Review of Auto-configuration Protocols for WANETs for IPv4 and IPv6 networking

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Abstract: The TCP/IP protocol associates a different IP address to each node in a network that allows different nodes in a network to communicate properly. Wired or wireless networks with infrastructure have a server or node acting as such which correctly assigns IP addresses, but in wireless ad-hoc networks there is no such centralized server. Therefore, a protocol is needed to perform this task of network configuration automatically, as networks may change their topology dynamically and spontaneously. The protocol may use all or part of the nodes in the network act like if they were servers that manage IP addresses. This article reviews and investigates the various protocols proposed for dynamic configuration of IP addresses in wireless Ad Hoc networks and analyzes them on the basis of overhead and guarantee of uniqueness. It also analyzes work by various researchers in the direction of dynamic configuration and how to configure or auto-configure addresses at link-local level, WANET level, and at the gateway level.

Keywords: auto-configuration protocol, Wireless Ad Hoc Network (WANET), IPv4, IPv6

I. INTRODUCTION

A wireless ad-hoc network (WANET) is a self-governing and self-directing network consisting of a set of identical mobile nodes which communicate with each other via wireless links. It has no established infrastructure and centralized administration. The network's topology is very much unpredictable and can change quickly. The flexibility, easy deployment, and self-configurability of WANETs are its most important features. The Integration of the Internet with heterogeneous networks viz. WLAN, WiMAX, ZigBee, Wi-fi, UMTS etc. increases the sphere of influence of ad hoc networks, as it extends its network coverage and scalability. But as the Internet and WANET architectures are different, therefore various sorts of assumptions are imposed on the structure, topology of the underlying networks and on the communication patterns of their mobile nodes to integrate them into a hybrid network which is very challenging.

With the advent of wireless technology and due to their seamless integration with the internet, addressing techniques are very important aspect to study and improve as each communicating entity on the Internet requires a unique network address to be reached. IP addresses can be configured in two ways: manual configuration and dynamic configuration. But Manual configuration can't be used due to highly dynamic nature of WANETs. So addresses of mobile or wireless devices as to be changed from time to time which is not possible manually. This means that dynamic configuration is required for WANETs. Therefore, auto-configuration protocol is required to assign temporary IP addresses to such nodes. The ad hoc nodes need to configure their interfaces with

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local addresses which are valid within the ad hoc network to communicate with each other [11]. Moreover, the ad hoc nodes may also need to set global routing addresses [1] to communicate with other devices on the Internet.

Section I gives the introduction. Rest of the paper is organized as follows: Section II discusses the various issues to auto-configuration and its objectives to achieve in WANETs. Section III discusses the classification of auto-configuration protocols for WANETs for IPv4 and IPv6. Section IV draws the conclusion. Section V proposes the future work.

II. AUTO-CONFIGURATION IN WANETS

WANETs can either be stand-alone networks or may be connected by a gateway to other wired networks (like the Internet) or other wireless networks. It is to be noted that wireless interfaces do not have a complete view of the network; instead each wireless interface has different unique partial view of the WANET. It may have a particular neighborhood, which afflicts the need of routing and auto-configuration algorithms. Also, nodes send and receive packets on the same interface, so duplicate IP messages may occur on WANET routers with several adjacent nodes.

Issues in auto-configuration:

The chief goal of auto-configuration is to configure globally unique and topologically correct IP addresses. It is achieved using following number of steps to ensure the address configured is unique and not duplicated to avoid ambiguity in transferring packets.

1. Configuration of locally unique addresses
2. Configuration of WANET-local unique addresses
3. Configuration of Internet gateways

Fig 1 and Fig 2 gives the state transition diagram and flowchart of Ad-hoc IP Address Auto-configuration respectively.

So to guarantee the proper and correct functioning of the network that may consist of several networks connected via Internet; auto-configuration protocol should try to achieve the following objectives. The more it gets closer to achieve the objectives, better is the protocol.

1) It should assign unique IP addresses to WANET nodes
2) Dynamic Allocation of IP addresses: An IP address is associated with a node only for the time that it is kept in the network and should then become available for other nodes.
3) Prevent two or more nodes from having the same IP address in case of any node failure or message loss.
4) It should allow multi-hop routing so that if any node of the network has a free IP address, it should get itself associated with any other node requesting IP address any distance apart.
5) Minimize the additional control packets traffic in the network for auto-configuration process as it decreases network performance
6) When two nodes request an IP address at the same time, it should be ensured that same IP address is not allocated to two requesting nodes.
7) The protocol must be able to achieve the partitioning and merging of the wireless ad hoc network.

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8) The synchronization should be carried out periodically to ensure proper and updated configuration of the network.

III. CLASSIFICATION OF AUTO-CONFIGURATION PROTOCOLS

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

- *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.
- *Hybrid*: They mix mechanisms generated by mixing characteristics of both Stateful and Stateless protocols to improve the scalability and reliability of the auto-configuration but these algorithms have a high level of complexity.

Proposals for Dynamic allocation

When a node is assigned an address, it needs to find out whether or not the address it chooses in unique within its network. Duplicate address detection (DAD) is performed to determine whether or not a chosen IP address is unique within a chosen network. Generally the different proposals differ in the technique they use to perform DAD. The proposals fall into two different categories:

1. *Hierarchical Approach:* In this, a clustering technique is used with one node (cluster head) takes the responsibility for the allocation of addresses to new nodes as they arrive. Cluster head also ordinates a duplicate address (DAD) process. MANETconf uses hierarchical approach for IP address allocation problem.
2. *Flat Topology Approach:* When a node joins the network and wants an IP address, it chooses an address at random and then performs a duplicate address detection procedure in order to determine whether or not that address is unique. Perkins et al. paper is based on this approach using AODV routing protocol.

IPv4 vs. IPv6

The IPv4 and IPv6 addressing presented previously were designed for wired networks, and we notice that the comparison of IPv4 and IPv6 addressing applied to ad hoc networks is similar to the wired networks. For example, network prefixes used in an IPv4 auto address configuration are mostly constant, whereas in IPv6, they could be dynamic and depend on available prefixes. Further, most IPv6 schemes use the mechanism of IPSA [2] to configure interface identifiers, thus distributed address assignment is adopted by almost all schemes. Whereas most proposed IPv6 schemes consider the hybrid case, that is, the ad hoc network also being connected to the Internet via gateways; most IPv4 schemes only consider the standalone case, without any window to the external network. Therefore, only local addresses are assigned in IPv4 auto-configuration, with the assumption that global addresses can be provided through solutions such as network address translator (NAT) or other means.

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A. Classification of auto-configuration protocols for IPv4

In a classical IP wired network, there are several used techniques to configure IP addresses to all hosts like Bootstrap, DHCP, Zeroconf, Zerouter etc. but these techniques are for IPv4 and for wired networks. But for WANETs, nodes are mobile so the main issue is to configure globally unique and topologically correct IP addresses for all nodes.

Perkins et al. [4] proposed a mechanism in which node performing the auto-configuration process picks two addresses, a temporary address and the actual address to use. Temporary address is used only once to check the uniqueness to minimize the possibility for it to be non-unique. The uniqueness check is based on sending as address request (AREQ) and expecting an address reply (AREP) back in case the address is not unique. In case no AREP is received, the uniqueness check is passed. For IPv4, a node attempts to select a random address on the network 169.254/16. The messages are Internet Control Message Protocol (ICMP) packets. But the major problem with this is that it does not consider the possibility of merging and partitioning.

Subir Das et. al. [5] proposes the Dynamic Registration and Configuration Protocol (DRCP). This paper presents a distributed DHCP architecture in which each node represents a DRCP client and server and owns an IPv4 address pool and the Dynamic Address Allocation Protocol (DAAP) is responsible for the distribution of the address pools. Network merging, partitioning or Internet connectivity are not considered in this paper.

Mohsin et. al. [6] uses the concept of binary split in order to perform dynamic configuration. When an un-configured node wishes to join the network, it requests the nearest configured node for an IP address. Configured node divides the set of IP addresses into two and gives one-half to the requesting node. This paper addresses the problem of network partitioning and merging by using partition ID. But this paper considers only a standalone WANET (Mobile Ad Hoc Network), so the network does not have access to the Internet.

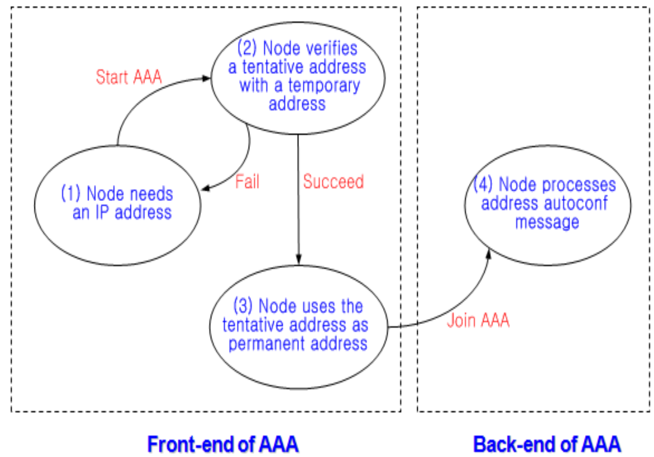

Fig 1: State Transition Diagram of node for Ad-hoc IP Address Auto-configuration (AAA)

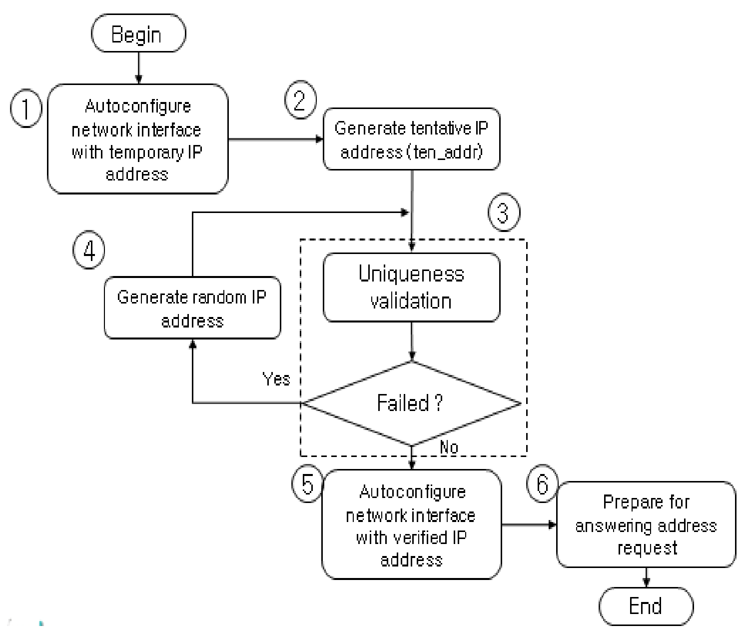

Fig 2: Flowchart of AAA

The goal of configuring global address for IPv4 is achieved using number of steps.

1. Configuration of locally unique IP addresses

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In order to communicate with adjacent nodes in the WANET, a node upon initialization may pick a link-local address. As in a WANET, each node is a router; a node having a link-local address may only communicate with its direct neighbors.

(i) Assign Tentative address and check uniqueness

Perkins et. al.[4] gave an approach in which a node first picks a temporary IP address from the range 1-2047 of the class B network 169.254/16. These addresses should never be assigned as a permanent address for a WANET node. Then the node attaches either part of its MAC address or the whole MAC address to the prefix. As these addresses may be duplicate even in the 1- or 2-hop neighborhood, duplicate address detection should be performed.

2. Configuration of WANET-local unique IP addresses

Nodes wishing to communicate mutually in a WANET need to have unique address within it. If any two (or more) addresses within a WANET are duplicated, the routing protocol will not be able to distinguish between the conflicting nodes and packets will either be delivered to the wrong node or will be dropped. There are several approaches proposed to assure WANET-local unique addresses.

i) **WANET-DAD (Strong DAD)**

A node floods the WANET by sending the tentative address in an Address Request (AREQ) to all adjacent nodes. A node receiving an AREQ first creates a unicast route back to the node then compares the tentative address from the originating node with its own [4]. If they do not match, the node forwards the AREQ packet to all of its neighbors. If the addresses match, the node sends back an Address Reply (AREP) using the unicast reverse route. The autoconfigurating node waits a certain time for receiving an Address Reply message after having sent the request. If it receives a reply within the time limit, it has either to choose another tentative address or has to be configured manually. If no reply has been received, however, the node resends its request for a certain predefined maximum number of tries. Still not having received a reply after these tries, the node assumes that no node in the WANET has chosen the same address and keeps that IP address permanently.

(ii) **Proxying**

Whenever an AREQ message arrives at a node, it compares the tentative address both with its own address and addresses in its routing table and its cache [19]. This can reduce the overhead and congestion in a WANET on a large term

(iii) **Weak DAD**

This technique constantly tries to find duplicate addresses even after the initial configuration process [14]. Nodes include a pair (IP address, key) in their packets. The key has to be unique and could be the MAC address. Whenever a node receives packets from one IP address but with different keys, it knows that there has been a conflict.

(iv) **Passive DAD**

The idea is to avoid overhead by sending packets throughout the WANET to detect an address conflict but rather to listen the network in a passive way [15]. Result is less overhead and congestion in the WANET while still detecting all conflicts. But the problem is to assure detecting all these conflicts.

3. Configuration of Internet gateways

In order to enable Internet access, border gateways to the Internet have to distribute their global prefixes and mobile nodes have to be configured correctly. IPv4 may have to use Network Address Translation (NAT) to communicate with other networks.

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	Protocol	Over head	Uniqueness Guarantee	Brief description
Stateful	MANET Conf[13]	High	No	common distributed table exists.
	DAAP	Medium	Yes	new node joining the network becomes the leader until the next node joins.
	Buddy system [20]	Medium	Yes	Manages mobility of nodes during address assignment, message loss, network partitioning and merging but uses flooding process.
Stateless	SDAD [4]	High	No	process limits itself to only the phase of initialization, so would not work for temporary disconnections or losing of the network.
	WDAD [14]	Medium	No	tolerates duplicated address in the network for a period of time. identifies node by means of a key-IP pair
	PDAD [15]	Medium	No	sends control information instead of detecting or solving duplicated IP addresses
	AROD [16]	High	Yes	existence of nodes that have an IP address reserved to deliver it to the new nodes that enter.
	AIPAC [17]	High	No	manages network merging. Each network is identified with its NetID.
Hybrid	HCQA [18]	High	Yes	adds robustness to the SDAD process, ensures no duplicity of IP addresses and manages network partitioning.

Table1: Comparison of the characteristics of IPv4 addressing protocols.

Table1 summarizes some of the addressing protocols for IPv4

B. **Classification of auto-configuration protocols for IPv6**

IPv6 works on stateless auto-configuration protocol (IPSA). The design goal of IPv6 stateless auto-configuration was to minimize manual user interaction. Hosts and router IP addresses are configured automatically. So IPv6 supports auto-configuration and no manual interaction both for wired and wireless networks. IPv6 have 128 bit address and it will be very complex also to assign 128-bit address manually.

Perkins et. al. [4] gave an approach for IPv6 using AREQ (modified neighbor solicitation) and AREP (modified neighbor advertisement) messages. This process allows for a node to obtain a globally unique IPv6 address making it able to connect to the Internet.

Steps in IPv6 SA for wired networks are [2]:

1. **Creation of a tentative link-local address:** This occurs whenever a network interface has been enabled or attached to the link.
2. **Duplicate address detection:** The node has to verify that its link-local address is unique on the link. Therefore, it broadcasts Neighborhood Solicitation (NS) messages using the neighbor discovery protocol [7]. If the node receives a neighbor Advertisement (NA) response from any node on the same link, it knows that its tentative address is already allocated to another node. In this case, the node has either to use a new interface identifier, or the auto-configuration process fails and another method of assigning an IP address has to be applied.

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3. **link-local address Assignment:** The node may finally assign the link-local address as permanent and can communicate with all other nodes on the same link if passes DAD test successfully.
4. **Getting a prefix from a router:** Node can either send a Router Solicitation (RS) message or wait for a periodically broadcasted Router Advertisement (RA) packet. This message contains the prefix of the router.
5. **Assigning a site-local or global prefix:** The node may create its new site-local or global address by simply attaching its interface ID to the received prefix.

For WANET configuration, steps are almost same as IPv4 but with some modifications:

1. **Configuration of locally unique IP addresses**

(i) **Assign Tentative address and check uniqueness**

Perkins et. al.[4] used an approach in which a node picks a temporary IP address from FE80::/64 for IPv6. Then the node attaches either part of its MAC address or the whole MAC address to the prefix. In IPv6 networks, the node has first to convert the 48 bit MAC address into a EUI-64 address [8]. Another method would be to attach a random number to the link-local prefix.

(ii) **Unique local addresses (ULA)**

C. Jelger [9] presented an idea to take FEB0::/10 as a prefix and choosing the following 54 bits randomly. Then either the MAC address could be attached or the last 64 bits can be chosen randomly for anonymity.

2. **Configuration of WANET-local unique IP addresses**

(i) IPv6 stateless auto-configuration (IPv6 SA):

[10] adopts IPv6 stateless auto-configuration for wired networks [2] to mobile ad hoc networks. Neighbor solicitation (NS) messages are used to detect if the chosen tentative link-local address has already been assigned. It uses the all-nodes multicast address as destination address and includes a hop limit of r_s. A node receiving a NS message decreases the hop count by one and forwards it if hopcount > 0. Thus, address uniqueness is guaranteed within the scope r_s of each node.

3. **Configuration of Internet gateways**

In order to enable Internet access, border gateways to the Internet have to distribute their global prefixes and mobile nodes have to be configured correctly. Gateway can be fixed in a network or it can be selected using Gateway Discovery mechanism based on certain parameters such as hop count, congestion, etc.[12] Configuration of Internet gateways is essential for unambiguous global communication.

IV. CONCLUSION

This paper discusses various issues in auto-configuration and classification of auto-configuration protocols in detail. Based on address assignment, auto-configuration protocols can be classified as stateful, stateless or hybrid. DAD can be performed using either hierarchical approach or flat topology approach. An analysis of current state-of-the-art auto-configuration protocols for wireless ad-hoc networks (WANETs) has shown that there exist many proposals being capable of attributing unique IP addresses within a WANET. Various deficiencies of current solutions have also been addressed in this paper.

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V. PROPOSED FUTURE WORK

There are a number of problem areas, which could be further researched. Our future research will focus on the dynamic IP address assignment problem for WANETs We will focus on integrating Internet with various networks. Most of the research work done is for IPv6 but IPv4 being complicated, not much been tested in the global environment. Auto-configuration Protocol will be used to dynamically assign IPv4 and IPv6 addresses to the nodes and comparison will be shown between IPv4 and IPv6 using various performance metrics to show how IPv6 is better than IPv4.

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