

MANET Autoconfiguration (AUTOCONF)  
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Survey of IP address autoconfiguration mechanisms for MANETs  
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## Abstract

This Internet Draft provides a detailed description of most of the existing IP autoconfiguration solutions proposed so far. The main aim of this document is to serve as a general reference for the AUTOCONF solution space. We present most of the previously proposed IP AUTOCONF mechanisms in MANETs, showing their key characteristics, conforming to the AUTOCONF problem statement draft and the MANET architecture draft. Furthermore, each solution is analysed based on a number of evaluation considerations.

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## 1. Introduction and motivation

Multi-hop communication in ad hoc networks presents some interesting advantages, where no permanent infrastructure is required. Also, the coverage area of an existing infrastructure can be extended through multi-hop ad hoc communication. Several MANET routing protocol specifications have been developed by the IETF MANET WG. In order to allow wide deployment of ad hoc networks, in which IP routing is the most candidate approach, IP configuration of nodes is a strong requirement that need to be satisfied. In this context, the AUTOCONF WG is working towards standard specifications and solutions for IP address autoconfiguration within different MANET environments.

Ad hoc networks present particular characteristics that should be taken into account when designing address auto-configuration protocols. Since existing solutions for IP infrastructure-based networks (e.g., RFCs 4861, 4862, 3315 etc.) were designed for a different scope than MANETs [[1](#)], there are several issues that need to be tackled, mainly (but not only) the following: the lack of multi-hop support, the lack of dynamic topology support, the lack of network merging support and the lack of network partitioning support.

The main goal of the AUTOCONF WG is to develop solutions for IPv6 address auto-configuration (both MANET-local and global scoped). The group has identified two possible scenarios of MANET where IP address auto-configuration is required [1]:

- o Standalone MANETs: these networks are not connected to any external network. All traffic is generated by MANET nodes and destined to nodes in the same MANET. Examples of these networks are conference networks, battlefield networks, surveillance networks, etc. In this scenario, nodes may join or leave randomly. Besides, most likely no pre-established nor reliable address or prefix allocation agency will be present in the network.
- o Connected MANETs. These networks have connectivity to one or more external networks, typically the Internet, by means of one or more gateways that are also known as MBRs (MANET Border Routers). These networks may be connected to the Internet in permanent fashion or in intermittent fashion.

This draft aims at providing a survey on most of the previously proposed IP autoconfiguration solutions, trying to serve as a useful reference for the AUTOCONF WG during the problem space analysis and solution design phases.

In the following section, we provide a description of several

existing AUTOCONF solution proposals, analysing them based on some evaluation considerations proposed in [2]. In order to present the analysed solutions in a structured way, two major classification levels are used: i) standalone/connected, and ii) partitioning/merging support.

The given analysis conforms to the AUTOCONF problem statement draft [1] and the MANET architecture draft [3].

## [2.](#) IP address auto-configuration protocols

In this section we briefly describe some of the existing proposals for IP address autoconfiguration, classifying them according to some of the evaluation considerations introduced in [\[2\]](#).

### [2.1.](#) Solutions for Standalone MANET scenarios

### 2.1.1. No merging support

#### 2.1.1.1. IP address Autoconfiguration for Ad Hoc Networks (Perkins et al.)

This address autoconfiguration mechanism -- proposed in [4] -- basically consists in choosing an address randomly from an address pool (i.e., a network prefix) available to the MANET and then performing a Duplicate Address Detection procedure within the MANET.

Assumptions: It is assumed that nodes performing this autoconfiguration protocol obtain a non-link-local prefix (it cannot be link-local, since the addresses have to be valid over a multiple-hop distance) from which to configure an address. The method to obtain a globally routable prefix is not specified in the solution and, in case it is not possible to obtain any suitable one, a reserved IPv6 prefix, called MANET\_PREFIX, is used: fec0:0:0:ffff::/64.

Approach description: This solution basically works as follows: a node first selects a random address from the non-link-local prefix that is deployed in the MANET and then performs a Non-unique Address Detection procedure to check for its uniqueness across the MANET. To perform this uniqueness check, the node sends an Address Request (AREQ) message, including the randomly chosen tentative non-link-local IP address. This message is broadcast to its neighbours, by sending the message using the all-nodes multicast IPv6 address as destination of the packet. The source address used by the node to send the AREQ message is another temporary IP address, acquired only for the purpose of sending these messages. This temporary IPv6 address belongs to a different non-overlapping prefix -- called MANET\_INITIAL\_PREFIX -- so the probability of this address to be duplicated in the network is very low, given its short lifetime (this address is only used in this message exchange and discarded thereafter). When a node receives an AREQ message, it creates a reverse route entry for the temporary IPv6 address of the node. If the tentative address contained in the AREQ message does not match the address of the receiving node, it rebroadcasts the message to its neighbours. If the IP address of the receiving node matches the tentative address contained in the AREQ message it sends an Address

Reply (AREP) message to the sender, indicating that the address is

already in use. The route created by the AREQ messages is used to route the message back to the source node.

A node waits for a certain amount of time after sending an AREQ message, for the reception of an AREP message. The process is repeated if no answer is received, and if after a number of attempts no AREP has been received, the node assumes that the tentatively chosen IPv6 address is unique and starts using it. The values configured for the involved timers and retry parameters have an impact on the maximum size of the MANET where the solution would properly work. Additionally, since the Non-unique Address Detection procedure is performed only when the node initially chooses the tentative IPv6 address to use, this mechanism does not support merging of MANETs.

AREQ and AREP are a modification of the standard ICMPv6 Neighbour Advertisement and Neighbour Solicitation messages, respectively.

Based on [2], this solution has the following key features:

- o MANET scenario: the solution targets standalone MANETs, although it considers the possibility of being applied to connected scenarios in those cases in which nodes are provided with the non-link-local prefix to be used in the MANET.
- o Routing protocols' dependency: the solution is routing protocol independent.
- o Address uniqueness: the proposed solution makes use of Non-unique Address Detection in the initial address assignment phase.
- o Distributed/centralised approach: the solution does not make use of any centralised server.
- o Merging support: the solution does not support merging.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: the solution requires additional message flooding (AREQ messages) to verify if an IP address is being used in the MANET.

### [2.1.2.](#) Merging support

#### [2.1.2.1.](#) IPv6 Autoconfiguration in Large Scale Mobile Ad-Hoc Networks (Weniger et al.)

The solution described in [\[5\]](#) extends the Neighbour Discovery and IPv6 Stateless Address Autoconfiguration mechanisms to work in multi-hop wireless networks.

Assumptions: The solution assumes a hierarchical approach, where there are two different types of participating nodes: those that obtain IPv6 addresses by using a modified version of IPv6 Neighbour Discovery, and special nodes -- called leader nodes --, that are responsible for parts of the address configuration of other nodes.

Approach description: The solution basically extends IPv6 Neighbour Discovery to provide nodes within a multi-hop environment with IPv6 address autoconfiguration capabilities. To do so, the following modifications to the IPv6 Neighbour Discovery protocol are proposed:

- o The Neighbour Solicitation message is modified to allow it to be broadcast to a bounded area of radius *r\_s* hops (instead of only a single hop). In addition, a new option for Neighbour Discovery is defined (called MANET option) which contains a Random Source ID (RS-ID) field, that is used to distinguish different nodes. Nodes use the all-nodes multicast address instead of the solicited-node multicast address. This mechanism guarantees link-local addresses to be unique within the scope (limited by *r\_s*) of each node.
- o To enable the configuration of unique site-local addresses, a hierarchy is established by special nodes (called leader nodes) that configure a group of nodes by issuing Router Advertisements (RA) within their scope, containing the subnet ID (i.e., network prefix) and its link-local address as source address. The subnet ID has to be unique for each leader node, so Non-unique Address Detection has to be performed between the leader nodes within the entire Ad hoc network. An algorithm is provided for the election of leader nodes.

It should be noted that because of the nature of the solution, it would be possible to have multihomed nodes -- that is, nodes with more than one IPv6 address -- if a node is within the scope of more than one leader node.

Based on [\[2\]](#), this solution has the following key features:

- o MANET scenario: the solution targets standalone MANETs, although it could be possible to extend it to support the assignment of

global IPv6 addresses.

- o Routing protocols' dependency: the solution does not depend on any particular ad-hoc routing protocol, but it may be advantageous the routing protocol it follows a hierarchical structure. Besides, it is also preferable that nodes move in logical groups. Otherwise, the cost of maintaining the hierarchical structure may be considerable.
- o Address uniqueness: the proposed solution makes use of a periodic Non-unique Address Detection for ensuring the address uniqueness within the scope of the leader node. Since each leader node makes use of a different Subnet ID, the uniqueness of the assigned address within the entire MANET is ensured.
- o Distributed/centralised approach: the solution does not make use of any centralised server, but considers the existence of special nodes (leader nodes) that participate in the mechanism in a distributed fashion.
- o Merging support: the solution support merging, by leader nodes performing periodic Non-unique Address Detection that ensures the uniqueness of Subnet IDs.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: the solution requires additional message flooding within a bounded area of radius  $r_s$  hops.

#### [2.1.2.2](#). Ad Hoc IP Address Autoconfiguration (Jeong et al.)

The solution described in [6] proposes two Non-unique Address Detection mechanisms. The first one -- called "strong DAD" -- is done in the initial phase when the ad hoc node does not have an IP address configured yet, it relates to the fact that before a randomly generated address is assigned and used, it should be verified that it will not create an address conflict. On the other hand the second Non-unique Address Detection mechanism -- called "weak DAD" -- is

always executed by nodes taking part in ad hoc routing in order to prevent any address conflicts due to mergers.

Assumptions: The solution assumes that initially a random address is selected by ad hoc nodes using the reserved IPv6 prefix MANET\_PREFIX.

Approach description: This approach includes two different Non-unique Address Detection mechanisms:

- o Strong DAD: based on [4]. Strong DAD is done initially after an ad hoc node has chosen randomly an IP address and it is trying to find out whether there is a duplication conflict or not. AREQ message for Strong DAD is broadcast in site-local scoped all node multicast address, IPV6\_MANET\_BROADCAST\_ADDRESS. The ad hoc node waits for an AREP message -- indicating the selected address has already been utilised -- until the timer for Strong DAD expires. In the case an AREP message arrives it chooses a new address and executes Strong DAD mechanism again. [6] describes the message format, using ICMPv6 messages (new types are defined). [7] describes the message format for AODV.
- o Weak DAD: based on [8]. During ad hoc routing, weak DAD is used to find out whether address duplication, due to merging has occurred or not. The concept of ``Virtual IP address'', which is the combination of an 'IP address' and an 'Key', is used, which is selected to be unique by each mobile ad hoc node. This 'key' is appended to control packets of ad hoc routing protocol, such as route discovery messages or hello messages. Intermediate routing points must store the 'key' value for each address in its routing table. Using these 'keys', duplication conflicts can be found out during ad hoc routing process. An AERR message is sent during Weak DAD for the purpose of indicating that an address duplication happened. The ad hoc node that receives an AERR message should autoconfigure a new IPv6 address through Strong DAD. The same AERR message is used to inform each peer node that its address has been changed. In order to keep ongoing sessions after an address duplication episode, data packets are sent to the new address through IP tunnelling. The destination address in outer IP header is the new IP address of the node that announced duplicate address and the inner IP header contains the duplicate IP address of the node, i.e. the old address of the

node. The match duplicate address and new address is done in an Address Mapping Cache.

Based on [2], this solution has the following key features:

- o MANET scenario: the solution targets standalone MANETs.
- o Routing protocols' dependency: the solution does not depend on any particular ad-hoc routing protocol.
- o Address uniqueness: the proposed solution makes use of two different Non-unique Address Detection mechanisms.
- o Distributed/centralised approach: the solution is distributed. It does not make use of either any centralised servers or special nodes.

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- o Merging support: the solution supports merging by looking for duplicate addresses on an ongoing basis.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: The Strong DAD mechanism requires additional message flooding (AREQ messages) to find out whether there is a duplication conflict or not. The Weak DAD mechanism introduces also some protocol overhead since the Key extension (20 bytes) is appended to each control packet of the ad hoc routing protocol.

#### 2.1.2.3. IP Address Assignment in a Mobile Ad Hoc Network (Mohsin et al.)

This proposed solution [9] is based on a dynamic allocation of IP addresses in MANETs using the concept of binary split. A proactive approach is used, in the sense that each node can independently assign a new IP address without consulting any other node in the network. Partitioning and merging as well as nodes abrupt departures are supported in this solution.

Assumptions: It is assumed that all nodes collectively perform the DHCP functionality; where each node is capable of configuring a new node and providing it with a new IP address. It is also assumed that

one MANET node have the entire pool of IP addresses at the beginning.

Approach description: In this proposed solution the concept of Buddy Systems is used. This is a type of segregated lists used in memory allocation and supports efficient splitting and coalescing. In the context of the proposed solution, binary buddies are used, where all buddy sizes are a power of two, and each size is divided into two equal parts. Thus, every node has a disjoint set of IP addresses that it can assign to a new node without consulting any other node in the network. When a new unconfigured mobile node (B) joins the network, it requests the nearest neighbour (A) an IP address. Node (A) divides its IP address set into two, giving one half to the requesting node (B). The new node assigns itself an IP address from the acquired pool of addresses, storing the rest of addresses to configure other nodes afterwards. The new node (B) is now configured and is considered as the Buddy of node (A). The scheme of the IP address assignment can be seen as a handshaking protocol between the server and the client, where the node requesting the IP address is considered as the client node and the node that actually assigns the IP address is considered as the server node.

Nodes synchronise the IP blocks which they store to keep track of the assigned IP addresses and detect any IP leakage, where every node

keeps a record of all the IP address blocks in the network by maintaining a corresponding table. Each node sends its IP address pool to all other nodes in the network, and each node receiving an IP pool from another node records the received information in its IP address table. Through this approach, the network has among its nodes the available IP addresses organised in the form of a binary tree with a division of two identical blocks (Buddies) per level.

Two mechanisms are proposed for releasing the node's IP address pool when the node leaves the network: i) graceful leave, in which the leaving node gives its IP address pool to any nearby node. This nearby node may keep the IP address pool for itself or may search in its IP address table the Buddy of the leaving node and forward to it the IP pool. ii) abrupt leave, in which the node leaves with its IP address pool that leads to IP leakage. In such a case, a pool of IP addresses that is not assigned to any node is not available. IP leakage is detected from the IP address table stored at each node. Each node scans from time to time its IP address table for the IP

pool of its Buddy node, if it does not find it, it concludes that the node has left and it merges this missing IP block to itself.

Based on [2], this solution has the following key features:

- o MANET scenario: This proposed solution targets standalone MANETs.
- o Routing protocols' dependency: This proposed solution is independent of the underlying routing protocol.
- o Address uniqueness: The proposed solution does not use any Non-unique Address Detection mechanism.
- o Distributed/Centralised approach: Although this solution is based on IP address pools assignment and splitting, it has a distributed approach, where all nodes collectively perform the functionality of a DHCP server.
- o Merging support: Thanks to employing the buddy systems, the proposed solution supports merging. In case of merging, the process of buddies splitting allows the merging node to be assigned an IP address and an IP pool.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: the solution requires a kind of flooding so that each node sends its IP address block to all other nodes in the network. Furthermore, other control messages are required in the form of request-reply messages to enable a new joining node to

be assigned an IP address, or in the form of announcement in the case of IP release.

#### 2.1.2.4. An Address Assignment for the Automatic Configuration of Mobile Ad Hoc Networks (Tayal et al.)

The solution described in [10] is very similar to the previous one ([9]), sharing the idea (also used by others) of nodes assignment of half of their address pools to newly arrived nodes that request IP addresses.

Assumptions: It is assumed that initially there is one node that configures itself as initiator node (when there is no other node in the network), configuring itself with a default IP address and starting to manage a default address pool.

Approach description: The solution basically works as follows: when a new node *i* (called requester node) is willing to join the MANET, it has to contact an existing node *j* in the network. If node *j* has the address pool, it divides it into two parts and allocates one part to node *i*. The starting address of the allocated pool is the address of node *i*. In case node *j* does not have the address pool, *j* starts searching for nodes that might have an address pool, by broadcasting a message (called SEARCH\_ADDR). The search message is forwarded by all the nodes which do not have an address pool. A node receiving the search message, either replies with the address pool or with negative ACK. If a node replies with its address pool, it marks half of its addresses as under allocation and wait for a POOL\_ACCEPTED message from node *j*. Node *j* replies with POOL\_ACCEPTED message to the node whose address pool it received first, and allocates the received address pool to node *i*.

This solution defines mechanisms to handle different scenarios, such as network partitioning and merging, message loss, etc. More details can be found in [10].

Based on [2], this solution has the following key features:

- o MANET scenario: This proposed solution targets standalone scenarios.
- o Routing protocols' dependency: This proposed solution is independent of the underlying routing protocol.
- o Address uniqueness: The proposed solution does not use any Non-unique Address Detection mechanism, since the uniqueness of the solution is based on the split of the initially available IP address pool.

- o Distributed/Centralised approach: the solution is based on IP address pools assignment and splitting, where all nodes collectively perform the functionality of assigning addresses to newcomers.

- o Merging support: the solution defines a mechanism to detect merging, through redistributing information about assigned addresses and pools. If an address collision is detected, then the solution defines a mechanism to solve that, based on giving up/shrinking the address pool used by one of the nodes detecting the conflict.
- o Prefix assignment support: Since the solution supports the assignment of address pools, it can be possible to use it to assign prefixes to nodes, although it is not explicitly covered by the mechanism.
- o Protocol overhead: the solution requires some message flooding to search nodes that have an address pool available.

#### 2.1.2.5. No Overhead Autoconfiguration OLSR (Mase et al.)

This solution [11] proposes some passive Non-unique Address Detection techniques to be used in MANETs running the OLSR protocol. It utilises the Passive Duplicate Address Detection concept [12], [13], which enables nodes to passively detect duplicate addresses in the network (e.g., occurring after network merging) by analysing received routing protocol messages. The basic idea of PDAD is to exploit the fact that some protocol events occur in case of duplicate address, but (almost) never in case of a unique address. The proposed techniques may be used to ensure uniqueness of an address when it is initially generated before being assigned to an interface and the solution also performs to ensure uniqueness of addresses which have been assigned and used, and then a network merger happens.

This is one of the multiple drafts proposing the use of PDAD for OLSR [14], [15].

Assumptions: The protocol assumes the existence of a Non-unique Address Detection-based IP address generation mechanism.

Approach description: The solution proposes an ongoing duplicate address detection mechanism, checking for inconsistencies in the routing protocol messages to diagnose duplicate address detection. The first kind of inconsistency is based on information included in OLSR messages (such as HELLO messages and TC messages) and the second kind of inconsistency is based on sequence numbers (when two nodes -- which selected the same IP address -- are present in a network, they

would send control messages that will be inconsistent).

Different Non-unique Address Detection rules -- twelve in total -- are proposed to handle the cases where the distance between conflicting nodes is one hop, two hops and, three hops or more. In the two first cases the detection is done by means of HELLO messages and in the last case -- three hops or more -- the detection is fulfilled by using information inside TC messages. Also, an additional case is taken into account: this is a specific multihop address conflict case, where the address conflict results in deficiencies in the MPR selection.

Each node has an "autoconfiguration state". This state is an indicator of how long the node has been in the network. The central idea, is that each time a node generates a tentative address, it should enter the network gradually, running a restrained version of the OLSR protocol. In this way, the node can detect which addresses are being used, checking for duplicates of its own address, while avoiding to disrupt the routing tables of the other nodes, in the event that its address is actually found to be in conflict.

Based on [\[2\]](#), this solution has the following key features:

- o MANET scenario: This Non-unique Address Detection technique is to be used in standalone MANETs.
- o Routing protocols' dependency: this mechanism depends on OLSR, since the Non-unique Address Detection technique is designed for MANETs running the OLSR protocol.
- o Address uniqueness: The proposed mechanism assumes the existence of a Non-unique Address Detection-based address assignment mechanism.
- o Distributed/centralised approach: the proposed solution follows a distributed approach given that all nodes have the same responsibility detecting address conflicts.
- o Merging support: The proposed solution supports merging, enabling nodes to continuously detect duplicate addresses by analysing received routing protocol messages.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: the proposed mechanism does not add any additional messages but it checks for inconsistencies in the

routing protocol messages to diagnose duplicate address detection.

[2.1.2.6](#). PDAD-OLSR: Passive Duplicate Address Detection for OLSR  
(Weniger et al.)

This solution [[14](#)] proposes a passive Non-unique Address Detection mechanism for configured address uniqueness maintenance in MANETs running the OLSR protocol.

Assumptions: The protocol assumes the existence of a Non-unique Address Detection-based address generation mechanism.

Approach description: The proposed solution is made up of a set of algorithms which specify how to detect duplicate addresses based on incoming routing protocol messages. The algorithms utilise different parameters in TC and HELLO messages such as link states (i.e., neighbour interface addresses), link codes, (message) sequence numbers, and addresses in OLSR routing protocol messages as well as addresses in the IP header. PDAD-OLSR allows the detection of conflicts by intermediate nodes that have unique addresses.

Each node conceptually maintains two tables for PDAD: a Last received Protocol Messages (LRM) table and a Neighbour History (NH) table. LRM table contains information about the last TC and HELLO protocol message received from a specific originator address (e.g., originator address, message type, sequence number, neighbour interface addresses, receive time). NH table contains the history of neighbouring node addresses and is built from received HELLO messages (e.g., neighbour interface address, last time the receiver has selected this neighbour interface address as MPR, Last time the receiver has been selected as MPR by this neighbour interface address, reception time).

The solution proposes eight different algorithms for conflict detection:

- o PDAD-Source Address (SA). Whenever a node receives a TC or HELLO message, it compares the source address in the IP header to its own address (the IP source address is always the address of the last forwarder). This mechanism (e.g., Both addresses coincide) allows nodes to detect conflicts with its neighbouring nodes.

- o PDAD-Sequence Numbers (SN): If a node receives a TC or HELLO message, it compares the originator address with its own address. If they are equal and the sequence number in the message is higher than the receiver's sequence number, a conflict of the originator address is detected. This mechanism allows to detect conflicts between nodes that are any number of hops away from each other.

- o PDAD-Sequence Number Difference (SND): If a node receives a TC or HELLO message, it compares the sequence number in the message with the sequence number in the previously received message from the same originator address and with the same message type (there is a relation between the time a node has originated two TC messages and the sequence number in those TC messages). This mechanism allows to detect conflicts between nodes that are any number of hops away from each other.
- o PDAD-Sequence Numbers Equal (SNE): If an intermediate node receives a TC or HELLO message, it searches its LRM table for a message with the same type value and the same tuple < sequence number, originator address > (the tuple < sequence number, originator address > uniquely identifies messages originated by a specific node. This mechanism allows to detect conflicts between nodes that are any number of hops away from each other.
- o PDAD-SNs Always Increment (SNI): If a node receives a HELLO message, it compares the sequence number in the message with the sequence number in the previous HELLO message from the same originator address (HELLO messages sent by a specific node are received in the order they are sent). This mechanism only allows to detect conflicts between nodes that are at most two hops away from each other.
- o PDAD-Neighbourhood History (NH): If a node receives a TC message, it checks whether its own address is part of the neighbour interface addresses in the TC message. If this is the case and the link code indicates a bi-directional link, the node searches the originator address in its NH table (a TC message only contains neighbours that have selected the originator address as MPRs and that requires a bi-directional link). This mechanism allows to detect conflicts between nodes that are any number of hops away

from each other.

- o PDAD-Link States (LS): If a node receives a TC message with its own address as originator address, it searches in its NH table for each of the neighbour interface addresses (if the message has been originated by the receiver, it must only contain addresses of recent neighbour interfaces). This mechanism allows to conflicts between nodes that are any number of hops away from each other.
- o PDAD-extended Neighbourhood History (eNH): If a node receives a TC message, it checks for each neighbour interface address in the message if it is a neighbour. This algorithm is basically the PAD-NH algorithm executed on behalf of a neighbouring node. Minimal additional signalling is needed. This mechanism allows to detect conflicts between nodes that are any number of hops away

from each other.

For some of the above mechanisms it is crucial to detect a possible sequence number wrap-around, so a mechanism to detect this kind of events is proposed.

Based on [\[2\]](#), this solution has the following key features:

- o MANET scenario: The solution targets standalone MANETs. Although it proposes a Non-unique Address Detection mechanism suitable for any kind of addresses exchanged in routing protocol messages, be it MANET-local or globally routable addresses, the solution does not address the issue of how to obtain global IPv6 addresses.
- o Routing protocols' dependency: this solution requires OLSR, since the set of proposed techniques are applicable to MANETs running the OLSR protocol.
- o Address uniqueness: The proposed mechanism assume the existence of an address assignment mechanism which may assign duplicate addresses.
- o Distributed/centralised approach: The solution follows a completely distributed approach, every node has the same responsibility in detecting duplicate addresses and does the same processing.

- o Merging support: The proposed solution supports merging given that it enables nodes to continuously detect duplicate addresses in the network by analysing received routing protocol messages.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: the solution enables nodes to passively detect duplicate addresses in the network by analysing received routing protocol messages and thus does not cause any overhead.

#### 2.1.2.7. Passive Duplicate Address Detection for On-demand Routing Protocols (Jeong et al.)

This solution [16] proposes a set of Non-unique Address Detection techniques to be used jointly with an on-demand routing protocol. In this proposal passive duplicate address detection is performed by analysing incoming on-demand routing protocol packets.

Assumptions: The protocol assumes the existence of an on-demand routing protocol and a Non-unique Address Detection-based IP address

configuration mechanism.

Approach description: In this proposal passive duplicate address detection is performed by analysing incoming on-demand routing protocol packets. Additional information included in routing protocol packets allows end-points of a communication -- source or destination -- to detect that the other end-point is using an address which is duplicated in the MANET.

This additional information is included into routing control packets exchanged for route discovery and it may be: the node location when it configured its IP address, the node's neighbour list when it configured its IP address, or a sequence number in RREP packets (increased whenever a destination node sends a new RREP packet).

The authors propose different mechanisms for detecting address conflicts:

- o PDAD-RREQ-with-Location-information Technique (RQL): This

technique includes location information in RREQ packets to differentiate between RREQ packets which contain the same source address but are generated by different nodes.

- o PDAD-RREQ-with-Neighbour-knowledge Technique (RQN): This technique includes a list of neighbour nodes (this list is captured and recorded when the node's IP address is configured) in RREQ packets to differentiate between RREQ packets which contain the same source address but are generated by different nodes.
- o PDAD-RREP-with-SEQ Technique (RPS) : This technique requires an incremental PDAD-sequence number to be included in each RREP packet transmitted by a destination node. Therefore, when a source node receives more than one RREP packet with the same PDAD-sequence number and the same destination address, the source node can detect the address conflict of destination nodes.
- o PDAD-RREP-with-Location-information Technique (RPL): This technique includes location information into RREP packets to differentiate between RREP packets which contain the same source address (the source address of RREP packets is the destination address of RREQ packets) but are generated by different nodes.
- o PDAD-RREP-with-Neighbour-knowledge Technique (RPN): When a destination node replies with an RREP packet, a list of neighbour nodes of the destination node (this list is captured and recorded when the node's IP address is configured) is included in the RREP packet.

The document does not include how to perform address conflict resolution.

Based on [\[2\]](#), this solution has the following key features:

- o MANET scenario: The solution targets standalone MANETs. Although the proposed Non-unique Address Detection mechanism is suitable for any kind of addresses exchanged in routing protocol messages, be it MANET-local or globally routable addresses, it does not define any mechanism to obtain global IPv6 addresses.
- o Routing protocols' dependency: The set of proposed techniques

supposes the existence of an on-demand ad-hoc routing protocol.

- o Address uniqueness: The proposed mechanism assumes the existence of a Non-unique Address Detection-based address assignment mechanism.
- o Distributed/centralised approach: The solution follows a completely distributed approach, every node has the same responsibility in detecting duplicate addresses and does the same processing.
- o Merging support: The proposed solution supports merging given that it enables nodes to continuously detect duplicate addresses in the network by analysing received routing protocol messages.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: the solution enables nodes to passively detect duplicate addresses in the network by analysing received routing protocol messages and thus does not cause any overhead.

#### 2.1.2.8. Prophet Address Allocation for Large Scale MANETs (Zhou et al.)

The mechanism defined in [17] is based on the use of a special type of function to derive the IPv6 addresses of nodes, so the probability of address duplication is very low, and therefore the use of a Non-unique Address Detection mechanism can be avoided.

Assumptions: This solution is based on the use of a stateful function  $f(n)$  (where the initial state of  $f(n)$  is the seed) that produces as output an integer sequence of numbers. Different seeds lead to different sequences, and the state of  $f(n)$  is updated. This function can be used to generate IP addresses, since it satisfies the following properties:

- o The interval between two occurrences of the same number in a sequence is extremely long.
- o The probability of more than one occurrence of the same number in a limited number of different sequences initiated by different

seeds during some interval is extremely low.

These properties may be satisfied if the space of available addresses is large, so it is relatively easy to achieve in IPv6.

Approach description: The mechanism basically work as follows: the first node in the MANET chooses a random number as its IP address and uses a random or default state value as the seed for its  $f(n)$ . When a different node approaches, the first node uses its  $f(n)$  to obtain a different number and state. This number is used by the second node as its IP address, and the state is used as the seed for its  $f(n)$ . After that both nodes are able to assign IP addresses to other nodes.

Authors of the mechanism propose different mechanisms to support partitioning/merging, such as for example including the seed used in the MANET in the messages of the routing protocol. By doing that, nodes of different merging MANETs can easily detect the merge (if different seeds are received, that would mean that a merge has happened) and start checking if there are potential IP address conflicts. Given the characteristics of the function  $f(n)$  if a MANET gets partitioned and later merges, IP address conflicts are very unlikely to occur.

Based on [2], this solution has the following key features:

- o MANET scenario: the solution targets standalone MANETs.
- o Routing protocols' dependency: the solution is routing protocol independent.
- o Address uniqueness: the proposed solution does not define any Non-unique Address Detection mechanism. The address uniqueness is ensured by using a "prophet" allocation with a very low probability of collision.
- o Distributed/centralised approach: the solution does not make use of any centralised server.
- o Merging support: the solution proposes different mechanisms to support merging.
- o Prefix assignment support: the solution supports the assignment of IPv6 prefixes to nodes, by using the DHCP prefix delegation.

- o Protocol overhead: only few additional messages are required to assign addresses to new nodes.

## [2.2.](#) Solutions for Connected MANET scenarios

### [2.2.1.](#) No merging support

#### [2.2.1.1.](#) Automatic Configuration of IPv6 Addresses for Nodes in a MANET with Multiple Gateways (Ruffino et al.)

This proposed solution [[18](#)] describes a mechanism enabling nodes belonging to a MANET connected to the infrastructure -- by means of one or more gateways -- to obtain global IPv6 addresses that could be used to communicate with external nodes.

Assumptions: This mechanism assumes the existence of one or more gateways that provide MANET nodes with connectivity to external networks (e.g., the Internet). It is also assumed that nodes running this solution obtain at the bootstrapping phase a MANET local IPv6 address (which is the address that the node uses when it participates in the routing protocol, which is assumed to be OLSR). The uniqueness of the obtained address should be ensured by means of a Non-unique Address Detection method. Neither the procedure followed to obtain this address, nor the Non-unique Address Detection method used to check its uniqueness, are defined in this solution.

Approach description: The mechanism basically works as follows: at bootstrap, a node configures a Primary Address (PADD) that is MANET-scoped and is used as main address in OLSR messages. The node then is able to start participating to OLSR and receiving topology information. Each of the gateways available at the MANET has a global IPv6 prefix that is announced using a new OLSR message type, called Prefix Advertisement (PA).

With the prefix information received in the PA messages, a node is able to build a set of global IPv6 addresses (called Secondary Addresses: SADDs). Among them, the node chooses the "best" prefix and starts using the address formed from this prefix (called, Designated Secondary Address: DSADD). The node introduces all (or a subset) of the SADDs (including the DSADD) in OLSR messages and starts broadcasting them, enabling these addresses to be routable and reachable within the MANET. It should be noted, that this solution does not define any new Non-unique Address Detection mechanism, while it is suggested to use a generic MANET Non-unique Address Detection procedure, such as [[4](#)], to verify the uniqueness of MANET-local and global addresses.

Based on [[2](#)], this solution has the following key features:

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- o MANET scenario: the solution targets connected MANETs.
- o Routing protocols' dependency: the solution requires OLSR to be run in the network.
- o Address uniqueness: the proposed solution does not define any Non-unique Address Detection mechanism, although requires some generic one to be used to ensure the uniqueness of MANET-local and global addresses.
- o Distributed/centralised approach: the solution does not make use of any centralised server, but requires gateways to announce the global IPv6 prefixes that can be used by MANET nodes in the configuration of their IPv6 addresses.
- o Merging support: the solution partially supports merging, since the scenario in which new gateways join the network as a result of a merger is considered. However, since no Non-unique Address Detection mechanism is defined, the solution does not describe how to deal with IPv6 address duplication after merging of different MANETs.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: the solution adds some overhead. since Gateways broadcast prefix information.

#### 2.2.1.2. Simple MANET Address Autoconfiguration (Clausen et al.)

This proposed solution [[19](#)] aims to provide a simple IP autoconfiguration mechanism for mobile nodes joining an existing MANET. This mechanism is designed for MANETs that act as an edge-extension to the Internet, where mobile nodes need to maintain the connections with each other and with the Internet.

Assumptions: It is assumed that at least one node in the network is already configured with a permanent address. In the absence of a configured node, it is assumed that an election mechanism is undertaken allowing a selected node to be self-configured.

Approach description: In this proposed solution, only configured

nodes can participate in the MANET and are considered as MANET nodes. These nodes are also considered as "configuring nodes" aiding the new joining nodes to acquire an IP address. Actually, each new joining node is firstly assigned a temporary local address then a permanent global address. The configuring nodes emit periodical ADDR\_BEACON messages to their neighbours in order to signal their existence to

new nodes. A new node joining the network selects a configuring node from its neighbours, then sends an Address Request (AREQ) to this selected configuring node and waits for a reply. The process of sending AREQ may be repeated for a number of trials until either receiving a reply or selecting a new configuring node. The configuring node replies by an Addr-Config message, containing a local temporary address, and keeps track of the link existence with the new joining node through local routing messages exchange on this link. If this link disappears then the configuring node gives up, otherwise the configuring node assigns a global address to the new joining node.

The process of obtaining a temporary address consists of having an address space, where each MANET node independently selects an address sequence from this space and signals it to its neighbours (through beacons). Each MANET node records the address sequence received from its neighbours to avoid conflicts in the chosen addresses. If a conflict is detected between two nodes, the node with the lowest ID should select a new sequence if both nodes are not configuring nodes (MANET nodes that are not yet engaged in configuring a new node). Otherwise, if one or more configuring nodes are involved in the conflict, each configuring node should narrow its sequence of addresses to contain only the address that is currently assigned (in order to keep on the configuring session). On the other hand two options exist for global addresses allocation. One option is that the configuring node acts as a modified DHCP proxy and transmits a request to a DHCP server to acquire a global address for each new node it configures. Another option is that the configuring node consults the nodes' topology tables (containing destinations and thus network addresses), and then picks up an unused address. It then sends an advertisement to all MANET nodes to be sure that this address is not used. If a node detects that its address is being used, it can signal the conflict to the originator of the advertisement.

Based on [2], this solution has the following key features:

- o MANET scenario: This proposed solution targets connected MANET scenarios.
- o Routing protocols' dependency: This proposed solution uses OLSR, typically extending OLSR messages, however it is not dependent on the routing protocol. Although the proposed solution is open to any routing protocol, the fact that periodical beacons are used requires a proactive routing protocol.
- o Address uniqueness: The proposed solution uses a Non-unique Address Detection mechanism to avoid conflicts in IP address

assignment. In global address allocation, using a Non-unique Address Detection mechanism is an option but the proposed solution can function without a Non-unique Address Detection mechanism if the modified DHCP proxy approach is followed. While in temporary address allocation, a limited Non-unique Address Detection mechanism is used with the neighbourhood to resolve any conflict when assigning temporary addresses sequences to MANET nodes.

- o Distributed/Centralised approach: The proposed solution is distributed in the sense that it can employ a decentralised DHCP server using the concept of proxy DHCP to reach the server.
- o Merging support: This proposed solution has no merging support.
- o Prefix assignment support: The proposed solution allows prefix assignment through using DHCP.
- o Protocol overhead: the solution requires a considerable number of signalling. This is mainly during the advertisement messages for global addresses flooded to all nodes in the network for verifying the global address uniqueness, the periodical ADDR\_BEACON messages that are transmitted by each configuring nodes to its neighbours, and the Beacon messages signalling the selected address space by each configuring node during the process of temporary address assignment. Furthermore, AREQ messages are used by each new joining node while communicating a neighbour configuring node, which in turn replies by an Addr-config message.

### 2.2.1.3. Extensible MANET Auto-configuration Protocol (EMAP) (Ros et al.)

The Extensible MANET Auto-configuration Protocol (EMAP) [20] provides an autoconfiguration solution for isolated as well as hybrid MANETs. EMAP is envisioned to be integrated within unicast routing protocols as DYM0 or OLSRv2. The notion of intermediate proxies is used in the autoconfiguration process. The general EMAP framework may be used as a service discovery protocol for MANETs, however the approach is extensible to other services. An optional feature in EMAP includes DNS discovery, where nodes can discover DNS servers reachable from the MANET, and this feature can be extended to services like SIP, proxies, and authentication entities.

Assumptions: It is assumed that at least one element must act as a gateway between the MANET and the fixed network. This element is called an Internet Gateway (IGW).

Approach description: EMAP allows MANET nodes to configure unique IP local addresses and globally routable IP addresses. The local

configuration allows a MANET node to communicate with other nodes in the same MANET. To configure a local address, the MANET node picks an IP address and asks the network if it is already being used, thus avoiding address duplication. In this process, a node generates a pair of IP addresses: temporary and tentative ones. The temporary address is used as the originator-address, where it can be a mobile IP home address or another sort of highly likely unique address. While the tentative address is the one which is being requested and is used as the requested address in the DAD\_REQ messages and the originator-address in DAD\_REP messages. Thanks to the proxy functionality, intermediate nodes can also answer with a DAD\_REP message if they do not own the requested address but they do know that it is being used by another node. If the MANET node sending the DAD\_REQ receives no DAD\_REP messages, then it understands that there is no address conflict and it considers that the tentative address is its local address.

On the other hand, global configuration takes place through using the Internet Gateway (IGW), which may be a fixed element belonging to each network, or a mobile one which detects the presence of an attachment point to the Internet (e.g. a wireless router). The

mobile node requesting a global address either waits for advertisements sent by the IGW (mainly advertising its prefix) to configure its global address or floods a global configuration request (GC\_REQ) message. When an IGW receives a GC\_REQ message, it sends a global configuration reply message (GC\_REP) to the originator-address through unicast. Thus, the originating node is able to auto-configure a global address by substituting the first bits of the requested local address by the prefix advertised by the IGW. When there are multiple IGWs announcing their own information, the MANET node selects one, and the selection rules are implementation-dependent.

A given option in EMAP allows a MANET node to issue a query to find DNS Server Advertisers, which provide IP addresses of available DNS servers. This feature may be quite useful in situations where a high degree of auto-configuration is desired.

Based on [2], this solution has the following key features:

- o MANET scenario: This proposed solution is designed for standalone MANETs and connected MANETs.
- o Routing protocols' dependency: Although EMAP is envisioned to be integrated with unicast routing protocols like DYM0 or OLSRv2, it may be implemented as a standalone daemon.

- o Address uniqueness: The proposed solution uses a Non-unique Address Detection mechanism during the autoconfiguration of MANET local addresses.
- o Distributed/Centralised approach: The proposed solution is a distributed solution in the sense of not being based on any DHCP servers.
- o Merging support: No special merging mechanisms are explained in this solution. However, no in-service Non-unique Address Detection is used which makes the merging support not feasible.
- o Prefix assignment support: This solution employs IPv6 prefixes, where gateway nodes are responsible for advertising their

prefixes.

- o Protocol overhead: the solution adds certain overhead, depending on the network size, the number of IGWs, and the applied option in global address configuration. The resulting overhead in this solution mainly concerns: flooding of the local address selected by each joining node to verify its uniqueness through the DAD\_REQ messages, prefix advertisement by IGWs during global address configuration (this has more impact on the overhead when the number of IGWs increases), and flooding of GC\_REQ messages by the node requesting a global address (in case that no prefix advertisement is taking place by the IGWs) where in this case GC\_REP messages are sent by IGWs through unicast. Furthermore, DAD\_REPLY messages could take place in case of address conflicts detection.

#### 2.2.1.4. Global Connectivity for IPv6 Mobile Ad Hoc Networks (Wakikawa et al.)

The solution described in [21] proposes how to provide Internet connectivity with mobile ad hoc networks. It describes how to obtain a globally routable IPv6 address from an Internet gateway. The Internet access method is not dependent on a particular MANET routing protocol, however there is still a need to a protocol.

Assumptions: The solution assumes that before configuring a global IPv6 address, the node has configured a routable address (i.e. MANET-local address or a Mobile IPv6 home address). The routable address is used for initial configuration when a node boots up and joins the MANET.

Approach description: This mechanism [21] is similar to [22] from the point of view of how IPv6 addresses are configured. Global prefix information is obtained from Internet gateways. Two methods are

proposed for the Internet gateway discovery: one method periodically disseminates gateway advertisements to all nodes in the MANET; the other method utilises solicitation and advertisement signalling between a MANET node and the gateway. Extended router solicitation and advertisements of the Neighbour Discovery Protocol (NDP) or extended control message of each MANET routing protocol can be used for this signalling. The proposed methods target all MANET protocols

regardless of whether they are reactive or proactive. Internet gateways supply their own global prefix information and IPv6 global address to MANET nodes somehow, either proactively or reactively. In this way, the reactive and proactive route discovery features of each MANET routing protocol are not disturbed. An advertisement from the Internet gateway provides prefix information -- IP routing prefix and prefix length -- and lifetime.

After accepting an advertisement from the Internet gateway inserts the Internet gateway address as an Internet route and the MANET node configures a global address from the prefix of the Internet gateway. It uses the 64-bit interface ID in order to construct a valid address with the acquired prefix. It is assumed that before configuring a global IPv6 address, the node has configured a routable local address (i.e. MANET-local address), and a Non-unique Address Detection mechanism has been performed for that routable local address (e.g. using the mechanism defined in [4] and [23]), so it is assumed that the global address would be also unique. If not, the node may perform another Non-unique Address Detection mechanism for this global address.

If the destination of a packet is inside the MANET even though a global routable address is used as destination address, the gateway prevents this packet from being forwarded to the Internet. It returns the packet back to the MANET if it has a MANET route for the destination. The source node receives an ICMP Redirect message from the Internet Gateway warning that it should use a host route (MANET-local address) instead of a default route (Internet route). To do so, each Internet gateway may manage a list of IP addresses of all the associated MANET nodes (mainly if a reactive ad hoc routing protocol is being used). So, each MANET node must contact the Internet gateway at least once it establishes an Internet route through the Internet Gateway in order to communicate its global routable address to the Internet Gateway.

Based on [2], this solution has the following key features:

- o MANET scenario: the solution targets connected MANETs.
- o Routing protocols' dependency: Not restricted to any particular ad hoc routing solution, and it is designed to work properly with

both proactive and reactive protocols.

- o Address uniqueness: It is assumed that the global address would be also unique. If not, the node may perform a Non-unique Address Detection mechanism for this global address. In any case the Non-unique Address Detection mechanism is considered out of scope.
- o Distributed/centralised approach: The proposed solution uses a distributed approach where nodes do not solicit any centralised server for IP address assignment.
- o Merging support: No special merging mechanisms are discussed in this solution. Also, no in-service Non-unique Address Detection is used which makes the merging support not feasible.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: depends on the approach utilised. If extended control messages of the MANET routing protocol -- including global prefix information -- are used the solution introduces low overhead, but if gateway advertisement messages are periodically flooded (with the hop limit field set to an appropriate value in the MANET) then the solution introduces high overhead.

#### 2.2.1.5. Multihop Radio Access Network (MRAN) Protocol Specification (Hofmann)

This proposed solution [24] presents the Multihop Radio Access Network (MRAN) protocol, which is an IPv6-based protocol for the interconnection of ad hoc networks and the Internet. MRAN proposes an approach that enables mobile ad hoc nodes to communicate with correspondent nodes on the Internet. The application scenario of this protocol is mainly when multiple gateways are available and mobile nodes are frequently changing these gateways. The gateways are supposed to be fixed and advertising different prefixes. MRAN treats the gateways discovery and selection, the autoconfiguration of global addresses, and the packet forwarding to/from the fixed network.

Assumptions: It is assumed that mobile nodes (MNs) and Gateways (GWs) use local addresses for communication within the MANET and that routing is performed by a MANET routing protocol. It is also assumed that a flooding protocol is used for broadcasting certain MRAN control messages, where the flooding functionality may be provided by the routing protocol.

Approach description: The operation of MRAN involves several

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functions: GW discovery, GW selection, address autoconfiguration, registration with the GW, packet forwarding and multi-hop handovers. Three modes of GW discovery are proposed and the choice between them depends on the application scenario. In proactive GW discovery, all GWs periodically broadcast advertisement messages "GW\_ADV", where MNs in proactive mode requiring Internet access waits until they receive such a message. The reactive mode discovery allows MNs to discover the available GWs when needed through broadcasting a GW solicitation message. A GW receiving such a message replies by unicast solicited GW advertisement message "sol\_GW\_ADV" to the MN. Hybrid GW discovery mode is a combination of both proactive and reactive discovery, where the GW is in proactive mode and the MN is in reactive one. All GW advertisement messages contain the GW globally valid prefix of 64 bits length. The GW selection process allows each MN to select the closet GW with respect to the number of hops. Other additional metrics may be included in the selection process. After the GW selection, the MN uses the selected GW's prefix and its own EUI-64 to autoconfigure the global address. It may subsequently perform a Non-unique Address Detection. Registration with the selected GW should take place, where the MN sends a registration request message "MN\_REG" to the selected GW. A GW receiving this message replies by a registration acknowledgement message "MN\_REG\_ACK" indicating the successful registration. The MN then periodically repeats the registration process and the registration may be used for other purposes as well (for instance the AAA). To assure appropriate packet forwarding between each MN and its selected GW, payload packets are tunnelled between MNs and GWs in both directions. The tunnelling approach uses IP-in-IP encapsulation thus allowing using local addresses for intra-MANET communication. In the tunnel from the GW to the MN, the destination address of the inner IP header is the MN global address and the destination address of the outer header is the local address of the MN. On the other hand, in the tunnel from the MN to the GW, the destination address of the inner IP header is the CN global address, whereas the destination address of the outer header is the local address of the GW. In the case of MN's disconnection from its current GW while communicating with a CN in the Internet, multihop handover takes place. Thus, the MN has to discover, select and register with another GW. This is called a "forced multihop handover". For optimisation reasons, the MN may also select a new GW that could be more close than the current GW. In this case, the MN performs the registration with the new GW while it is connected to the current one. This is known as "optimised multihop handover", and is much faster than the forced one.

Maintenance takes place through creating two tables: i) GW table, and ii) MN table. MNs maintain a GW table storing information about the available GWs (local address, prefix, expiration time, registration expiration). A table entry is created when the MN receives a GW\_ADV

or Sol\_GW\_ADV messages. On the other hand, GWs maintain MN tables storing information about mobile nodes having a valid registration, where each entry in this table stores the following information on MNs (local address, global address, registration expiration time).

Based on [2], this solution has the following key features:

- o MANET scenario: This proposed solution targets connected MANET scenarios enabling mobile nodes to communicate with correspondent nodes in the Internet.
- o Routing protocols' dependency: This proposed solution works independent of the MANET routing protocol.
- o Address uniqueness: The proposed solution may use a Non-unique Address Detection mechanism.
- o Distributed/Centralised approach: The proposed solution uses a distributed approach, where it does not solicit any centralised server for IP address assignment.
- o Merging support: No special merging mechanisms are discussed in this solution. Also, no in-service Non-unique Address Detection is used which makes the merging support not feasible.
- o Prefix assignment support: This proposed solution supports prefixes assignment, where the different gateways are responsible for IPv6 prefixes advertisements.
- o Protocol overhead: the solution integrates several mechanisms and there is a number of flooding used to achieve the proper mechanisms' functioning. The overhead in this solution mainly lies in the assumption of an existing flooding protocol for broadcasting certain MRAN control messages, and GWs periodical broadcast of GW\_ADV messages (containing the GW prefix) when proactive GW discovery is applied. Also, GW\_Solicitation messages

are broadcast on-demand when reactive GWs discovery is applied, and periodical MN\_REG messages are sent to the selected GWs by each node requesting an IP address which is acknowledged by a MN\_REG\_ACK by the selected GW. Furthermore, additional messages are used for maintenance.

#### [2.2.1.6](#). Automatic IP Address Configuration in VANETs (Fazio et al.)

Automatic IP address configuration is a challenging and still unexplored issue in vehicular ad hoc networks (VANETs) environments, where the vehicles' high mobility and variant density impede the direct utilisation of traditional networking techniques and

protocols. Aiming at integrating VANETs within the Internet and providing passengers with any kind of Internet applications, the IP address represents the natural identifier in the system. This work [25] proposes an IP autoconfiguration solution in VANETs environment, exploiting the VANETs topology and an enhanced DHCP service with dynamically elected leaders to provide a fast and reliable IP address configuration.

Assumptions: It is assumed that the network topology is linear and that a group of nodes move following a track with an internal mobility with respect to each other. It is also assumed that the relative speed between nodes is low.

Approach description: This work proposes a novel automatic IP address configuration protocol named Vehicular Address Autoconfiguration (VAC), that is characterised by a low configuration time. VAC represents the first protocol for IP address configuration in VANETs. It exploits the VANET topology and a distributed dynamic host configuration protocol (DHCP) runs by dynamically elected leader vehicles to quickly provide unique identifiers and reduce the frequency of IP address re-configurations due to mobility. VAC organises leaders in a connected chain such that every node (vehicle) lies in the communication range of at least one leader. This hierarchical organisation allows limiting the signal overhead for the address management tasks. Only leaders communicate with each others to maintain updated information on configured addresses in the network. Leaders act as servers of a distributed DHCP protocol and normal nodes ask leaders for a valid IP address whenever they need to be configured.

VAC guarantees unique IP addresses within a defined SCOPE around the leader, where the SCOPE of the leader A is the set of leaders whose distance from A is less or equal to SCOPE hops. Considering the normal node Y that received the IPy address from A, IPy will be unique as long as Y moves within the SCOPE of A. If Y goes out of the SCOPE of A, in order to still ensure the address uniqueness, Y has to ask the new leader for another address. Considering that the relative speed between the nodes is low, changes in the address configuration due to having left the own leader's SCOPE are not frequent.

Based on [2], this solution has the following key features:

- o MANET scenario: The proposed solution targets connected MANET scenarios, enabling mobile nodes (vehicles) to communicate with correspondent nodes on the Internet.

- o Routing protocols' dependency: Apparently VAC does not depend on a special routing protocol. However no clear definition is given on how and what control messages are exchanged in order to configure each node requiring an IP address.
- o Address uniqueness: The proposed solution does not employ any Non-unique Address Detection mechanisms, however it guarantees address uniqueness for each configured node.
- o Distributed/Centralised approach: The proposed solution employs a partially distributed approach, where distributed DHCP run by some mobile nodes (vehicles) that are elected in a dynamic manner to assign IP addresses to the requesting nodes.
- o Merging support: No special merging mechanisms are explained in this proposed solution, however it could support merging. The SCOPE principle together with the distributed DHCP permit the nodes to join/leave different SCOPES while acquiring a new address from the SCOPE leader.
- o Prefix assignment support: This proposed solution does not employ any IPv6 prefix assignment to nodes.

- o Protocol overhead: the hierarchical organisation in this solution limits the signalling overhead and avoids flooding. The overhead in this solution mainly concerns: the signalling messages for communication between leaders nodes, the request messages sent by mobile nodes requesting an IP address from their leaders (this takes place in a limited scope), and the reply messages from the leaders to the requesting mobile nodes for assigning IP addresses (this also takes place in a limited scope). It is noticed that this solution does not use Non-unique Address Detection mechanisms due to the distributed DHCP functionality among leader nodes, which helps in limiting the signalling overhead.

### [2.2.2.](#) Merging support

#### [2.2.2.1.](#) Address Autoconfiguration in Optimized Link State Routing Protocol (Adjih et al.)

This proposed solution [26] is based on the concept of conflict detection. Each node periodically sends its address and an identifier. The node identifier is a sequence of bits, of fixed length (L), that is randomly generated. An address conflict is detected when the identifier mismatches. This proposed solution is suitable for OLSR routing protocol with a light increase of control message overhead, however, it might be used with any MANET protocol. Two issues are addressed in this solution, an IPv6 stateless

autoconfiguration mechanism and a mechanism promoting address uniqueness in the situation where different ad hoc networks merge.

Assumptions: Two assumptions are mainly considered in this proposed solution. Firstly, it is assumed that the identifier of each node is globally unique in the network. Secondly, it is assumed that a MANET may be isolated.

Approach description: In this proposed solution, a new mobile node joining the network is assigned an IP address then it carries out a conflict detection procedure through running a Non-unique Address Detection mechanism. If another node is detected to have the same address, the new joining node selects a new address. The address assignment process takes place as follows: i) consulting a neighbour node that should configure an address for the new node. The

neighbour node then selects an IP address and sends it to the new node. This takes place by control messages exchange. ii) picking up a random address inside a given subnet with MANET\_prefix either from a pool of allocated addresses or through a set of addresses advertised by each MANET node and are believed not used. In case of address pool existence, this pool could be reserved by the IANA for local use only (i.e. not forwarded outside MANET). In addition, in case of MANETs connected to the Internet, nodes acting as gateways diffuse IPv6 router advertisement messages. In this case each address in the pool would be a global address that can be seen from the outside.

The Non-unique Address Detection algorithm uses a single special control message to perform conflict detection. Each node periodically diffuses to the entire network a special message called MAD (Multiple Address Declaration). This message contains the node address and a unique identifier for the node. Several mechanisms are proposed for MAD messages propagation. When using OLSR, propagation of MAD messages mainly relies on the MPR flooding, where a number of MPR selection rules are explained, presenting different options. If another routing protocol is used, default pure flooding is used for MAD messages propagation. In case of IP conflict discovery, this is resolved by the node with the smaller identifier in each conflicting pair. This node should change its IP, selecting a new IP at random (that is believed to be free) following the same approach of IP address assignment.

When OLSR routing protocol is used, an additional proposed option is using Passive Duplicate Detection. In this case, the topological information diffused by the OLSR routing protocol is sufficient to detect address conflict. However, some MPR selection mechanisms are used to ensure that the control messages are properly propagated.

Based on [\[2\]](#), this solution has the following key features:

- o MANET scenario: This proposed solution targets both standalone and connected MANETs scenarios.
- o Routing protocols' dependency: This proposed solution depends on the underlying routing protocol.

- o Address uniqueness: the proposed solution comprises a Non-unique Address Detection mechanism. The notion of passive duplicate detection is also used, where the solution makes use of the routing protocol messages propagation to detect the address conflicts.
- o Distributed/Centralised approach: The proposed solution uses a distributed approach in the sense of not communicating with a centralised DHCP server to acquire IP addresses.
- o Merging support: This proposed solution has a merging support, since the conflict detection process is periodically carried out by mobile nodes. Thus, this solution assures address uniqueness in case of ad hoc networks merge.
- o Prefix assignment support: This solution does not support IPv6 prefix assignment to nodes.
- o Protocol overhead: the solution adds low protocol overhead, since this solution benefits from the OLSR routing protocol signalling and MPRs concept to verify the address conflicts. The signalling in this solution is limited to a single control message (MAD message) to perform conflicts detection. If passive duplicate detection option is applied with OLSR, the overhead is almost none, as the topological information diffused by OLSR is sufficient to detect address conflict. However, if another routing protocol is used (which is an option), the MAD messages have to be flooded resulting in a 'medium' overhead since the flooding is limited to only one message in this case.

#### 2.2.2.2. Extended Support for Global Connectivity for IPv6 Mobile Ad Hoc Networks (Cha et al.)

The solution described in [27] proposes a stateful global IP autoconfiguration for MANETs with the goal of providing enhanced Internet connectivity to mobile ad-hoc networks. This stateful autoconfiguration is performed through the exchange of extended control messages of MANET routing protocols. The protocol is devised as an extension to AODV, but the concept may be applicable to proactive routing protocols.

Assumptions: The solution assumes that each node has a

local\_IP\_address configured.

Approach description: The protocol basically consists in nodes requesting global addresses to a gateway, which assigns a non-used address to the requesting node. When an ad hoc node needs a global IP address it sends an Internet-gateway solicitation message (GW\_SOL message). The Gateway uses an Internet-gateway advertisement (GW\_ADV message) to assign the solicited global IP address to the ad hoc node.

Given the event that an ad hoc node which has a Global IP address (e.g., G-A1) assigned by a gateway (e.g., GW1) cannot reach GW1 anymore due to a partition in the MANET but this ad hoc node has Internet connectivity through a different gateway (e.g., GW2), the ad hoc node gets another global IP address from GW2 (e.g., G-A2) and it performs a Locator Registration Procedure with GW1. This locator registration procedure is similar to Binding Updates in Mobile IPv6. Using this procedure the ad hoc node registers G-A2 as CoA -- Care of Address in Mobile IPv6 terminology -- of G-A1, so that ongoing communications are kept.

More details can be found in [\[27\]](#).

Based on [\[2\]](#), this solution has the following key features:

- o MANET scenario: the solution targets connected MANETs.
- o Routing protocols' dependency: although the protocol is devised as an extension to AODV, it could be applicable to proactive routing protocols.
- o Address uniqueness: since non-duplicate addresses are assigned to ad hoc nodes, the proposed solution is Non-unique Address Detection-free.
- o Distributed/centralised approach: the solution makes use of centralised servers (gateways) in order to assign IP global addresses.
- o Merging support: given that the proposed solution assigns global IP addresses avoiding duplicates, merging is supported. On the other hand it supports partitions through the Locator Registration Procedure.
- o Prefix assignment support: the solution does not support the assignment of IPv6 prefixes to nodes.

- o Protocol overhead: the solution adds certain protocol overhead, since the mechanism appends some fields to AODV routing protocol (RREQ message) to ask for a global IP address and gateway information, and the replay (GW-ADV message) is unicast to the originator MANET node. The solution includes the possibility of gratuitous GW\_ADV broadcast periodically.

#### [2.2.2.3](#). Gateway and Address Autoconfiguration for IPv6 Adhoc Networks (Jelger et al.)

This proposed solution [22] allows nodes in an ad hoc network to proactively discover a gateway/prefix pair to be used in building an IPv6 global address and to maintain a default route towards the Internet. The core element of this proposed solution is the concept of "Prefix Continuity". With prefix continuity, any node A that selected a given prefix P has at least one neighbour with prefix P on its path to the selected gateway G, thus assuring that each node on the path between node A and the Gateway G uses the same prefix P.

Assumptions: It is assumed that each node can find a Gateway to connect with and that each node can be assigned a global address through this gateway. It is also assumed that one (or possibly more) nodes of the ad hoc network should provide connectivity to the Internet, thus acting as Gateways to other nodes.

Approach description: In this proposed solution, each Gateway (GW) periodically sends a GW\_INFO message notifying nodes in the ad hoc network about its existence as well as the prefix it uses. Some information in the GW\_INFO message allows nodes to select the more appropriate GW when more than one GW exist. Other information contained in this message concerns: the GW global address, the length of the prefix part of the address, and the distance to the gateway as perceived by the node sending the message. The node receiving the GW\_INFO message forwards it to its 1-hop neighbourhood, where the forwarder node is considered as the upstream node for each node that receives the message. Among the transmitted GW-Info messages, each mobile node selects (through a selection algorithm) only one neighbour as its upstream neighbour and receives the GW\_INFO messages from this neighbour (i.e. consider this upstream as an intermediate node to the gateway), then it forwards the message. A node must not forward a GW\_INFO message sent by a node that is not its upstream neighbour. The destination address of the IPv6 header of the packet containing the GW\_INFO message must be FF02::1 (all nodes), while the source address of such a packet must be the link local address of the sender. Thanks to the prefix continuity, the routing via the GW can be achieved without the need of an IPv6 routing header. Each mobile

node creates its IPv6 global address as follows: {Extended Unique Identifier (EUI) of the interface from which the GW\_INFO message is

received + prefix contained in the message}. No Non-unique Address Detection mechanism is needed in this approach, as there is a very little probability of address duplication when EUI is used.

Based on [2], this solution has the following key features:

- o MANET scenario: This proposed solution targets connected MANETs scenarios.
- o Routing protocols' dependency: This proposed solution is independent (in terms of message semantics) of the underlying routing protocol. Thus, it can be integrated in the operation of the routing protocol or it can run as standalone daemon.
- o Address uniqueness: The proposed solution does not depend on a Non-unique Address Detection procedure or mechanism.
- o Distributed/Centralised approach: The proposed solution is distributed in the sense of not employing any centralised DHCP server.
- o Merging support: Although no Non-unique Address Detection mechanism is used, this proposed solution supports networking partitioning and merging as it is based on generating an IPv6 address for each node based on the prefix advertisements.
- o Prefix assignment support: This proposed solution is based on the prefix continuity and is thus supporting prefix assignment. Each gateway advertises the IPv6 prefix that it uses.
- o Protocol overhead: depends on the network size and the number of GWs. The main signalling in this solution mainly concerns the GW\_INFO messages that are periodically sent by each GW notifying its existence as well as its prefix. Since no Non-unique Address Detection mechanism is needed in this solution, this helps in limiting the signalling and hence the overhead.

#### [2.2.2.4.](#) MANET Autoconfiguration using DHCP (Templin et al.)

This draft [28] discusses about possible solution architectures to provide MANET nodes with IP address autoconfiguration capabilities. Basically, the solution proposes to connect nodes within a MANET by means of virtual ethernet, which are imaginary shared links that connects the MANET nodes. The nodes attach to the virtual ethernet via an interface configured over underlying MANET interface(s). Using this virtual ethernet, MANET nodes can configure global IPv6 addresses using for example DHCPv6.

Assumptions: It is assumed that a MANET Router (MR) embodies a router entity linked to one or more host entities by virtual point-to-point interfaces. It is also assumed that the router entity also connects to an imaginary shared link (i.e., a "virtual ethernet") that connects all MRs in the MANET.

MANETs are connected to other networks by means of MANET Border Routers (MBRs). MBRs are assumed to have configured a DHCP relay and/or a DHCP server.

Approach description: The proposed solution considers that MANET Routers are attached to an imaginary shared link (called "virtual ethernet") that connects all the MRs in the MANET. Two different types of "virtual ethernet" are defined:

- o An "enhanced" view of this virtual ethernet sees the MANET as a fully-connected shared link that connects all MRs. With this approach, the MR encapsulates each IP packet in an outer IP header and then sends it on an underlying MANET interface such that the HOP Limit in the inner IP header is not decremented as the packet traverses the MANET. Therefore, with this view, all MRs are neighbours and standard Neighbour Discovery works as-normal. In [29], this particular approach is separately documented.
- o An "unenanced" view sees the MANET as a multilink site. With this approach, the MR sends each IP packet on an underlying MANET interface without further encapsulation, and therefore the Hop Limit may be decremented as the packet traverses the MANET. With this view, since there are multiple hops between MRs, a "site-scoped" equivalent of ND is defined (called Extended Neighbour Discovery, END). In [30], this particular approach is separately documented.

The MANET Router autoconfiguration procedure works as follows: first, each MR configures MANET Local Addresses (MLAs) on each MANET interface. These MLAs should be unique within the MANET and are used as an identifier for operating the routing protocol (can also be used as a locator for packets forwarded within the scope of the MANET). In IPv6, MLAs are typically generated using Unique Local Addresses with interface identifiers that are either managed for uniqueness or self-generated using a suitable random interface identifier generation mechanism that is compatible with EUI-64 format.

In a second step, the MR engages in the routing protocol over its MANET interfaces and discovers the list(s) of MBRs that identify the MANET(s). There are multiple approaches that can be used to perform this MBR discovery, such as the use of information contained in the routing protocol, a DHCP option, etc.

For each MANET to which the MR attaches, it also configures a virtual ethernet interface over the underlying MANET interfaces connected to the MANET. After the MR configures the virtual ethernet interface, it can verify the reachability of MBRs and discover prefixes associated with the MANET's virtual ethernet. This is done by using Router Solicitation/Router Advertisement exchanges, either using normal IPv6 Neighbour Discovery -- in the case of "enhanced" view -- or Extended Neighbour Discovery -- for the "unenanced" view. It is also possible to use information conveyed in the routing protocol itself, or through some other means associated with the particular link technology.

After the MR discovers MBRs, it can configure addresses/prefixes according to either DHCPv6 or IPv6 Stateless Address AutoConfiguration (SLAAC). When the former method is used, the MR sends a DHCPv6 request to the MBR(s) to get global address/prefix delegations and then assigns addresses/prefixes to internal virtual interfaces and/or downstream- attached physical interfaces. Once the MR has obtained a global IPv6 address/prefix, it can send packets with global source addresses using [RFC4191](#) [31] router selection.

It should be noted that for the global addresses/prefixes [32] obtained through DHCPv6, a Non-unique Address Detection mechanism is not needed, since DHCPv6 ensures the uniqueness of the delegated addresses/prefixes. However, the MLAs assigned to MANET interfaces

should be statistically unique so MANET-wide pre-service Non-unique Address Detection mechanism is not needed. Alternatively, passive in-service Non-unique Address Detection mechanisms can be used to detect other MRs potentially using the same MLA.

Based on [2], this solution has the following key features:

- o MANET scenario: the solution targets connected MANETs.
- o Routing protocols' dependency: the solution is routing protocol independent.
- o Address uniqueness: the proposed solution does not define any Non-unique Address Detection mechanism. the uniqueness of MANET Local Addresses assigned to MANET interfaces should be statistically ensured so MANET-wide pre-service Non-unique Address Detection is not needed. If this cannot be achieved, passive in-service Non-unique Address Detection mechanisms can be used to detect other MRs potentially using the same MLA. The uniqueness of the global IPv6 assigned addresses/prefixes is ensured by DHCPv6.
- o Distributed/centralised approach: the solution makes use of the available DHCPv6 servers to assign global IPv6 addresses/prefixes,

although some hints about the use of IPv6 Stateless Address AutoConfiguration (SLAAC) are also provided in [Appendix B](#) of [28].

- o Merging support: the solution supports merging. Different mechanisms are proposed to deal with different defined partitioning/merging scenarios.
- o Prefix assignment support: the solution supports the assignment of IPv6 prefixes to nodes.
- o Protocol overhead: depending on the virtual ethernet approach followed, it can add overhead -- for the 'enhanced' view, where normal IPv6 SLAAC or DHCPv6 can be used --, or medium overhead -- for the 'unenhanced' view, where an Extended Neighbour Discovery mechanism (that makes use of site-scoped message flooding) is required.

### [3.](#) Security Considerations

Due to the open wireless environment of ad hoc networks, IP autoconfiguration mechanisms are susceptible to a number of attacks. The autoconfiguration problem statement draft [\[1\]](#) states some security issues that worth consideration.

#### [4.](#) IANA Considerations

This document has no actions for IANA.



## [5.](#) Acknowledgements

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## [Appendix A](#). Change Log

Changes from -02 to -03:

- o New release to keep the document alive.
- o Update of some references.

Changes from -01 to -02:

- o The classification criteria section has been removed, since it is now part of the evaluation considerations in [\[2\]](#). Solutions are now analysed conforming to some of these evaluation considerations in [\[2\]](#).
- o The Conclusions section has been removed.
- o The Terminology section has been removed.

- o The term "DAD" has been removed in the document (when possible), using Non-unique Address Detection instead.
- o Many editorial changes.

Changes from -00 to -01:

- o The structure of the I-D has modified, classifying the analysed solutions according to a number of useful criteria, conforming to the AUTOCONF problem statement draft and the MANET architecture draft.
- o More solutions have been added to the I-D.
- o Adding of a security consideration section.

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