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TRaM: Transmission Range-based Mobility Model for Mobile Ad-hoc Networks

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Abstract

The free movement of nodes in the MANET causes continuous changes in network connectivity. In order to provide various services to the node, a transmission path must be established between the nodes. This process is performed among nodes located with-in the node's transmission range, and the path among all the nodes is established by flooding the corresponding information. The change of the node position is recognized at the moment when the routing is performed. Therefore, from the viewpoint of routing protocol, the exact trajectory of the node moving at the interval of routing is not known unless it is tracked in real time. In this paper, we design a TRaM mobility model based on routing interval and node transmission range. The proposed model improves unrealistic movements because sharp changes in velocity and direction generated in random mobility models occur with low probability. From simulation results, we confirm that the proposed scheme offers substantially better performance.

Keywords: *Mobility model of mobile ad-hoc network, V2I, Handover, Multicast in WLAN.*

1. INTRODUCTION

Highlight Mobile network has different characteristics from the wired network because it should guarantee the service without interruption due to the movement of the node. Mobile ad-hoc net-work (MANET) is a network composed only of nodes [1]. Since there are no dedicated devices in charge of the transmission in the networks, the node must perform all tasks related to the transmission itself. Issues such as topology control, service access and routing management occur in MANET [2]. Topology control is to find neighbor nodes, set up links, manage them, and so on. Service access involves security, Quality of Service (QoS), multimedia support, power management, etc. The routing management sets the path between the transmitting node and the receiving node, updates the location information of the node due to the movement, and manages data transmission. MANET is a decentralized network that uses multi-hop transmission fashion among nodes. This provides various transmission paths for the sending node and the receiving node, so it can cope with the failure more flexibly than the centralized network. Nodes are easily added and deleted on the network, so MANET pro-vides excellent flexibility and scalability. However, due to the topology change caused by the movement of the node, the transmission path must be continuously managed over time. In the case of operating as a forwarding node, the burden and power consumption of the node increases due to the data transmission which is not needed. The free movement of node continuously changes the communication environment. This leads to the previously established delivery path and QoS unreliable [3]. These issues can be settled by keeping the location information of the nodes up to date. Thus, node mobility has a great effect on network performance. The routing scheme for delivery path management is based on the current location of the nodes [4]. The position of the nodes should be tracked in real time in order to obtain high reliability of the route. In a mobile communication environment using limited energy, this method is less efficient. Assume that the node moves at the pedestrian speed. The slower the speed of movement is, the lower the probability of changing the path between nodes every moment is. If routing is performed using a time interval that minimizes performance degradation due to a change in connecting information between nodes, unnecessary processing is not perform, thereby increasing the efficiency of energy usage. Since the location of the node is not tracked in real time, the path between two neighboring points is not a

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consideration. In this environment, the movement of a node can be expressed as a set of discrete coordinates over time. The transmission range of the node is proportional to the traveling speed. Because the vehicle is moving faster than the pedestrian, it uses a larger transmission range to ensure connectivity that minimizes the impact due to the update of the route information caused by the movement of the node. In a mobile network, a node uses a relatively large transmission range. A long routing interval can be used for route updates between nodes moving at a walking speed. The change in the speed and direction of movement of the nodes is recognized only when the routing is performed [5]. A node can't know what path another node has moved between two points during the routing interval. The surrounding situation affects the movement of the node. The movement of a car de-pends on the structure of the road and the traffic situation in V2I as well as VANET. Pedestrian cases are affected by the current location such as school, park, city, and so on. Therefore, it is impractical to define the mobility of nodes in various environments with a single mobility model. The routing technique is important for the location-related information that is perceived at the time the routing is performed rather than the actual movement path of the node.

This paper presents a new mobility model that determines the speed and the direction of movement whenever routing is per-formed to reduce the load of energy limited nodes in MANET as well as wireless LAN. The newly selected moving speed is determined by the transmission range of the node and routing interval. To prevent unrealistic abrupt changes in the direction of movement, we adopt probability based on the current velocity. A node can move in all directions in a stationary state, and it will only go straight at maximum speed. As the speed increases, the newly selected direction gradually converges to the current moving direction. The node moves to a new destination selected for each routing interval linearly for simplicity of implementation. The proposed model has less linear travel time of nodes. The probability that the node is located near the center of the network is lowered. Therefore, the centralization phenomenon, a relatively large number of nodes are located at a specific location, can be improved.

The remainder of the paper is organized as follows: The next section we summarize related works. Section 3 describes a mobility model based on node's transmission range and routing interval to reduce the load on nodes using the limited capacity of energy. In section 4, we present the simulations and analysis of the results. Finally, we give out conclusion in section 5.

2. RELATED WORK

MANET is characterized in that all processes such as connection, maintenance, and termination are performed among mobile nodes without the aid of any dedicated communication equipment. Routing performs the functions of connecting, man-aging, and releasing the transmission path caused by the movement of the node. The routing schemes for MANET are divided into two categories according to the way of updating the route information: proactive and reactive.

In the proactive scheme a node periodically broadcasts its location information [4], [6], [7]. Nodes located within the trans-mission range of each other can establish connection information through this process. The node receiving this information adds its own information and rebroadcasts the updated information. This process is repeated until all the connected nodes update their routing information. This technique has the advantage of being able to connect immediately without needing a separate route search process because it keeps up-to-date route information. However, since routing information is periodically flooded to the network, there is a disadvantage that transmission bandwidth and node energy consumption are large. The reactive method is a method of searching for a path only when transmission is necessary[4], [8]. This method can solve the problem of the proactive method because the path information is not flooded on the network. The service delay occurs initially since this technique does not reflect the latest path information. As the number of service request nodes increases, the difference from the proactive method becomes smaller, which is suit-able for a case where the service request rate is low.

Mobility models are defined in terms of speed and direction with respect to time and can be divided into two types according to the method of determining speed and direction: random and real. Random mobility models choose speed and direction based on randomness[9], [10]. In Random Walk (RW), when a node arrives at a destination, it moves to the target immediately after randomly selecting new destination, speed and direction. An unrealistic problem occurs in which the speed and direction are largely changed in comparison with the previous values at this moment[10]. Unlike RW, Random WayPoint (RWP) has a stationary state for a certain period of time to prevent unrealistic movement of the node[9], [10], [11]. When a node arrives at a destination, it stops at a certain time and then moves to the destination using a randomly selected speed and direction. The previously mentioned models randomly select an arbitrary position of the network as the next movement destination. In Random Direction (RD), a node selects an arbitrary speed and direction and moves continuously until it encounters a net-work boundary[12]. Therefore, since the movement of the node always continues to the network boundary, the node has a low probability of being located near the center of network and evenly moves over the entire area of the network. Limiting the distance to the newly selected destination can improve network centralization [13]. The random models are

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widely used as a tool for evaluating various techniques for mobile environments due to the simplicity of implementation. The real models are defined based on the results of tracing the movement path of the node, which improve unrealistic mobility where sudden change in speed and direction occur. It is impractical for a node moving at a vehicle speed to change directions rapidly [14]. The redirection of the car is executed through a series of process: deceleration, redirection, and acceleration. A mobility model for realistic redirection switching is proposed [15]. This model improves the convergence phenomenon of the random model, but it is not suitable to apply the direction change process in case of the pedestrian speed. Jardosh et al.[16] proposes a technique for defining node mobility using realistic obstacles such as buildings in campus, park and cities. This model is affected by the mobility of node depending on the implementation environment. As described in [17], a movement of a node can be influenced by its social relations with other nodes such as accidentally meeting a friend on the road.

A number of mobility models have been proposed, but most of them focus on the movement of the nodes in a given environment. Since the movement of a node is recognized in the process of routing, the mobility of the node needs to be considered in terms of routing.

3. PROPOSED MOBILITY MODEL

MANET has not any preinstalled communication infrastructure such as access point, repeater and router and so on. A mobile device performs the entire process to communicate among mobile devices by oneself. The delivery route change due to the unconstrained movement of mobile devices causes the huge burden of a path management, a transmission quality, an effectiveness usage of battery, etc. Thus the property of the mobile node's movement is one of the main factors to design and to evaluate a mechanism for mobile ad hoc network.

The directivity is that a mobile node moves along the same direction for a long time. If a node moves under the directivity condition, the probability of crossing the center area of network is relatively high compared to that of the rest of network. This centralization leads to the following cases.

1. The path between a server and a client (service requester) gets shorter.
2. The service blocking possibility in the center area of network gets higher if there are many service requests
3. The energy consumption of a mobile node crossing the center area gets higher due to the process of the relatively large volume of data compared to that of other regions.

Probability based mobility models [9], [10], [11], [12] generally show the directivity and centralization characteristics mentioned above. If a mobile node moves along the same direction for a short time, as the probability of crossing center area gets lower, the situations above mentioned can be reduced. For this, we propose a mobility model with low linearity and centralization characteristics. To define node's mobility, we restrict the node's maximum moving distance before changing its direction within the transmission range, i.e. Transmission Range-based Mobility (TRaM). To determine the speed and the moving direction of a mobile node, we propose two kinds of mobility models: probabilistic mobility model and synchronous mobility model. The former selects the next moving direction based on its previous speed. The latter selects the direction based on its previous moving distance. First, we describe the probabilistic mobility model. Initially, a mobile node moves to its destination that is a randomly selected position in transmission range with initial velocity and direction denoted by v_1 and θ_1, respectively. Let V_m be the mean velocity and V_{offset} be the offset speed, respectively. Initially, the speed and the direction of the node are determined randomly, as in Equation (1) and (2).

$$v_1 = [V_{min}, V_{max}] \tag{1}$$

$$\theta_1 = [-\pi, \pi] \tag{2}$$

When a node arrives at its destination, it moves to the newly selected destination with v_1 and θ_1. To reduce unrealistic sudden changes in speed or direction, we use the moderating variables m_v and m_θ with Gaussian distribution G, where the mean is 0. Thus the nth movement of a mobile node can be defined as follows.

$$v_n = v_{n-1} + m_v \tag{3}$$

$$\theta_n = \theta_{n-1} + m_\theta \quad \text{where, } m_\theta = (1 - v_{n-1}/V_{max})G_\theta \tag{4}$$

In Equation (3) and (4), m_v and G_θ are the probabilistically selected value with Gaussian distribution ranged in [$-V_{offset}$, V_{offset}] and [$-\pi$, π], respectively. If the selected velocity is above V_{max} or under V_{min}, the velocity is set to V_{max} and V_{min}, respectively. From "(4)", if the moving speed is the maximum, no direction switching occurs. The slower the speed, the greater the range of G_θ increases the turning angle proportionally.

Fig. 1 shows the example of a mobile node's movement under the proposed mobility model. Let $\vec{M}_n$ be the movement vector for expressing the nth movement and L_n be the location of the nth selected target destination, respectively. Assume that V_{offset} is ±1m/s and $\vec{M}_1$ has the moving velocity $v_1 = V_{max}/2$ and the direction $\theta_1 = \pi/3$, respectively. For next movement, from the "(3)", the selected velocity is ranged in [$V_{max}/2 - m_v$, $V_{max}/2 + m_v$] where mv is set to [-1, 1] in the real number selected by

Gaussian distribution where the mean is 0. The moving direction for the second movement is ranged in [$V_{max}/2 - m_\theta$, $V_{max}/2 + m_\theta$] where m_θ is the value selected by Gaussian distribution ranged in [$-\pi/2$, $\pi/2$] from the "(4)".

In synchronous mobility model, the target destinations of all mobile nodes are newly selected by every predefined time period T and all mobile nodes have arrived at their destinations by T. The traveling time of every mobile node is identical T but the travel distance to target destination is quite different from each other. To reach the previously selected destination by T, each mobile node determines its next moving speed, [V_{min} , V_{max}] = [0, R/T] where R is transmission range, depending on the distance from the current location L_i to the next destination L_{i+1}. From "(3)" and "(4)", the speed and the direction for n^{th} movement is as follows, where d is the Euclidian distance between L_n and L_{n-1}.

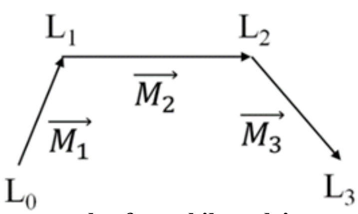

Fig. 1: The example of a mobile node's movement

$$v_n = V_{max} \text{ x } d/R \quad \text{where, } d = \|L_{i+1} - L_i\| \tag{5}$$

$$\theta_n = \theta_{n-1} + m_\theta \quad \text{where, } m_\theta = (1 - d/R)G_\theta \tag{6}$$

When the node reaches the vicinity of the network periphery, the movement direction is changed to the network center. The area where the direction is switched has a ε size from the network boundary.

4. SIMULATION AND ANALYSIS

In this section, we show simulation results to demonstrate the benefit of proposed mobility model for mobile ad-hoc networks and analyses the results of performance using it. The mobile nodes are randomly distributed in the network by Poisson distribution at initial time. Simulation parameters are listed in Table 1.

Table 1 Simulation parameters

Parameter	Default	Range	Unit
Velocity	4	0 ~ 8	km/h
Angle	0	-π ~ π	radian
Pause	-	0 ~ 5	sec
Network area	100 × 100	-	meter
Transmission range	10	10 ~ 20	meter
Routing interval	10	1 ~ 10	sec

The network boundary ε is 2 m. We also vary some of these parameters to do sensitivity analysis. The size of simulation network is 100m × 100m in rectangular plan. The routing process is periodically executed by 1 second.

Fig. 2 shows an illustration of two dimensional node position of the proposed mobility model. We distribute 500 nodes randomly in the simulation network at initial time and sample the location of the nodes at the 1000th second later. The range of velocity offset value in "(3)" is [-1, 1] km/h. The result shows that the nodes in the proposed model are evenly distributed in the network domain without centralization.

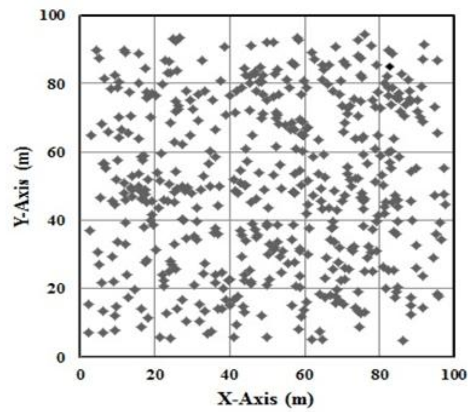

Fig. 2: Top view of node distribution of the proposed mobility model with 500 nodes at 1000 seconds

Fig. 3 shows a comparison result of cumulative mean velocity to 1000 simulation times for RWP, TRaM- probability and TRaM-synchronous mobility model. In Fig. 3, we observe that the average speed of the TRaM model is stable from the beginning of simulation to a value of 4 km/h. However the average speed of RWP and TRaM-probability decreases continuously as the simulation time progresses. The TRaM-probability model has similar traveling characteristics as RWP except that the distance for continuous movement is limited to the transmission range.

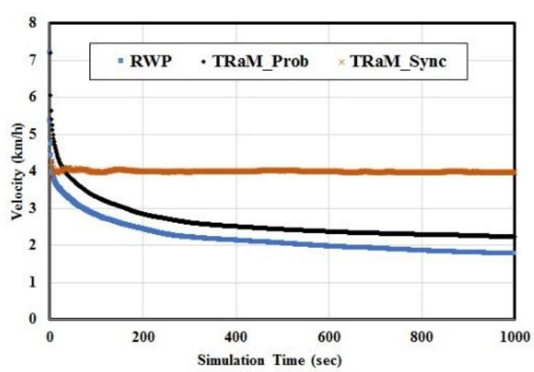

Fig. 3: Comparison of cumulative mean velocity to 1000 simulation times for RWP, TRaM-probability and TRaM-Synchronous

Fig. 4 shows an example of moving and cumulative average angles of a node for 10000 seconds with TRaM-synchronous.

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In this model, the direction of movement of the node is de-pendent on the velocity from (6).

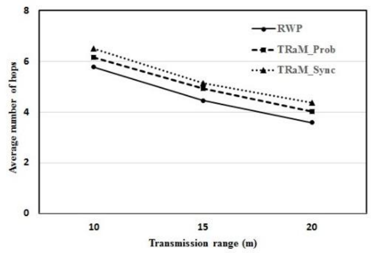

Fig. 4: An example of moving angles and cumulative average angles of a node for 10000 seconds

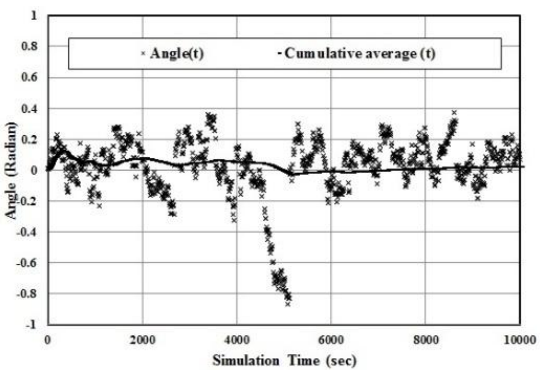

Fig. 5: Comparison of average transmission hops of RWP, TRaM-probability, and TRaM-synchronous

Fig. 5 shows the number of transmission hops between a randomly selected server and a requester in a simulation performed for 1000 seconds using RWP, TRaM-probability and TRaM-synchronous, where routing protocol is DSDV (Destination Sequenced Distance Vector) and routing interval is 10 seconds [6], [7]. Simulation results show that the proposed models have a slightly longer average transmission hops than those of RWP in all cases because they do not cause network centralization [18-19].

5. CONCLUSION

In this paper, we designed the TRaM mobility model from the routing point of views to provide accurate performance evaluation and parameter analysis for MANET. The movements de-fined in TRaM mobility model indicate characteristics depending on the transmission range and routing interval of the node. The proposed model shows more realistic mobility and less network centralization compared to RWP because the change in speed and direction occurs with a small amount. Comparing the simulation results of the RWP, we have confirmed that the TRaM model generates stable moving velocity over time and distributes the nodes evenly over the network. Therefore, the proposed mobility model is more suitable as a tool for evaluating routing protocols and network connectivity study for MANET.

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