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A Novel Adaptive Routing Scheme for the QoS-Based Multimedia Services in Mobile Ad-Hoc Networks

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Abstract

A mobile ad-hoc network is composed of only mobile nodes, which are distributed dynamically, without any wired backbone or centralized entities. Since the existing works on ad-hoc routing protocol are mostly biased toward a military application, we need a new routing scheme for a support of multimedia services in mobile ad-hoc networks. Therefore, we propose a novel scheme that can support a variety of traffic attributes and can be applicable to high-speed and multimedia data services in mobile ad-hoc networks by using adaptive transmission power level. As a result of simulation, the proposed scheme has better performance than conventional method, which is performed with uniform transmission power level, in view of route query delay time.

Ⅰ. Introduction

A mobile ad-hoc network is a multi-hop wireless network in which mobile hosts communicate over a shared, limited radio channel. In general cellular networks, there are a number of centralized entities, such as BS (Base Station), MSC (Mobile Switching Center), HLR (Home Location Registry) and so on. These centralized entities perform the function of coordination. But a mobile ad-hoc network is characterized by the lack of a wired backbone or centralized entities. Thus, in ad-hoc networks, we need more sophisticated distributed algorithms to perform these functions of coordination. Specially, the conventional algorithms for mobility management, which rely on the HLR/VLR and the MAC (Medium Access Control) schemes, which rely on the BS/MSC support, cannot be used here [1].

In ad-hoc networks, since all communications between all network elements are carried within limited resources, we have many constraints on the efficient network management; *e.g.*, conservation of wireless spectrum and reduction in transmission power. Thus, for communication between two entities in ad-hoc network, we have to apply multi-hop routing to be relayed through intermediate nodes. In addition, since the network topology is changed rapidly in ad-hoc networks, it is very significant and difficult problem to find and maintain the optimized route. Therefore, ad-hoc routing algorithm must react quickly to topology changes.

The architecture of an ad-hoc network can be either *hierarchical* or *flat* [1]. In a hierarchical network, the network elements are partitioned into several groups, called *cluster*. And in each *cluster*, there is a cluster *head*, which is selected to manage all the other nodes

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within the cluster. The depth of the network can vary from a single tier to multiple tiers. In a flat network, all nodes have equal rank. After all, flat networks are equivalent to zero-tier hierarchical networks. Examples of two-tier hierarchical network and flat network are shown in Figure 1 and Figure 2.

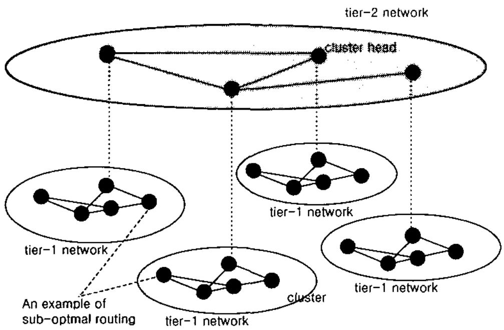

Figure 1: A two-tier hierarchical ad-hoc network

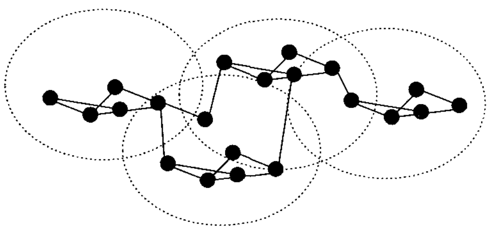

Figure 2 : A flat ad-hoc network

Hierarchical network architecture can accomplish the mobility management process more easily, but routing is often sub-optimal because of the lack of direct connectivity between the two different cluster heads. On the other hand, the most important advantage of the flat network is that there are multiple paths between source and destination. This allows congestion reduction and we can choose the best route to satisfy the specific requirements of a traffic attribute. In other words, QoS-based routing is possible. That is, while flat addressing may be less complicated and easier to use, there are doubts as to its scalability.

There are many applications of the mobile ad-hoc networks; *e.g.*, tactical military communication, disaster recovery operation, commercial installation, home/office network and so on. Recently, the commercial use of ad-hoc networking has received an increased attention. In particular, the interest in ad-hoc LAN (Local Area Network) construction technology for the home/office network is increased, and the most important requirements of ad-hoc LAN are the support of multimedia services and a variety of traffic attribute, that is, the guarantee of QoS (Quality of Service). But since previous works are mainly carried out on military applications, it is not enough to apply those results to commercial usage without any modification. Also, there is no consideration for guarantee of QoS even in the conventional works on non-military application. Thus, in this paper, we propose a novel routing protocol for QoS-based multimedia services in mobile ad-hoc network. For real-time traffic, such as voice or urgent data traffic, we can find the optimized route more quickly because transmitting a query request using higher power decreases the number of hops. On the other hand, for non real-time traffic, such as data traffic, which is insensitive to delay, we can apply smaller transmission power. So we can provide more reliable data services.

The rest of the paper is organized as follows. In Section 2, we present existing ad-hoc routing protocols. In Section 3, we explain our proposed scheme, and in Section 4 and 5, we analyze the performance of our proposed scheme through simulation. Finally, conclusions are given in Section 6.

Ⅱ. Existing Ad-Hoc Routing Protocols

The primary goal of all the routing protocols is correct and efficient route establishment between two nodes within the network. In particular, in ad-hoc networks, route construction should be done with a minimum of overhead and bandwidth consumption because of shared and limited resources.

In general, as shown in Figure 3, the existing routing protocols can be classified into either table-driven or demand-driven method [2]. Table-driven protocol attempts to evaluate the route continuously and maintain routing information from each node to every other node within the network, so that when a packet needs to be forwarded, the route can be immediately used. An example of a table-driven protocol is the family of Distance-Vector protocols; *e.g.*, the Destination-Sequenced Distance-Vector Routing (DSDV), the Cluster-head Gateway Switch Routing (CGSR), the Wireless Routing Protocol (WRP) and so forth. Demand-driven protocol, on the other hand, creates routes only when desired by the source node. Thus, when a node requires a route to a destination, it initiates a route discovery process. There are many examples of demand-driven protocol as follows; the Ad-Hoc On-Demand Distance Vector Routing (AODV), the Dynamic Source Routing (DSR), the Lightweight Mobile Routing (LMR), the Temporally Ordered Routing Algorithm (TORA), the Associativity-Based Routing (ABR), the Signal Stability Routing (SSR) and so on [3-5].

The advantage of table-driven scheme is that there is little delay until the route is determined, but this scheme is not appropriate for ad-hoc network environment because of excessive network capacity to keep the routing information. Since both bandwidth and battery power are scarce resources in mobile computers, this becomes a serious limitation. In demand-driven scheme, the delay to determine a route can be quite large. Thus, it cannot be applicable to real-time communication.

In addition, there is a hybrid table-driven/demand-driven routing protocol. An example of such a protocol is the Zone Routing Protocol (ZRP) [6]. This protocol limits the scope of the table-driven procedure only to the nodes local neighborhood, called *zone*. On the other hand, the search throughout the network is performed by efficiently querying only selected nodes, *i.e.*, nodes on the boundary of its zone, as opposed to querying all the network nodes.

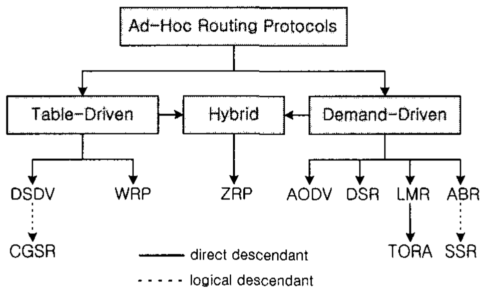

Figure 3. Classification of ad-hoc routing protocols

As mentioned above, the routing algorithms for ad-hoc network environment can be categorized as table-driven and demand-driven. Thus, we could know the facts that the pure table-driven scheme cannot be applicable to ad-hoc network and the pure demand-driven scheme is inefficient to support a real-time communication. And the ZRP, which is a hybrid routing protocol, has been proposed in order to complement the drawbacks of each protocol. But since there is no consideration for QoS-based multimedia services, it is not proper to apply the traditional routing schemes to mobile ad-hoc LAN environment for home/office network. Thus, we propose the novel algorithm which guarantee QoS based on various traffic streams. The details of the proposed algorithm are given in Section 3.

III. Proposed Routing Algorithm

In order to provide multimedia services in ad-hoc network, we consider an attribute of multimedia traffic.

When an urgent data or voice traffic is applied, we should support a real-time transmission since it is most important to reduce route query response time. In this case, we use a larger transmission power level. In other words, the number of nodes that can communicate with source node directly is increased. At first, the source node, which receives the route query request, scans all the nodes within its coverage area. If we cannot find the destination node, we choose several furthest nodes in the coverage area of source node. And then, for each chosen node, we carry out the node selection process repeatedly until the destination node is founded in coverage area of the chosen node, of course, excluding the area covered by previous node. After all, multiple paths from source to destination are generated, and we can obtain the optimal route by selecting path that has the fewest number of hops among all the paths. Therefore, an average route query response time is reduced because of the decrease of the number of hops. On the other hand, for a non real-time data traffic, which is insensitive to delay, we can use a smaller transmission power level. A detail process of this algorithm is shown as Figure 4.

In Figure 5, we can see an example of the proposed routing algorithm. Solid lines in this figure represent optimal route (S-B-F-T) for real-time traffic, while dotted lines depict optimal route (S-A-C-D-E-G-T) for non real-time traffic. As shown, we can reduce the number of hops with a larger power level in the case of real-time transmission. Of course, it is possible to find another optimal path because there are multiple paths from source to target.

IV. Evaluation of the proposed scheme

In this section, we analyze the performance of the proposed scheme through simulation. We use the

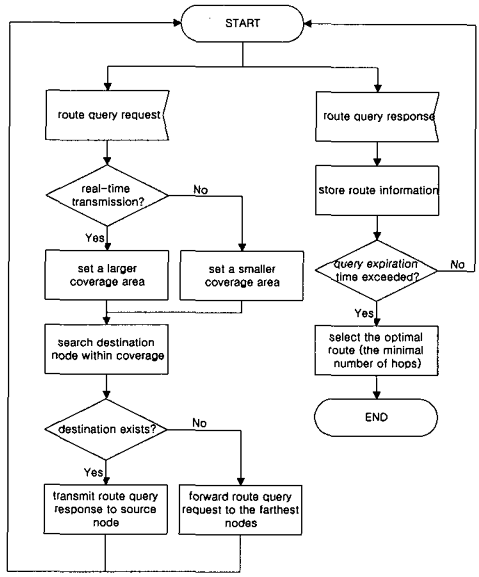

Figure 4. A flow chart of the proposed routing algorithm

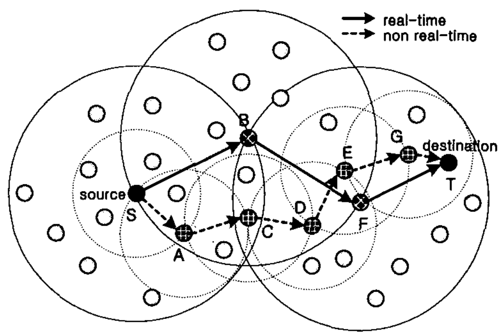

Figure 5. An example of the proposed routing algorithm

Cadence BONeS™ Designer network simulator, which is an event driven simulation package.

The simulation parameters are shown as Table 1.

Our simulated network consists of 5 - 30 mobile nodes, whose initial positions are chosen from a uniform random distribution over an area of 15 [m] by 15 [m]. All nodes move at a constant speed, v, with an initial direction, θ, which is uniformly distributed between 0 and 2π. Direction is measured as an angle relative to

Table 1. Simulation Parameters

Parameter (Symbol)		Value
Network coverage area (A)		15 [m] 15 [m]
Number of nodes (n)		5 10 15 20 25 30
Speed of nodes (v)		Uniform distribution 0 3 [m/sec]
Initial direction of nodes ()		Uniform distribution 0 2 [rad]
Transmission radius (rTx)	Real-time	11 [m]
	Existing scheme	10 [m]
	Non real-time	9 [m]

the positive *x*-axis. When a node reaches the edge of the simulation region, it is reflected back into the coverage area, by setting its direction to -Θ (horizontal edges) or π - Θ (vertical edges). The magnitude of the velocity is not altered. These simulation conditions are due to mobile ad-hoc LAN environment for home/office networks.

The simulation of the proposed scheme is based on the assumption that the network topology remains constant over the duration of a route discovery. Also, we assume that there is no MAC layer channel contention. This assumption prevents the delay measurements from being biased by the delays associated with any particular MAC collision avoidance scheme. In addition, we assume that any packet can be received, error-free, within a radius of r_{Tx} from the transmitter, but is lost beyond r_{Tx}. Here, r_{Tx} is the radius of coverage area for each node

V. Performance Results

Results of our simulation are presented in the following Figure 6.

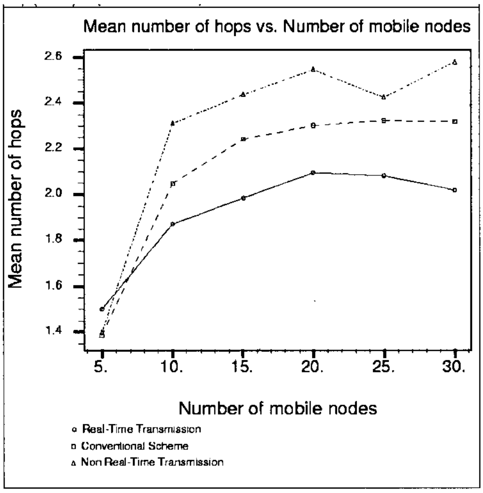

Figure 6. Mean number of hops vs. Number of mobile terminals

In Figure 6, for real-time transmission, mean number of routing hops is smaller than conventional scheme, that is, the route query delay time is reduced. Since we use a higher transmission power level, the coverage area of each mobile node is extended. Thus, it makes possible to reduce mean number of routing hops. Meanwhile, for non real-time transmission, on the contrary, the characteristic of delay performance changes for the worse. Moreover, as the number of mobile terminals is increased, mean number of routing hops is also increased.

As especially remarkable result, when the mobile node distribution is very thin, we can observe that mean number of hops for real-time transmission is rather larger than conventional case. When there are few nodes in local area network, the possibility of successful routing is relatively low and most established routes are also limited to neighboring nodes. But, if coverage area is larger, we can find further target nodes, which cannot find with low transmission power level. Thus, mean number of routing hops for real-time transmission is larger because the possibility of route establishment is higher. Of course, as the mobile node density becomes larger, the feature of route query delay reverts to the predicted result.

In addition, considering route dropping rate, caused by a backward search, a loop-back search or a loss of route queries, a non real-time data service has better performance than real-time service. Because a larger coverage needs more complicated routing table and complex calculation, the probability of routing failure is larger.

And in ad-hoc environment, since there are only limited and shared resources, the power-saving protocol is significant. Thus, the routing scheme with low power consumption is mandatory except the special case, such as voice traffic or urgent data traffic transmission.

In summary, for non real-time transmission, since it is not sensitive to delay, with smaller power level, we can get several advantages, that is, low probability of failure and low power consumption. For real-time transmission, we can reduce the route query delay time in place of high power consumption.

Ⅵ. Conclusions

Since a mobile ad-hoc network has no fixed infrastructure, we need more sophisticated distributed algorithms for the efficient network management. In particular, many research works on mobile ad-hoc routing algorithm have been performed, but there is no consideration for supporting QoS-based multimedia services. Thus, we proposed the adaptive routing scheme for multimedia services in mobile ad-hoc environment. When real-time traffic is applied, we used a larger transmission power level since it is most important to reduce route query response time. On the other hand, for the non real-time data traffic, which is insensitive to delay, we can use a smaller transmission power level. As a result of simulation through Cadence BONeS™ Designer, our proposed scheme has better performance than traditional method, which is performed with uniform transmission power level, in view of route query delay time.

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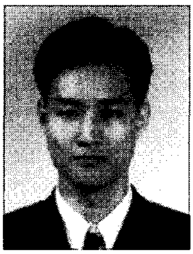

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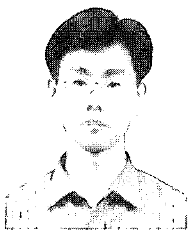

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