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| Performance Evaluation of Address Auto configuration  Protocols in Mobile Ad-hoc Wireless Networks |
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#### **Abstract**

The TCP/IP protocol allows the different nodes in a network to communicate by associating a different IP address to each node. In wired or wireless networks with infrastructure, we have a server or node acting as such which correctly assigns IP addresses, but in mobile ad hoc networks there is no such centralized entity capable of carrying out this function. Therefore, a protocol is needed to perform the network configuration automatically and in a dynamic way, which will use all nodes in the network (or part thereof) as if they were servers that manage IP addresses. This article reviews the major proposed auto-configuration protocols for mobile ad hoc networks, with particular emphasis on one of the most recent: D2HCP. This work also includes a comparison of auto-configuration protocols for mobile ad hoc networks by specifying the most relevant metrics, such as a guarantee of uniqueness, overhead, latency, dependency on the routing protocol and uniformity.

**Keywords**: Mobile Ad-hoc Networks, Auto-configuration Protocols, Address Assignment

1. **Introduction**

A Mobile Ad hoc NETwork (MANET) is a set of mobile nodes which communicate between themselves through wireless links. In contrast with conventional networks, a MANET does not need any previous infrastructure, since nodes rely on each other to operate themselves, forming what is called multi-hop communication. Such networks have more problems and disadvantages than a conventional network. The topology of mobile networks may change quickly and in an unpredictable way. Moreover, variations in the capacity of nodes and links, frequent transmission errors and a lack of security may occur. Finally, the limited resources of the nodes must be taken into account given that an ad hoc network will normally be formed by battery operated devices [1].

To communicate with each other the ad hoc nodes need to configure their interfaces with local addresses which are valid within the ad hoc network [2]. The ad hoc nodes may also need to set global routing addresses to communicate with other devices on the Internet. From the perspective of the IP layer, an ad hoc network presents itself as a multi-hop level 3 network constituted by a collection of links.

1. **Auto-configuration in MANET**

With the increasing deployment of wireless devices (e.g., laptops, PDAs, cellphones, etc), ad hoc networking is becoming an increasingly important class of infrastructure less technology for connecting a group of wireless devices. Ad hoc wireless protocols have been extensively investigated at all layers from physical to applications. However, a systematic development of ad hoc wireless network tools is still lacking. In particular, as a difference from the Internet, there are no efﬁcient end-to-end tools to evaluate ad hoc network resources (e.g., path capacity, available bandwidth, etc.).[3] Yet, the end-to-end knowledge of resources such as path capacity is important for network utilization and management.

For instance, in a video conference application supported by an ‘‘overlay’’ that spans wired and wireless ad hoc users, the knowledge of path capacity to different destinations helps the sources and proxies adapt the audio/video streaming rates to match user capacities and provide better quality of services Due to the dynamic topology of mobile ad hoc networks (constant movement of the nodes that can join and leave the network frequently and even simultaneously), auto-configuration protocols are faced with various problems in guaranteeing the uniqueness of IP addresses and in allowing network partitioning and merging.

For proper functioning of network, the protocols should achieve the following objectives [4]:

* Assign unique IP addresses: Ensure that two or more nodes do not obtain the same IP address.
* Function correctly: An IP address is only associated with a node for the time that it is kept in the network. When a node leaves the network, its IP address should then became available for association to another node.
* Fix the problems derived from the loss of messages: In case of any node failure or if message loss occurs, the protocol should operate quick enough to prevent two or more nodes from having the same IP address.\
* Allow multi-hop routing: A node will not be configured with an IP address if there aren’t any available in the whole network. Thus, if any node of the network has a free IP address, it has to associate itself with the node which is requesting an IP address, even though it is at two-hops of distance or more.
* Minimize the additional packet traffic in the network: The protocol must minimize the number of packets exchanged among the nodes in the auto-configuration process. In other words, control packets traffic must cause as little harm as possible to the data packet traffic, given that in the extreme case, the network performance would decrease.
* Verify the existence of competing petitions for an IP address: When two nodes request an IP address at the same time, the protocol must carry out the pertinent treatment so that the same IP address is not given to two nodes.
* Be flexible to partitioning and merging of the mobile ad hoc network: The protocol must be able to achieve the union of two different mobile ad hoc networks as well as the possible partitioning into two networks.
* Conduct synchronization: The protocol must adapt itself to the rapid changes of the wireless network topology due to the frequent mobility of the nodes. The synchronization is carried out periodically to ensure the configuration of the network is as up to date as possible.

1. **Adapting Standard Solutions**

There are two standard solutions:

* 1. **SLAAC**

StateLess Address AutoConfiguration (SLAAC) is a standard that allows the automatic auto-configuration of an IPv6 address without the need of a router node. For this, it needs help from the protocol Neighbour Discovery Protocol (NDP), a standard to transmit the messages and to discover its neighbours. A node automatically creates an IPv6 address joining its host identifier (it is usually the MAC address) with a local well-known prefix and undergoes a DAD process by broadcasting NDP messages to the neighbours.

The applicability of this protocol in mobile ad hoc networks is limited because it uses the NDP protocol to send the messages and NDP assumes that all the nodes are connected to each other in the network. Consequently, it only supports one-hop transmission, whereas mobile ad hoc networks are most frequently multi-hop, thus not reaching the majority of the nodes to carry out the DAD processes and not being able, therefore, to ensure that the obtained IPv6 address is unique.

* 1. **DHCP-PD**

Dynamic Host Configuration Protocol – Prefix Delegation (DHCP-PD) [8] is an option derived from DHCPv6 [9] which provides a mechanism for the delegation of the IPv6 address prefixes and lets one of these be assigned automatically. For this, if a node wishes to get an IPv6 address, it sends a DHCP message with the activated prefix delegation option to obtain a prefix from a DHCP server in the network. Its applicability is limited in mobile ad hoc networks because it is based on DHCP, so it assumes that all the nodes can connect to a DHCP server, whether directly or through several hops, and due to the MANET topology, the direct connection to DHCP server is not usually frequent with the consequence that the connection through several hops can make the server unreachable.

1. **Classification of Auto-configuration Protocols**

The auto-configuration protocols may be classified according to address management:

* Stateful: The nodes know the network state, i.e., they keep tables with the IP addresses of the nodes.
* Stateless: The IP address of a node is managed by itself. Generally they create a random address and perform a process of duplicated address detection steps to verify their uniqueness.

**4.1 Stateful Protocols**

**4.1.1 MANETConf**

MANETConf, which is an improvement of, is based on existence of a common distributed table so that all the nodes are able to assign IP addresses. When a node wants to join the network, it sends broadcast messages to other nodes and the first one which replies to the message, chooses it as an initiator node and it can supply an IP address. The initiator node chooses one of the free IP

Addresses located in the network and before assigning it, asks for permission from the rest of the nodes, because it is possible that another node may have also chosen this address or the tables might not be totally synchronized due to message delays. If the answer from the nodes is positive, it assigns the IP address to the joining node and it communicates this action by broadcasting so that the rest of the nodes keep their tables updated [8]. If there is a node which does not reply, it is put in direct contact with it (unicast) to get an answer. If it still cannot get it, it will assume that the node has left the network, and will communicate this to the rest of the nodes in the network in order to keep the tables updated.

**4.1.2 DAAP**

Dynamic Address Allocation Protocol (DAAP) is based on the concept of address assignment by a leader. The leader functionality is shared among all network nodes. When a new node joins the network, it becomes the leader until the next node joins. The leader maintains the highest IP address within the ad hoc network and a unique identifier is associated with the network. Each node stores the highest IP address, which is that of the leader, and periodically sends HELLO messages to its neighbours. These HELLO messages include the network identifier so that any merging and partitioning can be detected. When a node receives a HELLO message with a different network ID, merging is detected, if a node does not receive the message that contains the current network ID, then after a timeout, a partition is detected.

* + 1. **EMAP**

Extensible Manet Auto-configuration Protocol (EMAP) is an auto-configuration protocol based on the idea of a protocol of REQUEST/REPLAY messages. The main advantage of this protocol is the possibility of doing it extensibly, i.e., it can include new functionalities in the future that are analyzed in a theoretical way, such as Domain Name Server (DNS). This protocol also considers the possibility of exterior communications to the mobile ad hoc network via Internet. The route discovery mechanism among nodes is similar to the Ad Hoc On-Demand Distance Vector (AODV) protocol [11]. The main idea of this auto-configuration protocol consists in having three different addresses for a non-configured node that wants to join the created network. These are three addresses for the interior communications: temporary address, tentative address and mobile ad hoc network local address.

* 1. **Stateless Protocols**

Duplicate Address Detection (DAD) is a process which uses the protocols to check the uniqueness of IP addresses. This process takes a relatively long time to complete, so several solutions have been implemented to reduce it like Strong Duplicate Address Detection (SDAD), Weak Duplicate Address Detection (WDAD) and Passive Duplicate Address Detection (PDAD) [5].

* + 1. **APAC**

Agent based Passive Auto-configuration (APAC) [23] is an auto-configuration protocol based on PDAD. Its main feature is the use of certain nodes which centralize the distribution of addresses. The

mechanism by which a node configures its IP address upon entering the network consists of asking if it has some node type Address Agent (AA) within a one hop distance. In that case, the AA node will give it an IP address.

If it does not receive a response from any AA node, the incoming node is configured to operate in AA mode, and it will be a server of addresses for the next incoming nodes. When it is configured as AA, the node randomly generates an identifier number agentID, in order to form a table with the addresses that it will assign to the nodes that arrive. These addresses have the form agented + hostID.

When a node is moved in the network and leaves the radio coverage of AA proportionately to its IP address, this node must ask for another address from another node AA within its new radio coverage. This is complemented by a mechanism preventing communication interruptions in the process. In this situation, the previous AA will mark its IP address as free in order to be allocated to some other node later.

* + 1. **AROD**

In Address auto-configuration with address Reservation and Optimistic duplicated address Detection (AROD) [15], the address reservation is based on the existence of nodes that have an IP address reserved to deliver it to the new nodes that enter.

Two types of nodes will exist:

* Agents type 1 with a reserved IP address, apart from the IP address that has its network interfaces. When a node joins the network, this reserved IP will be assigned to it immediately.
* Agents type 2, which do not have reserved IP addresses. If a node that joins newly asks one of these for an IP address, this node borrows the reserved address of one of its neighbours who is of type 1, and it is assigned to the new one immediately.

It establishes a mechanism so that the network does not remain without nodes of type 1, whenever an IP address is assigned to a new node, the node that has delivered the address generates two random IP addresses (one for itself and another one for the new node that has joined) and does a DAD process to detect if these addresses are unique. Once the process has been carried out the following possibilities can arise:

* The IP addresses are unique; therefore, the two nodes turn into node type 1.
* If only one is unique, the one that gave the IP address will be turned into node type 1.
* If none is unique, the two nodes will remain as type 2.
  + 1. **AIPAC**

Automatic IP Address Configuration in Mobile Ad Hoc Networks (AIPAC) is a protocol for IP address auto-configuration using a reactive approach in the IP address assignment, so it should manage duplicate addresses; it is also focused on maintaining the address uniqueness after network merging due to the node mobility.

The protocol has as its priority the supporting of the following features of ad hoc networks: limited resources of the devices and the unreliability in the wireless channels. Each network is identified with its NetID. When two networks merge, and the merger is persistent, the NetID should be unified. To accomplish that, it uses a gradual fusion mechanism. This allows a

node to pass from a NetID to another one, according to network changes observed by the node. This procedure allows a homogeneous system to be made in the case of multiple overlapping networks, according to the evolution of their topologies.

1. **Performance Evaluation of Auto-configuration Protocols**

The following Table 1 describes the matrices have been considered for performance evaluation of auto-configuration protocols.

**Table 1:** Performance Matrics

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| **Metrics** | **Description** |
| Uniqueness | Each MANET node have a unique IP address for each node to avoid duplicate address |
| Overhead | Control packets to obtain IP address |
| Latency | Node timeout to obtain IP address |
| Routing Protocol Independence | Learning on a routing protocol to allow the routing of the new nodes joining the network, or regardless of routing protocol |
| Un-uniformity | All nodes perform same operation in auto-configuration process |

The following Table 2 describes the performance evaluation of studies protocols with characteristics in IPv4 version.

**Table 2:** Comparative study of protocols with matrices

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| --- | --- | --- | --- | --- | --- | --- |
|  | **Protocol** | **Guarantee of uniqueness** | **Overhead** | **Latency** | **Dependent Routing** | **Uniform** |
| **Stateful** | MANETConf | No | High | High | No | Yes |
| DAAP | Yes | Medium | Medium | No | No |
| EMAP | No | Low | High | No | Yes |
| **Stateless** | APAC | No | High | High | Yes | No |
| AROD | Yes | High | High | No | No |
| AIPAC | No | High | High | No | No |

1. **Conclusion**

The nodes of a network need a mechanism to exchange messages. The TCP/IP protocols can allow the different nodes of the same network to be associated with a different IP address. Due to the dynamic topology of mobile ad hoc networks (constant movement of the nodes that can enter and leave the network frequently or even simultaneously), auto-configuration protocols face many problems with guaranteeing the uniqueness of IP addresses. This work presents a classification of auto-configuration protocols for the most representative mobile ad hoc networks in literature with special emphasis on D2HCP protocol, and in particular in its design considerations and the advantages over their predecessors, especially when efficiently managing the IP address space of the ad hoc wireless network.

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