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변동성이 높은 이동 애드 혹 네크워크를 위한 적응적 다중 라우팅 프로토콜 적용 기법

(Adaptive Multi-routing Protocol for a High Mobility MANET)

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(Deepak G.C., Heo Ung, and Jaeho Choi)

요 약

네트워크의 토폴로지 변형, 모바일 노드의 이동 모델 및 지형의 조건 등은 이동 애드 혹 네트워크 라우팅의 불확실성을 높이는 주요한 요소들이며 또한 네트워크의 성능을 제한하는 요소들이다. 본 논문에서는 애드 혹 네트워크의 효과적인 라우팅 방법을 살펴본다. 특히, 노드의 이동 속도가 높은 애드 혹 네트워크 통신 환경에 적합한 라우팅 프로토콜 지원 아키텍쳐를 제안하다. 이 모델은 다중의 라우팅 프로토콜을 네트워크의 특성의 변화에 따라 가장 적합한 라우팅으로 변환할 수 있는 적응적 기능을 가지고 있다. 여러 종류의 특성 파라미터 중에서 본 논문에서는 이동 애드 혹 네트워크를 구성하는 노드의 커버리지, 연결성, 이동성을 사용하여 삼차원의 라우팅 프로토콜 변환 환경을 정의하였다. 수치적 실험 결과에서 제안한 다중 라우팅 프로토콜이 네트워크의 환경 변화에 적응적으로 대응하는 성능을 보유하고 있음을 확인하였다.

Abstract

When there is uncertainty in topological rate of change, mobility model and terrain condition, the performance severely degrades in MANET. The concept of transition of routing protocol on the fly according to the network parameters such as coverage, connectivity and mobility etc. may counterbalance the problems stated above. The mathematical modeling of feedback parameters has been derived, and the architecture for the multi-routing protocol system providing an adaptation from one routing protocol to another is also.investigated. This paper is extensively devoted on the analysis of mobility, connectivity and their effects on the network and finally transition into another routing protocol according to them.

Keywords: Adaptability, MANET, Multi-routing protocol, Mobility, Self-configuration

I. Introduction

Mobile Ad Hoc networks are such networks in which autonomous sets of mobile nodes are dynamically connected via wireless links without using an infrastructure network. Due to the dynamic nature of Ad Hoc networks, the allocated resources in priori are not matched with the requirement and the method of communication between them cannot be fixed in priori. Because the mobility model of nodes is random way point, the mobility function defined in terms of time cannot be formulated exactly. In such a flexible network, there must be some flexibility to choose a suitable routing protocol from a protocol box which is defined later. Therefore, an adaptive multi-protocol system should be developed, which transits into appropriate mode of protocol. However, the term multi-mode is different from the multi-protocol. In the former, the network is segmented and each segment has different routing policy and duty the second one is what we have

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proposed here.

It is clear from a circuit theory that the feedback system is more stable because it is able to adapt in any changing environment. Our proposed scheme will use the same concept on protocol design so that it can perform well in various conditions without performance degradation. Since all routing protocol can function well only under particular environment, they are categorized into different classes and sub-classes. One can refer [9] for a brief classification of routing protocols. We will discuss some of them here in short which we are going to implement. In [1], Multi-Mode routing protocol has been described considering two algorithms namely Limited Link States (LLS) and Self Organized (SO). This paper has proposed a reference area concept as the closer to the destination a node is, the more information related to that destination it will have. But it does not consider what happens when the destinations move out of the reference area. The packet move here and there if we do not change the routing protocol, instantly.

The collaborative management of MANET, which calculates a capability function [3] as an optimizing factor, is a self-configuring strategy. The service discovery as a multi-protocol framework [2] has designed a common architecture for an individual discovery protocol to enhance configuration and re-configuration of the network, which is just a core framework and does not deal with the decision support parameters. The ref. [5] has described adaptable ad hoc routing experience as LID and Pattern Extraction mechanism, which is merely an extension of [1], but has described views of an adaptable architecture as structure learning/engaging modules. The Terminode Project [6] basically operates on a self-organized mobile Ad Hoc Network and even explores interlayer interactions. Here, the Self-Organized networks are defined as a network run solely by the end users. The AutoCom principle [7] addresses some requirements of self-organized networks as well as interoperability problems due to merge and split problems. It has proposed a heterogeneous routing protocol as a solution. The combination of Stateless Configuration Initialization (SCI) and Configuration Conflict Detection and Resolution (CCDR) is proposed in [10]. Here, it is assumed that some nodes may work on two routing protocols if both routing protocols are operated on neighbors, simultaneously. It is not significant way of auto-configuration because of the high cost of hardware and software to maintain a duality.

The remainder of the paper is organized as follows. Section II presents routing scenarios for Ad Hoc Networks. Section III discusses our proposed scheme which is further divided into three sub-sections: namely, adaptable module, configuration parameters and configuration beacon. Section IV describes an analysis of the overall modules. Section V discusses some of implementation issues. The paper draws conclusions in Section VI with discussions on some future works.

II. Routing Scenario

For a pair of ad hoc network nodes, the communication will occur between them over a period of time until the session is finished or one of the nodes moves away; or the battery backup power diminishes. An efficient routing protocol must support load balancing of traffic. So, each node needs some knowledge of network topology beyond the local neighbors. This concept attempts to collect and process that knowledge efficiently. Most of routing protocols assume that the nodes have homogeneous resources and capabilities. The bidirectional links are often assumed.

No single protocol works well in all environments. Some attempts are made to develop adaptive/hybrid protocols. The proactive protocols are based on periodic updates, which involve a high routing overhead. In the reactive protocols, the source initiates route discovery and determines route time-to-time basis. The hybrid is a combination of reactive and proactive. Even though it is adaptive, it does not change protocol when the network is working. The curious readers can refer [9] and [11] for further details and comparison. Algorithms that are computationally complex however require significant processing cycles. So, we have chosen well studied and easy to implement routing protocols in our adaptive modules. These protocols are DSDV, ZRP, TORA, and AODV respectively. All routing protocols are invalid when the network connection ratio (NCR) is smaller than unity. Because of this condition, no protocol is implemented for NCR < 1. Some properties concerning each routing protocol are given below:

Destination Sequence Distance Vector (DSDV): This routing is needs periodic update transmissions and guarantees loop free paths. The latency of route discovery is very low because the source uses a ready-made route to a valid destination. For the network with highly dynamic nodes, this protocol should be avoided otherwise, the bandwidth will be wasted due to excessive control overheads. It is suitable for a network with high bandwidth, low mobility, and lower number of nodes.

Ad Hoc On-Demand Distance Vector (AODV): This routing protocol searches routes to destination when source needs to communicate. It is less secure because of its distributed nature. Though its performance is not satisfactory when nodes are highly mobile, however, it is better than DSDV. Moreover, it is more scalable because the control overhead is lower by just keeping information about the destination.

Zone Routing Protocol (ZRP): This routing is a scalable and highly efficient method. Its performance comes between reactive and proactive protocols.

Temporally Ordered Routing Protocol (TORA): TORA has advantage to support multiple routes. It performs in a dynamic mobile networking environment. It has loop free, distributed, and on-demand properties. It allows a route to be created and maintained proactively for some destinations while reactively for others. This protocol needs synchronized clock and requires an extra device such as the GPS.

Ⅲ. Proposed Method

Therefore, the protocols should be configured on the fly as it can be dynamically started up and closed down at runtime. The auto-configured routing protocol should adapt itself to the present network conditions considering the traffic level and patterns as well as the mobility patterns of whole network. They are necessary but not sufficient conditions because the larger the number of decision parameters we measure, the better will be the performance.

1. Configuration Parameters

The first parameter considered is the network coverage ratio. Given the networking field of a certain size, this gives basic idea how the nodes are connected and distributed uniformly all over the field so that any part of the field can be reach. The coverage ratio is defined as follows:

$$W=\frac{\hat{d}\cdot\sum_{n=1}^{N}\sum_{i\in\Delta_n}A_n\cap A_i^n}{|A_T-\bigcup_{j=1}^{N}A_j|} \tag{1}$$

Where A_T is the networking field of a certain size less than a few square kilometers, A_k is the average transmission area covered by a node k; N is the number of nodes in the network; Δ_n is the set of neighboring nodes connected to the node n; $\hat{d}$ is the average distance among the nodes in the network field:

$$\hat{d}=\frac{1}{\left(\frac{N-1}{2}\right)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}|\overrightarrow{n_i}-\overrightarrow{n_j}| \tag{2}$$

$$\check{d}=\begin{cases}\hat{d}\ obtained\ \text{for}\ |\overrightarrow{n_i}-\overrightarrow{n_j}|\le\tilde{r}\\ 0\ \text{for}\ otherwise\end{cases}$$

where $|\overrightarrow{n_p}-\overrightarrow{n_q}|$ is the distance between the nodes p and q, $\tilde{r}$ is the average transmission range of a node, and $\check{d}$ is the average distance among the nodes with strong connection. Furthermore, the union and intersection of transmission areas are defined as follows:

$$\bigcup_{i=1}^{N} A_i = A_1 \cup A_2 \dots\dots \cup A_n \tag{3}$$

and,

$$\begin{aligned}\sum_{n=1}^{N}\sum_{i\in\Delta_n} A_n \cap A_i^n = &\{A_1\cap A_i^1 + A_1\cap A_{i+1}^1 + \dots + A_1\cap A_{i+\Delta_1-1}^1\} \\ &+\{A_2\cap A_i^2 + A_2\cap A_{i+1}^2 + \dots + A_2\cap A_{i+\Delta_2-1}^2\} \\ &\cdot \\ &\cdot \\ &+\{A_N\cap A_i^N + A_N\cap A_{i+1}^N + \dots + A_N\cap A_{i+\Delta_N-1}^N\}\end{aligned} \tag{4}$$

The intersection area between two nodes is determined as follows [12]:

$$A_i \cap A_j = 2\tilde{r}^2\left[\cos^{-1}(x) - x\sqrt{(1-x^2)}\right] \quad \text{for } x = \frac{|\vec{n_i} - \vec{n_j}|}{2\tilde{r}} \tag{5}$$

Equation (1) indicates that the coverage ratio is proportional to the average distance $\hat{d}$, and it is also proportional to the amount of intersection areas that are covered by neighboring nodes. The value of W can be specifically controlled by the transmission range of a mobile station that can be increased or decreased. If so, it becomes a power control routing mechanism, which has been described in large volume of previous research works. However, we follow a different way since adaptive transitions between protocols may not be easy, if not impossible, just by considering the transmission range. Instead, another new parameter is developed here for making a protocol selection criterion. Fig. 1(a), 1(b), and 1(c) show the conditions for different value of W. In Fig. 1(a), it shows the node connection topology that the communication is not possible in Fig. 1(b), nodes connected but they provide a low coverage with smaller intersection areas among the nodes and Fig. 1(c), the proper communication can be done between the nodes.

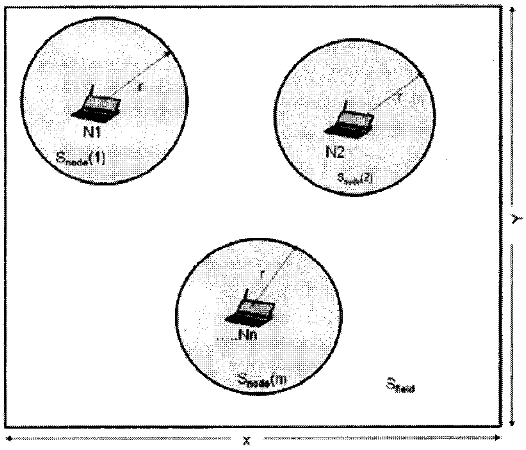

그림 1(a). 커버리지가 없는 토폴로지
Fig. 1(a). No coverage topology.

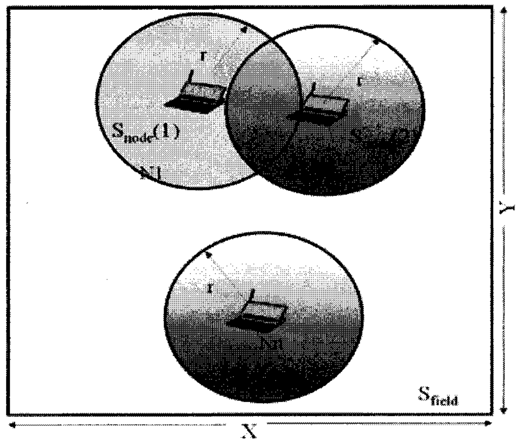

그림 1(b). 커버리지가 낮은 토폴로지
Fig. 1(b). Low coverage topology.

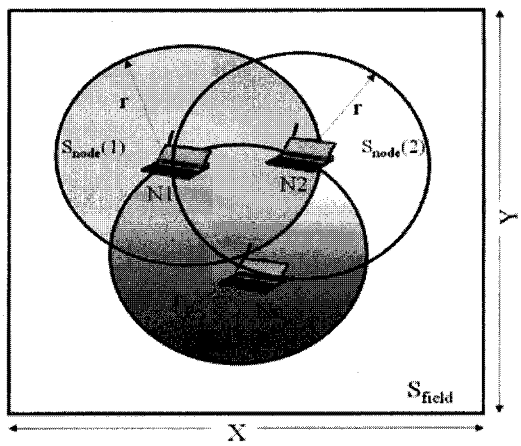

그림 1(c). 커버리지가 높은 토폴로지
Fig. 1(c). High coverage topology

Now, the second parameter considered is the connectivity. Given the networking field, the connectivity determines how closely the nodes are connected together, i. e. the number of neighbor nodes with good connection [4]. Both connectivity and coverage ratio are two major factors closely related to provide critical routing criteria for the multi-routing protocol system. It may also be reasonable to say "Good coverage means good connectivity." The connectivity is defined in terms of the coverage ratio W and the average distance among the nodes $\hat{d}$ as follows:

$$C = \frac{\sum_{n=1}^{N} \sum_{i \epsilon \Delta_n} A_n \cap A_i^n}{\hat{d}} \tag{6}$$

This parameter indicates whether the communication is possible among the nodes and helps to determine a particular instant of choosing a better-fitting routing protocol. Because the higher connectivity is always desirable in networking, the connectivity needs to be maximized with respect to the power constraint or network resource constraint. To check the validity of equations, equation (2) is first simplified.

$$\hat{d} = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{\left|\overrightarrow{n_i} - \overrightarrow{n_j}\right|}{2r} 2r \tag{7}$$
$$= \frac{4xnr}{N-1} \text{ for } n \geq 2$$

It is assumed that all the nodes have an equal transmission range r and isotropic pattern of antenna such that the coverage area becomes circular. For relatively large number of nodes, $N \simeq (N-1)$, then the average distance $\hat{d} = 4xr$, only depends on radius of coverage and distance between two nodes I and j. Putting values of $\hat{d}$ and intersection area from equation (5) into equation of connectivity and testing when it becomes zero, we can get following results:

$$C = \frac{2\tilde{r}^2 \left[\cos^{-1}(x) - x\sqrt{1-x^2}\,\right] N \Delta_n}{4xr} = 0 \tag{8}$$
$$\cos^{-1}(x) - x\sqrt{1-x^2} = 0$$

Equation (8) is satisfied if x=1 which means (r/2R) = 1 and finally r = 2R. Where r is distance between nodes i and j and R is radius of area of coverage of nodes. In conclusion, C=0 when distance between two nodes is equal to summation of their radius, i.e, their area of coverage just touches each other. This satisfies the above relations. Figures 1(a), (b) and (c) show the different scenario of topology and the communications is very effective in last topology and is always expected.

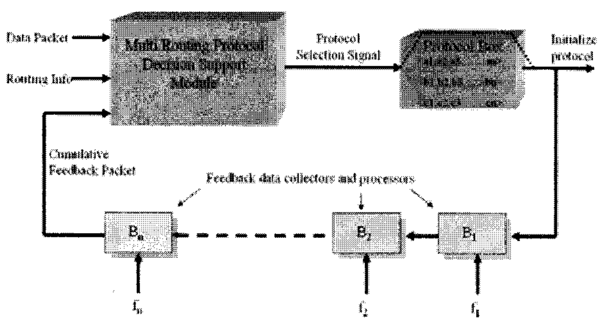

그림 2. 적응적 다중-라우팅 프로토콜 아키텍처
Fig. 2. Architecture of adaptive multi-routing protocol.

2. Adaptable Module

The architecture of auto-configuration routing module is shown in Figure 4. The Multi-Routing Protocol Decision Support Module is provided by data packets and CONF_Beacon packet. The module gets either data or beacon at a time by some switching mechanism between them. Generally, CONF_Beacon is transmitted first throughout the network and this is called configuration session. Once the system is stable, the data packet transmission session starts. The time it takes to enter from first session (configuration) to second session (data transmission) depends on the network size, CONF_Beacon length, and bandwidth of the network.

As shown in Figure 2, there are n feedback modules referred to a Decision Support Function. They are denoted by {f1,f2,f3,……,fn} and the corresponding processing modules are {B1,B2, ……,Bn}. Here, the functional parameters fi , i=1,2 ,…,n, can be number of nodes, transmission range, or mobility patterns, etc. All the calculations are performed in Bi, i=1,2,...,n, which are shown in Eqs. (1) - (5). All these parameters go into the multi-routing protocol decision support module as cumulative feedback packets. This module decides more suitable routing protocol on the present scenario. It then designs CONF_Beacon control packet and data packet, appropriately.

The Protocol Box is a fairly simple module which keeps track on routing protocols. It stores the control frame format of each protocol to be used in future. When it gets hints about the very next protocol to be used, it generates CONF_Beacon and broadcasts it. After some specified time period, it sends control packets. The dotted line in the module means that it keeps on working on the same protocol unless it gets another control packet to change the protocol. The same algorithm runs on each node so that there will be a same decision throughout the network.

3. Configuration Beacon

When there is transition from one routing protocol to another, all neighbor nodes are informed first. Because of this signaling, a network layer beacon has to be defined, which carries information regarding the appropriate protocol changes. This beacon is named as the configuration beacon (CONF_Beacon) and is designed as shown in Figure 5. This beacon is broadcasted most of the time, i. e. at the initial point where the protocol transition is going to happen. Due to the mobility of nodes and without any fixed infrastructure of mobile ad hoc network, a neighbor node may not be informed well in the case a node joins network lately. At this situation, the beacon is unicasted only to that particular node. The beacon fields in bits are described follows:

B/U (4) - indication for broadcast or unicast: if the packet is a broadcast type, the third field Dest_ID is not present in the frame. Iffewer nodes need to be informed, the unicast is appropriate one:

S_ID (32) - 32-bit IP address of the sender node: the assignment of IP address is beyond the scope of this work. Instead, it is assumed that the address management protocol is provided in the system.

1	32	32	8	8	4	8	8	Bits
B/U	S_ID	R_ID	Old_P	New_P	M	Seq_Num	TTL	

그림 3. 자가 구성 비콘의 프레임 포맷

Fig. 3. Frame format of AUTO_Conf beacon control packet.

R_ID (32) - 32-bit IP address of the receiver node: It is absent if the first field indicates that the packet is broadcasting type.

Old_P1 (8) - the current routing protocol.

New_P2 (8) - the selected adaptable routing protocol.

M (4) - the indication for protocol transition method.

BC_Id (8) - broadcast identity field: it avoids loop formation. When a node generates this CONF Beacon, this field is incremented by one. If a node receives a beacon having the broadcast id, which it has already broadcasted, is simply discarded. It is reinitialized when it reaches to maximum value.

TTL (8) - time to live field: it is decremented each time a node relay this packet to its neighbors. The beacon having TTL field zero is discarded. The value of this field is determined according to the size of network.

IV. Analysis

One of the major issues is to minimize transition time from one protocol to another. There are a lot of factors which plays vital role to maintain transition time. Those include processing capacity, memory unit, information acquisition of feedback module, however, but we do not mention them here. In this analysis, we are focused to the issue regarding the configuration beacon.

Field R_Id is not needed for broadcasting and it is known by the first field B/U. in this case the frame size is 72 bits. For the unicast with Nb=1, the frame size is 72+32 bits, where Nb is the number of neighbors nodes to be broadcasted. Sometimes, a node may have to inform to some of the neighbors in the case a few nodes join the network a few moments later. It takes more time to make them informed about the routing protocol changes by sending the unicast packets. The limited-broadcasting may be a better idea for information dissemination to limited number of users. For example, with Nb=5, the frame size increases and becomes 72+32(5) bits.

Considering a mobile device with a data rate 2 Mbps, then Tc the minimum ideal time needed to change the routing protocol from one to another is as follows assuming δ represents the transmission and processing delay:

For Broadcasting, Tc = (36+ δ) μsec

For Unicasting, Tc = (51+ δ) μsec and

For limited broadcasting (say 5 nodes), Tc = (116+ δ) μsec

V. Implementation Issues

The investigated self-organizing network and its auto-configuration routing protocol design are drawing immense attention because it is new and emerging field in ubiquitous and mobile computing. When considering implementation of architectural modules and their procedure, there are two important issues to discuss.

The external issues deals with the parameters required for internodes communication. The important one is "data gathering module." It may be a sensor or actuator, which feeds bandwidth requirements, speed of nodes, coverage area of nodes, N as inputs to Bi ,i=1,2,..,n. Another issue is to design the frame size. There must be a compromise between a larger frame size and the amount of bandwidth for broadcasting. If the packet type is unicast, there must be a field indicating the IP address of destination. For the existing IPv4 addressing scheme, the beacon size is increased by at least 32 bits plus other additional information. This dilemma makes system design and implementation more complex.

VI. Conclusions and Future Works

The recent development in ad-hoc networking is fast growing and a large amount of literatures are accumulating. In key point of the proposed scheme is not to design new one but to use existing protocols in efficient way. With that strategic point in mind, our investigation has been focused on how to collect parametric information and use them to adaptively control the routing protocol from one to another on a fly depending on various network conditions and scenarios. Few network parameters provide the basic building block of our multi-routing protocol method

In addition, we have designed configuration beacon frame format and also presented the length of the control and data packets under the consideration of protocol change decision time and the network bandwidth.

In our best understanding, a scheme to change the routing protocol according to feedback parameters is first time proposed here. By fully extending the investigation, we expect more new ideas can be derived. Specifically, we need to obtain a better design on multi-protocol decision module that can comprehensively model the dynamics of ad hoc network. Some exotic techniques such as neural networks and/or fuzzy logic theory can also be adopted for such purposes.

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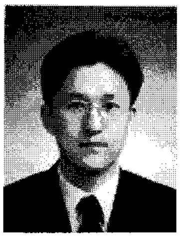

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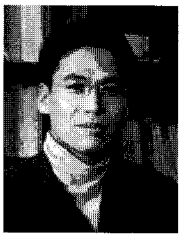

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