	Yes	On the spot	Yes	Yes	⑥⑧
	Tourism Guide	Yes	On the spot/ Predefined	No	Yes	②⑥

In the next step, we develop the new workgroup / session control for MANET application. Then we will compare with the existing method (SIP etc.).

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