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LaConf: A Localized Address Autoconfiguration Scheme for Wireless Ad Hoc Networks*

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Abstract: We propose a localized address autoconfiguration (LaConf) scheme for wireless ad hoc networks. Address allocation information is maintained on the network border nodes, called addressing agents (AAs), which are locally identified by a geographic routing protocol GFG (Greedy-FACE-Greedy). When a node joins the network, it acquires an address from a neighboring AA (if any exists) by local communication or from the head AA (a geographic extreme AA) by GFG-based multi-hop communication. A Geographic Hash Table (GHT) is adopted for duplicate address detection. Each address is hashed to a unique location in the network field, and the associated assignment information is stored along the face perimeter enclosing that location (in the planar graph). When a node receives an address assignment, it consults with the perimeter nodes around the hash location of the assigned address about any conflicts. AAs detect network partitions and merger locally according to neighborhood change and trigger AA re-selection and network re-configuration (if necessary). We propose to apply a Connected Dominating Set (CDS) to improve the performance. We also evaluate LaConf through simulation using different planar graphs.

Key words: address autoconfiguration; localized algorithms; wireless ad hoc networks

1 Introduction

A wireless ad hoc network is a spontaneous network of nodes that communicate through radio frequency signals without centralized administration or fixed infrastructure. Because the wireless nodes often have limited power supply (thus restricted transmission range), their communication relies mainly on multi-hop message relays, which renders routing a primary issue, e.g., Refs. [1-4]. Many existing ad hoc routing protocols, e.g., Refs. [5,6], assume that nodes are configured with a unique address. Because wireless ad hoc networks are an open dynamic environment where nodes are free to join and leave, this assumption cannot be realized by address pre-configuration. It is necessary to have an automated *localized* mechanism in the network that manages nodal addresses on the fly. A localized protocol is a distributed algorithm where simple local behavior achieves the desired global objective[7]. It is known to be efficient, scalable and fault-tolerant, most suitable for wireless ad hoc networks.

1.1 Motivation

Dynamic address configuration was first implemented by the Dynamic Host Configuration Protocol (DHCP)[8]. The basic idea is the following. One or a few nodes are specified as the DHCP server. Each new joining node (client) discovers a DHCP server by

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flooding a message into the network. Upon receiving this message, the DHCP server that is able to assign an address to the client reserves the address and replies by flooding a DHCP offer message carrying the reserved address and other necessary information. The client sends a DHCP request to the first discovered server to confirm the reception of an address, which then replies with an acknowledgment.

A DHCP infrastructure is not suitable for dynamic networks where no central servers are available. In this case, IPv4 Link-Local addresses[9] (referred to as Zeroconf) were proposed. This approach requires nodes to be connected to the same physical (or logical) link. When a node joins the network, it chooses an address at random and probes this address in the network by sending an ARP (Address Resolution Protocol) message destined to it. If the address is already in use, the new node will receive a message indicating so, and it will choose another address and repeat the same procedure. If nothing is received, then it can safely use the address.

Unfortunately, Zeroconf cannot be directly applied to multi-hop wireless ad hoc networks, since it is intended only for local communication between nodes within the same MAC (Media Access Control) broadcast domain (i.e., within each other's wireless communication range). A dynamic and self-organized mechanism covering the entire network is therefore needed. This mechanism should be easy to implement, and it should be able to handle network partitioning and merger as well as node addition and removal, due to node mobility or node failure. In 2005, IETF AUTOCONF Working Group was created to address this issue. Thus far, no standard solution has been provided yet.

1.2 Our contributions

We propose a localized address autoconfiguration (LaConf) scheme for wireless ad hoc networks. All the nodes on the network border are defined as addressing agent and are responsible for address configuration. Each node is aware of its own geographic location, and spontaneously sends a message to the east by Greedy-FACE-Greedy (GFG) routing[10]. The message stops at the globally easternmost node (located on the network border), called head AA (addressing agent). The head AA is in charge of synchronizing the address allocation information stored on AA nodes by periodically routing an update message along the network border by the FACE mode of GFG. Each AA node monitors neighborhood topology. Whenever it detects network partition or merger, it re-initializes the network.

A new joining node may be configured by any AA. If it is neighboring an AA node, then it asks that node directly for address assignment through local communication. Otherwise, it obtains one from the head AA by routing a request message to it. Because address assignment is based on local address allocation information and information synchronization has delays, address duplication is possible. A Geographic Hash Table (GHT)[11] is adopted for duplicate address detection. Each address is hashed to a unique location in the network field; the assignment information is stored on the face perimeter enclosing that location. When a node receives an address assignment, it consults with the perimeter nodes around the hash location of the assigned address about any conflict. We also suggest to apply the Connected Dominating Set (CDS) concept[12] to further improve the performance. Through an extensive set of simulations we evaluate LaConf using different local planar graphs, i.e., Gabriel Graph (GG) and Partial Delaunay Triangulation (PDT)[13], in an unbiased manner. We show that use of PDT and CDS leads to significantly better performance.

The remainder of this paper is organized as follows. We briefly review some recent related work in Section 2 and introduce the basic techniques used by LaConf in Section 3. We elaborate LaConf in Section 4 and improve its performance by CDS in Section 5. We then evaluate LaConf through simulation in Section 6. Finally, we conclude the paper in Section 7.

2 Previous Work

There is a rich body of research on address autoconfiguration in wireless ad hoc networks in the literature. Existing algorithms are usually classified as *stateful* or *stateless*. A stateful approach, e.g., Refs. [14-16], relies on a global address allocation table, either centralized or distributed, to ensure exclusive address assignment. An stateless approach, e.g., Refs. [17-19], allows local address allocation and uses duplicate address detection mechanisms to detect and resolve address conflicts. Hybridization of the two approaches, e.g., Refs. [20-22], has also been investigated. In a hybrid