Improvement of Route Detection Ratio by Node Mobility in Wireless Multihop Networks

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Abstract—In wireless multihop networks, inter-route collisions caused by data message transmissions with neighbor intermediate wireless nodes in different routes reduces performance of wireless multihop transmissions. Hence, various routing protocols excluding neighbor wireless nodes of intermediate wireless nodes of another route have been proposed. However, since the number of candidate intermediate wireless nodes is reduced, route detection ratio tends to become lower. In order to solve this problem, this paper proposes the method to move the neighbor wireless nodes out of the wireless transmission range of the intermediate wireless nodes and to utilize the m as intermediate wireless nodes of other routes. For higher efficiency of the node mobility for higher route detection ratio, outside neighbor nodes are selectively moved. Here, the number of neighbor intermediate nodes is used to select outside nodes. Results of simulation experiments show the better performance of the proposed method.

I. INTRODUCTION

Wireless multihop transmissions of data messages are mandatory for enough high connectivity in wireless networks with battery limited wireless nodes. Collisions should be avoided or reduced to keep the performance high for high throughput and low latency in wireless multihop networks. In order to avoid inter-route collisions, any pair of wireless multihop transmission routes are required to be disjoint. However, it reduces utilization of wireless nodes, i.e., the number of available wireless nodes for an additional route becomes low. This paper proposes that mobility of wireless nodes improves the connectivity. In addition, the proposed selective mobility achieves better trade-offs between connectivity improvement and energy consumption for mobility.

II. RELATED WORKS

In wireless networks in which data messages are transmitted between neighbor wireless nodes included in their wireless transmission range each other, data messages are broadcasted by a sender wireless node. Thus, collisions may occur at any of the neighbor wireless nodes of the sender wireless node. In wireless LAN protocols such as IEEE802.11, Bluetooth and ZigBee, for recovery from the collisions, reply of acknowledgement control messages and retransmissions of data messages are adopted. Thus, reachability of data messages are improved; however, due to introduction of the random back-off mechanism for avoidance of repetitions of retransmissions of data messages, longer transmission delay is required. Though the RTS/CTS control is also introduced to avoid collisions caused by the hidden terminal problem, exchanges of some additional control messages before data message transmissions are mandatory and waiting time for the contention is unavoidable. There are two kinds of collisions; inter-route and intra-route ones. Suppose the following two wireless multihop transmission routes \( R := \langle N_0 \ldots N_n \rangle \) and \( R' := \langle N'_0 \ldots N'_n \rangle \). If \( N_i \in R \) and \( N'_i \in R' \) are mutually included in the wireless signal transmission ranges, data messages transmitted from \( N_i \) to \( N'_i \) may collide at \( N_i \) and those from \( N'_i \) to \( N_i+1 \) may collide at \( N_i \). In [6], such collision and additional overhead for avoidance such collisions are avoided by using wireless-signal disjoint routes. Here, wireless multihop transmission routes are detected by using flooding of route detection control messages, and the newly detected routes consist only of intermediate wireless nodes which are out of the wireless transmission ranges of the intermediate wireless nodes of already detected and in-use wireless multihop transmission route. In the routing protocol in [1], all the intermediate wireless nodes of existing wireless multihop transmission routes never broadcast the route detection control message even if they receive one from one of their neighbor wireless nodes.

III. PROPOSAL

A. Improvement of Route Detection Ratio by Mobility

A wireless multihop network may consist of stationary and/or mobile wireless nodes. Some mobile wireless nodes move autonomously and the others move passively depending on environmental conditions and restrictions. In this paper, all wireless nodes are assumed to be autonomously mobile. As discussed in the previous section, for avoidance of collisions, any pair of wireless multihop transmission routes are required to be wireless signal disjoint. However, in order to realize the wireless signal disjoint routes, a newly detected wireless multihop transmission route should consist only of the wireless nodes except for the intermediate wireless nodes \( N_i \) in an existing wireless multihop transmission route \( R := \langle N_0 \ldots N_n \rangle \) and their 1-hop neighbor wireless nodes \( N \in \text{Neighbor}(N_i) \). In general, the route detection ratio, i.e., connectivity of the wireless multihop network monotonically increases according to the density of wireless nodes [8]. In addition, the connectivity gets quickly lower when the node density becomes lower than a certain threshold. Thus, number of available wireless node is critical for the higher route detection ratio. However, as increasing the number of wireless multihop transmission routes, the route detection ratio gets lower.
In order to improve the route detection ratio, the number of available wireless nodes should be kept high even after detection of an additional wireless multihop transmission route. This paper proposes the following method: After detection of a wireless multihop transmission route, 1-hop neighbor wireless nodes of the intermediate wireless nodes of the route move out of the wireless signal transmission ranges of the intermediate wireless nodes. Since the moved wireless nodes are out of the wireless transmission ranges of the intermediate wireless nodes and all the intermediate wireless nodes are also out of the wireless signal transmission ranges of the moved wireless nodes, no collisions occur between them. Thus, all the moved wireless nodes are available for detection of an additional wireless multihop transmission routes and the route detection ratio is expected to be kept high.

Fig. 1: Route Detection Ratio Improvement by Mobility.

B. Mobile Node Selection

As discussed in 3.1, the mobility of 1-hop neighbor wireless nodes out of the wireless signal transmission ranges of the intermediate wireless nodes of a detected wireless multihop transmission route seems to be efficient to achieve higher route detection ratio for avoidance of inter-route collisions between neighboring wireless multihop transmission routes. Since certain energy consumption is required for the mobility, the mobility does not contribute if the moved wireless nodes are not included in another wireless multihop transmission routes. Hence, 1-hop neighbor wireless nodes with high expectation to be included in another wireless multihop transmission route are required to move out of the wireless transmission ranges.

In various on-demand ad-hoc routing protocols such as AODV and DSR based on a flooding of route detection request control message $R_{req}$, a shorter wireless multihop transmission route, i.e., a wireless multihop transmission route with less hop counts is detected. In this case, wireless nodes in a depression area tends to become intermediate wireless nodes of wireless multihop transmission routes and wireless nodes in a convex area tends not to become intermediate wireless nodes. Hence, if 1-hop neighbor wireless nodes move to depression areas, they are expected to contribute to achieve higher route detection ratio; whereas if 1-hop neighbor wireless nodes move to convex areas, they rarely contribute for the higher route detection ratio.

Fig. 2: Convex and Depression Areas.

Generally speaking, a wireless multihop transmission route is not always straight due to wireless node distribution especially the existence of void areas, there are some bent parts in a wireless multihop transmission route. As shown in Figure 3, 1-hop neighbor wireless nodes of intermediate wireless nodes in the inside of a bent part move to a convex area and those in the outside of a bent part to a depression area. Thus, for achieving higher route detection ratio, mobility of “outside” 1-hop neighbor wireless nodes are more expected than mobility of “inside” 1-hop neighbor wireless nodes to provide higher contribution for higher route detection ratio.

Fig. 3: Mobility of “outside” and “inside” Neighbor Nodes.

One of the methods to determine whether each 1-hop neighbor wireless node is “inside” or “outside” is to measure the angle of successive three intermediate wireless nodes, i.e. $\angle N_{i-1}N_iN_{i+1}$. However, required communication overhead for exchanging location information among neighbor wireless nodes is high and expected precision of the angle seems to be low. Thus, some heuristics to the “inside” or “outside” determination with lower communication overhead are required. As shown in Figure 4, “inside” 1-hop neighbor wireless nodes of intermediate wireless nodes have more neighbor intermediate wireless nodes, i.e., it is included in many wireless signal
transmission ranges of the intermediate wireless nodes. On the other hand, “outside” 1-hop neighbor wireless nodes of intermediate wireless nodes have less neighbor intermediate wireless nodes, i.e., it is included in less wireless signal transmission ranges of the intermediate wireless nodes. Hence, numbers of neighbor intermediate wireless nodes may be used to determine whether a 1-hop neighbor wireless node is an “inside” node or an “outside” one.

Fig. 4: Wireless Signal Transmission Ranges of Intermediate Wireless Nodes in Bent Part of Route.

Table 1 shows the existence ratios of “inside” or “outside” wireless nodes with various numbers of neighbor intermediate wireless nodes of a wireless multihop transmission route evaluated by simulation experiments. Based on the table, the following “inside” or “outside” determination method is induced.

[inside/outside Determination]

If the number of neighbor intermediate wireless nodes of a wireless multihop transmission route is less than or equal to 2, it is an “outside” 1-hop neighbor wireless node of the route. On the other hand, if the number of neighbor intermediate wireless nodes of a wireless multihop transmission route is more than or equal to 3, it is an “outside” 1-hop neighbor wireless node of the route. □

According to the above criterion, “outside” 1-hop neighbor wireless node move out of the wireless signal transmission ranges of the intermediate wireless nodes to contribute to configure another wireless multihop transmission route as an intermediate wireless node without collisions with the existing wireless multihop transmission route. On the other hand, “inside” 1-hop neighbor wireless nodes do not move out of the wireless signal transmission ranges of the intermediate wireless nodes for avoidance of waste energy resource consumption for their mobility. Therefore, as shown in Figure 5, only “outside” 1-hop neighbor wireless nodes move for trade-off between route detection ratio improvement and energy consumption.

IV. Evaluation

In order to evaluate how the proposed method by which 1-hop neighbor wireless nodes of the intermediate wireless nodes of a wireless multihop transmission route out of any wireless signal transmission ranges of the intermediate wireless nodes contribute the route detection ratio, this section shows the results of simulation experiments. The simulation field is a 1,000m × 1,000m square and a wireless signal transmission range of each wireless node is 100m. As shown in Figure 6, there is a 5-hop wireless multihop transmission route and another wireless multihop transmission route is searched. 150–300 wireless nodes are randomly distributed in accordance with the unique distribution randomness. Based on the proposed decision method for “inside or outside”, the following three methods are under comparison: (1) only “outside” 1-hop neighbor wireless nodes move. (proposal) (2) all 1-hop neighbor wireless nodes move. (conventional) Here, additional wireless multihop transmission routes are detected one-by-one where its source and destination nodes are randomly selected.

Figures 7 and 8 show the simulation results. Due to the comparison of the proposed and the conventional methods, the mobility of 1-hop neighbor wireless nodes contributes the improvement of route detection ratio. In addition, due to the comparison of the proposed methods and the method with mobility of all 1-hop neighbor wireless nodes, almost all the contribution is caused by the mobility of the “outside” 1-hop neighbor wireless nodes. That is, the “inside” wireless nodes provides almost no improvement of route detection ratio and our proposed selective mobility is evaluated to be much efficient. For achieving almost the same route detection ratio, the proposed selective method reduces averagely about 34.5% total mobility than that of all 1-hop neighbor wireless node mobility.

TABLE I: “inside” or “outside” with Number of Neighbor Nodes.

<table>
<thead>
<tr>
<th>Number of Neighbor Intermediate Wireless Nodes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existence Ratio [%]</td>
<td>inside</td>
<td>6.7</td>
<td>31.9</td>
<td>73.2</td>
</tr>
<tr>
<td></td>
<td>outside</td>
<td>93.3</td>
<td>68.1</td>
<td>26.8</td>
</tr>
</tbody>
</table>

Fig. 5: Only “outside” Node Mobility.
V. CONCLUDING REMARKS

This paper proposes a novel method to configure inter-route collision-free wireless multihop transmission routes with higher route detection ratio. Here, 1-hop neighbor wireless nodes of a detected wireless multihop transmission route move out of the wireless signal transmission range of the intermediate wireless nodes. As the 1-hop neighbor wireless nodes selectively move, i.e., only the “outside” 1-hop wireless nodes move, the trade-off between improvement of route detection ratio and energy consumption for mobility is realized.

REFERENCES


