# Neighbor Discovery in Wireless Ad Hoc Networks: A Review

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**Abstract-** Neighbor Discovery (ND) is an important pre-requisite for a typical Wireless Ad-hoc Network for achieving self-organization and multi-hop communications which subsequently affect routing, MAC and topology control protocols. Reliability, Resource Efficiency and Responsiveness could be termed as important performance parameters for a typical Neighbor Discovery protocols. This paper attempts to review the working/ operations of some of the popular ND approaches/techniques under various operating scenarios/ assumptions.

**INDEX TERMS-** Wireless Ad Hoc Networks, Neighbor Discovery, Randomized Algorithms

## 1. INTRODUCTION

Self-Organization and Multi-Hop communication are two major characteristics of a typical Wireless Ad-Hoc network. To achieve Self-Organizing and Multi-Hop communication, it is imperative for a given node to discover its neighbors. In the most of the applications of wireless ad hoc networks, the communication pattern is multi-hop. Multi-hop communication is preferred by the routing protocols because of energy efficiency. However, for achieving multi-hop communications a node is supposed to first identify those nodes around the given node which are exactly one hop away, such nodes are termed to be as neighbors of the given node and the process initiated by the given node to identify such one hop distant surrounding nodes is called as Neighbor Discovery (ND). Knowledge of neighbors is an essential to start proper operations for the MAC protocols and routing protocols. However, it is expected that the ND process should not only be accurate and precise but also resource efficient and quick.

## 2. NEIGHBOR DISCOVERY

In [1], authors discussed about the Neighbor discovery algorithms. They can be classified into two categories, viz. randomized or deterministic. In a randomized strategy neighbor discovery, starts with randomly chosen times and discovers all its neighbors by a given time. In a deterministic neighbor discovery algorithm, each node transmits according to a pre-determined transmission schedule that allows it to discover all its neighbors by a given time with probability one. Guaranteed neighbor discovery typically comes at the cost of increased running time and often requires unrealistic assumptions such as synchronization between nodes and apriori knowledge of the number of neighbors [8]. Authors, therefore, choose to investigate randomized neighbor discovery algorithms.

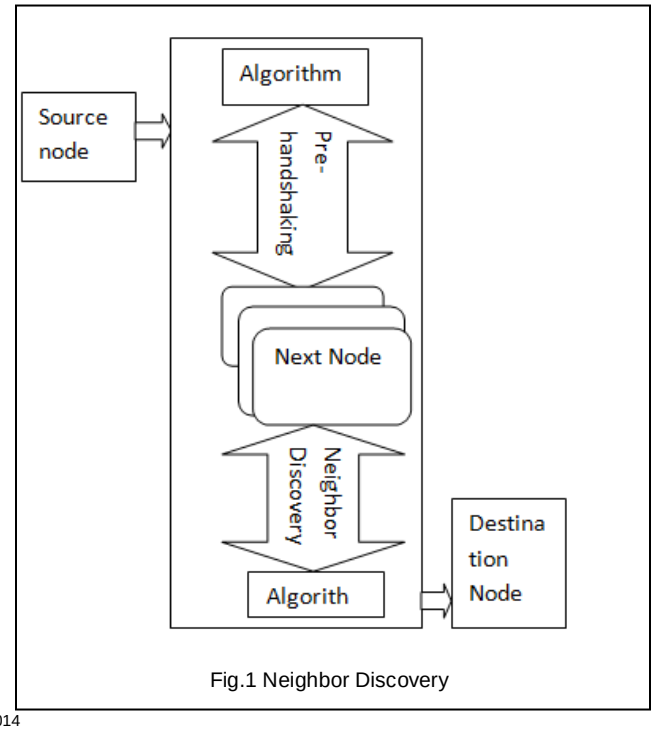


Fig.1 Neighbor Discovery

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The performance can be analyzed in terms of time taken for ND, energy consumed by ND process, system resources spent, accuracy or reliability of result. The characteristics of a typical ND process are:

1. Nodes have either a prior knowledge of neighbors or not.
2. Nodes are either collision aware or not.
3. ND process is done either in a synchronous or in an asynchronous manner.
4. Nodes are either aware about initialization and termination criteria or not.

Non-trivialness of randomized ND are as follows [1]:

1. Nodes have no knowledge of the number of neighbors, which makes coping with collisions even harder.
2. When nodes do not have access to a global clock, they need to operate asynchronously and still be able to discover their neighbors efficiently.
3. In asynchronous systems, nodes can potentially start the neighbor discovery process at different time instants and consequently, may miss each other's transmissions.
4. Furthermore, when the number of neighbors is un-known, nodes do not know apriori when/how to terminate the neighbor discovery process.

## 3. NEIGHBOR DISCOVERY ALGORITHM

In [2], M. J. McGlynn and S. A. Borbash, address two problems associated with static ad hoc wireless networks. First is, methods of saving energy during a deployment of the nodes and second is, efficient methods of performing adjacent ND. Birthday protocols use random independent transmission to discover nodes. Authors also discussed that the Birthday protocols are a promising tool for saving energy as well as an efficient and flexible means of having the nodes discover their neighbors.

TABLE 1. ALGORITHM / PROTOCOL: BIRTHDAY PROTOCOL[2]

| ND Scenarios / Assumptions | Remarks / Comments |
|---|---|
| • Randomized strategy,<br>• Time is slotted,<br>• n is large,<br>• Total number of nodes is known,<br>• Nodes do not coordinate their actions in any way,<br>• Nodes are placed randomly in some area,<br>• Nodes are distinguishable by an ID such as a MAC address,<br>• Each node has some internal memory to record local topology | • Optimal probability that a node transmits is 1/n,<br>• Expected time slots needed to finish ND process is neHn, where Hn is the n-th Harmonic number. |

TABLE 2. ALGORITHM / PROTOCOL: ALOHA-LIKE ALGORITHM[1]

| ND scenarios / Assumptions | Remarks / Comments |
|---|---|
| • Randomized neighbor discovery algorithms ,<br>• Nodes have Omni-directional antennas | • Reduces to the classical coupon collector's problem |
| • When nodes do not have | • Each node discovers all its n |

| | |
|---|---|
| a collision detection mechanism | neighbors in an expected time equal to ne (ln n+c), for some constant c,<br>• O(ne ln n) |
| • When nodes have a collision detection mechanism,<br>• Propose an algorithm based on receiver status feedback,<br>• Nodes can detect collision | • Which yields a ln n improvement over the ALOHA-like algorithm,<br>• O(ne) |
| • Absence of an estimate of the number of neighbors | • Results in a slowdown of no more than a factor of two, compared to when nodes know n. |
| • Lack of synchronization among nodes | • Results in at most a factor of two slowdown in the algorithm performance from the case when nodes are synchronized |
| • Starting execution at different time instants | • Each node can discover all its neighbors |
| • Multipacket reception situation | • Expected time needed to discover all nodes is Θ(n ln n/k) [10] |

TABLE 3. ALGORITHM / PROTOCOL: FRIEND PROTOCOL

| ND Scenarios / Assumptions | Remarks/ Comments |
|---|---|
| • Pre-Handshaking Strategy<br>• Full duplex technology<br>• Multi-hop networks<br>• Each node has a unique ID (e.g., the MAC address).<br>• Time is identically slotted<br>• Nodes are synchronized on slot boundaries.<br>• Nodes are in a clique of size n.<br>• n is known to all nodes in the clique.<br>• n can be pre-configured on nodes before deploying<br>• Nodes use omnidirectional antennas,<br>• Nodes have the same transmission range.<br>• No multipacket reception technique is used, | • Reduce the probabilities of generating idle slots and collisions<br>• To accelerate the ND process<br>• Performs better than the ALOHA-like protocol |

| | |
|---|---|
| • Nodes can listen and transmit on the same channel simultaneously.<br>• Nodes can distinguish between collisions and idle slots. | |

Many papers have focused on the neighbor discovery problem when nodes have Omni-directional antennas. However, these solutions require either apriori knowledge of the number of neighbors [2, 4, 8], or node synchronization [2, 8]. Neighbor discovery algorithms when nodes have directional antennas have been proposed in [5, 6, 7]. Again, the proposed solutions assume knowledge of the number of neighbors [6], or node synchronization [5]. In [7], the authors propose antenna scanning mechanisms for directional neighbor discovery.

In [3], authors discussed FRIEND protocol to initialize synchronous full duplex wireless ad hoc networks. Many existing protocols like, deterministic [8] and multi-user detection-based [9] protocols, randomized protocols are most commonly used to conduct ND process in wireless networks. In those protocols, each node transmits at different randomly chosen time instants to reduce the possibility of the collision with other nodes.

G. Sun, F. Wu, X. Gao, and G. Chen, pointed out that many existing protocols have high probabilities to generate idle slots. FRIEND protocol decrease the duration of ND in comparison to the classical ALOHA-like protocols [1,2].It is a randomized protocol and expected value of time slots needed is 1.5n and upper bound is 3n for ND process.

## 4. CONCLUSION

In this paper, different ND approaches have been surveyed. As per Birthday protocols, ND is applicable only for wireless static ad hoc networks. For such networks propose protocols based on the Birthday paradox. These protocols are probabilistic in nature and prove to be a better choice than deterministic protocols. These protocols provide a nice trade of energy efficiency, reliability and delay regarding ND. Furthermore, the neighbor discovery as a classical coupon collector's problem and many researches on ND are based on these protocols which improves the results. Friend protocols can decrease the duration of ND in comparison to the classical Aloha-like protocols.

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