Addressing Scheme for IOT Network Using IPV6

H. Zormati, J. Chebil, J. Bel Hadj Taher

Abstract—The goal of this paper is to present an addressing scheme that allows for assigning a unique IPv6 address to each node in the Internet of Things (IoT) network. This scheme guarantees uniqueness by extracting the clock skew of each communication device and converting it into an IPv6 address. Simulation analysis confirms that the presented scheme provides reductions in terms of energy consumption, communication overhead and response time as compared to four studied addressing schemes Strong DAD, LEADS, SIPA and CLOSA.

Keywords—Addressing, IoT, IPv6, network, nodes.

I. INTRODUCTION

THE term "Internet of Things" originated 20 years ago and represents the exchange of information and data between devices [2]. It covers three types of communication that can be established in restricted areas: Object-to-Person, object-to-object and machine-to-machine (M2M).

The IoT includes an incredibly high number of nodes, each one of them produces a content that should be accessible by any authorized user, regardless of his/her position. This requires effective addressing policies. Currently, the IPv4 protocol identifies each node via a 32-bit address so there are a very limited number of addresses available in IPv4 addressing and will soon reach zero level. Therefore, it is clear that other control policies must be used other than that used by IPv4. In this context and to solve this problem, there is a need for the IPv6 addressing system that has been proposed for wireless communication nodes. IPv6 addresses are expressed using 128 bits and therefore it is possible to define 3.4×10^{38} addresses, which should suffice to identify any object in the world. As a result, we can think of assigning an IPv6 address for all things included in the network which means that there is an address available for every sand grain on every beach in the world. This analogy to understand that assigning an IP address to each of the thousands of objects in our daily life is quite achievable. The transition to IPv6 addressing is of course indispensable for the realization of a network of interconnected objects. Thus, it is expected that IPv6 will be adopted in addressing in IoT [2], [3].

II. RELATED WORK

In order to facilitate our work, we have studied several articles that deal with the same problem of addressing nodes, in this section we present some algorithms that have been exploited, each of these algorithms uses a specific method to assign an address for each node. These four algorithms are:

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i)   Strong DAD (Double Address Detection)
ii) The LEADS algorithm (Low-Energy ADdress Allocation Scheme)
iii) The Spatial IP Address Assignment (SIPA)
iv) CLOSA (CLOck Skew Addressing scheme)

A. The "Strong DAD" Algorithm

Reference [4] proposed a new dynamic IP configuration algorithm for mobile multi-hop ad hoc networks called "Strong DAD". In this algorithm, when a new node joins the network, it randomly generates an IPv6 address and distributes it to each node of the network to check its uniqueness. It prevents nodes that have already received a broadcast message for the same address from transferring multiple copies of the same message to reduce overall communication overhead. This algorithm relates to ad hoc network which consists of several mobile nodes using radio communication and do not require a fixed communication infrastructure. Ad-hoc networks are adapted to situations where only temporary communication is necessary, and the establishment of a communication infrastructure is not possible or not desirable [5].

B. The LEADS Algorithm

In [6], Lu and Valois have proposed the LEADS algorithm. In this algorithm, there are ADA nodes responsible for assigning IPV6 addresses to new nodes.

When a new node joins the network, it waits for a notification message from its nearest ADA node (Address Agent). The information contained in this message helps the new node to discover the existing LEADS structure. Upon the reception of this message, the new node sends a unicast message directly to the ADA node to request a unique address; finally, the new node confirms the reception of the address to the ADA node by sending an address acknowledgment message.

There are two problems with LEADS. First, the nodes ADA of the network are overwhelmed by the responsibility of assigning addresses to other nodes, which will lead to an increase in power consumption. Second, dissemination messages sent by LEADS to inform other ADAs or ADP nodes about the new node have considerable expense on the network.

C. The SIPA Algorithm

Reference [7] introduced a static address allocation system called SIPA (Spatial IP address assignment), where it uses the location information of new nodes as part of their IP addresses. When a new node joins the network, it converts its location information into x y coordinates according to the size of the network and then combines this information with its IP

address. Duplicate Address Detection process is used to confirm uniqueness of the generated IP address, but it consumes network bandwidth. More importantly, the use of GPS in the nodes of the network is still expensive. Low precision incurred using relatively cheap localization techniques, can result in an increasing likelihood of conflict addresses.

D. The CLOSA Algorithm

In [1], the authors worked on the presentation of the CLOSA algorithm which uses the clock skew of the new node to calculate its IPV6 address. In the CLOSA algorithm, the new node sends its clock to the base station. The base station receives the message from the new node and calculates the clock skew of that node and then converts it to an IPv6 address. For any communication device, the clock counts the oscillations occurring in a determined frequency (resonant frequency), but practically the clock operates at a defined band of the resonance frequency. The clock skew is the difference between the clock frequencies of two communication devices [8]. It is given by (1). For each point n we define respectively c_i and off_i the clock of the point i and the offset between two nodes:

$$C_{skew} = \frac{N \sum_{i=1}^{N} C(i) \times off(i) - (\sum_{i=1}^{N} C(i)) \times (\sum_{i=1}^{N} off(i))}{(N \sum_{i=1}^{N} C(i)^2) - (\sum_{i=1}^{N} C(i))^2} \quad (1)$$

III. PROPOSED SCHEME

The nodes are distributed randomly in a given region, a new node can be added by choosing its location by a simple click on the graph then the algorithm determines the nearest node that will process the request of the new node, as shown Fig. 1.
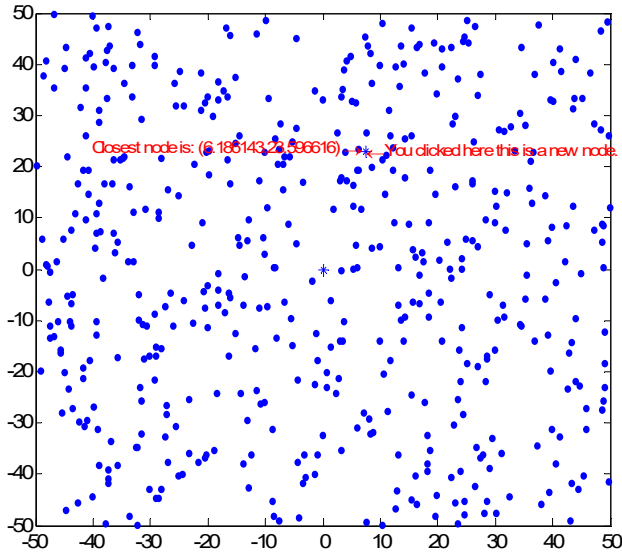

Fig. 1 500 nodes random network

The new node that joins the network sends an address assignment request through an ARQ (Address ReQuest) message to the node closest to him; the node receives the

request and records the received clock, and then calculates its clock Skew and transforms it into IPv6 address and assigns it this address.

IV. PERFORMANCE EVALUATION

A. Evaluation Parameters

All mentioned algorithms have been evaluated in addition to the proposed algorithm in terms of total energy consumption, communication overhead and response time in order to know which one has the best performance.

1. Energy Consumption

The total energy consumption is the energy consumed by all the nodes during the phase of allocation of address. We use (2) and (3) to calculate transmission energy (E_{TX}) and reception energy (E_{RX}):

$$E_{TX} = E_{elec} \times k + E_{amp} \times k \times d^2 \quad (2)$$

$$E_{RX} = E_{elec} \times k \quad (3)$$

where E_{elec} is the energy dissipates to run radio circuits, E_{amp} is the emission amplifier, K is the number of transmitted bits, D is the distance between the transmitter and receiver. The energy consumption of the five schemes is represented in the Table I.

TABLE I
ENERGY CONSUMPTION EQUATIONS [1]

Scheme	Energy consumption
Strong DAD	$E_{validation} + E_{Replace}$
LEADS	$E_{LEADS\_unicast} + E_{LEADS\_Broadcast}$
SIPA	$E_{DAD} + E_{reply} + E_{echo}$
CLOSA	$E_{SendClock} + E_{SendAddress}$
Proposed	$E_{unicast} + E_{Sendresponse}$

$E_{validation}$ consumed energy for Address validation, $E_{Replace}$ consumed energy for address replacement, $E_{LEADS\_unicast}$ the consumed energy can be due to unicast, $E_{LEADS\_Broadcast}$ the consumed energy can be due to broadcast, E_{DAD} DAD consumed energy, E_{reply} cost of response message, E_{echo} cost for echo message, $E_{SendClock}$ consumed energy to send clock to base station, $E_{SendAddress}$ cost to send address to the new node, $E_{Sendresponse}$ cost to send a response to new node.

TABLE II
COMMUNICATION OVERHEAD EQUATIONS [1]

Scheme	Communication overhead
Strong DAD	$N \times (N+t)$
LEADS	$3 \times Nunicast + \sum_{i=1..NBroadcast} (4+Nei_i+N_{ADA}+N_{ADP})$
SIPA	$N \times ((2T+N)+Nconflict)$
CLOSA	$2 \times \sum_{i=1..N} (hopi-1)$
Proposed	$3 \times Nunicast$

N number of nodes t is the max hop count between a node and a duplicated address node, Nunicast is the number of nodes configured with unicast process, Nei_i is number of neighbors for node (i), NBroadcast is number of nodes configured with broadcast procedures, N_{ADA}, N_{ADP} are total number of ADA, and ADP nodes , T is the maximum hop count between network nodes and base station, Nconflict is the number of nodes with duplicate addresses, hopi is the hop count between new node and the base station, Nunicast is number of nodes configured with unicast procedures.

2. Communication Overhead

Communication overhead is the total number of unicast and

broadcast messages exchanged between nodes on the network to self-configure each node. The communication overhead of the presented scheme is given by Table II.

3. Response Time

Response time is the time spent to finish the address allocation phase thus it is the difference between getting the final address and sending the request to get this address.

B. Simulation Parameters

In order to perform our simulation, we have taken the following parameters:

- Region [X, Y]: 100x100 m^2;
- Number of nodes: N between 100 and 500;
- Transmission range: T_R = 20 m;
- Energy dissipates to run radio circuitry E_{elec} = 50 nJ / bit;
- Energy dissipates due to transmit amplifier E_{amp} = 100pJ / bitm^2;
- Energy consumption for multiply E_{mul} operator = 6.93 nJ / bit;
- Energy consumption for shift operator E_{sht} = 4.26 nJ / bit;
- Packet length k = 4000 bit.

V. RESULTS

Fig. 2 shows the energy consumption of the various addressing schemes. As can be seen, the presented scheme surpasses both Strong DAD and SIPA. This is expected as these two schemes broadcast a large number of packets. It can also be seen from the figure that the LEADS algorithm has low total energy consumption due to the fact that most address assignment processes are performed by means of a unicast message exchange and only a small number of nodes configure themselves with broadcast procedures. On the other hand, the CLOSA addressing system uses unicast messages sent to the base station which is at a distance greater than one hop from the new node; However, CLOSA does not use the allocation table method to assign an address to the new node because this method consumes a lot of energy. For the presented algorithm, it presents the lowest energy consumption because it only uses the unicast messages to carry out an address assignment request and the same for the reply path, moreover the nearest node is found at a distance close to the new node.

Fig. 3 shows the communication overhead for the five schemes. As shown, the presented algorithm reaches the lowest communication overhead, this is expected because it only uses unicast messages to perform an address assignment request and unicast messages are sent only to the nearest node which is in most cases distant one hop to the new node. Thus, among the five regimes, the presented algorithm has the lowest communication costs.

After having evaluated the mentioned algorithms in terms of energy consumption and communication overhead, a comparative study of these algorithms was made in terms of response time; the results obtained are shown in Fig. 4, which represents the response time depending on the number of nodes. The curve show that the presented system has the

lowest response time when this is our goal. The CLOSA and SIPA algorithms significantly exceed the other addressing systems, whereas the Strong DAD and LEADS algorithms have a performance close to the proposed system in terms of response time especially for LEADS which present the minimal response time if the node number is limited. In conclusion, the presented algorithm is the fastest; this is expected because it uses only unicast messages addressed to the nearest node, whereas the other addressing scheme use either broadcast messages or allocation tables addresses.
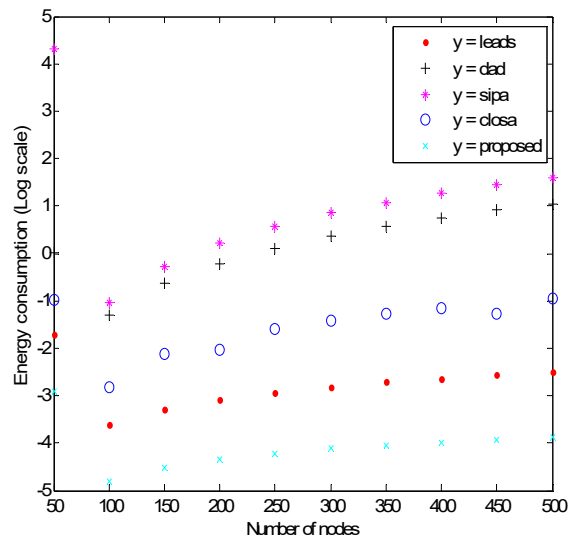

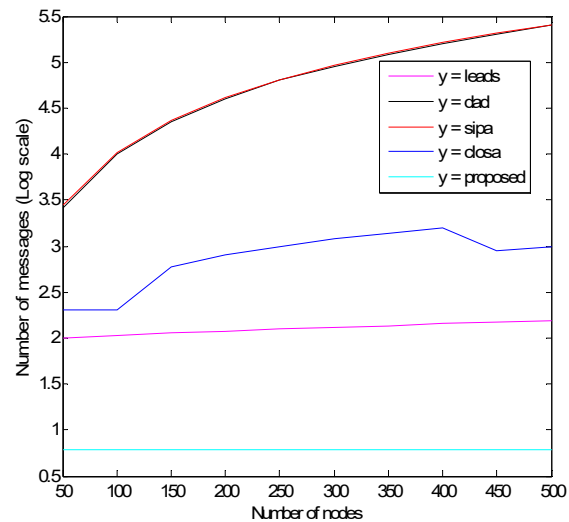Fig. 2 Energy consumption for five addressing algorithms

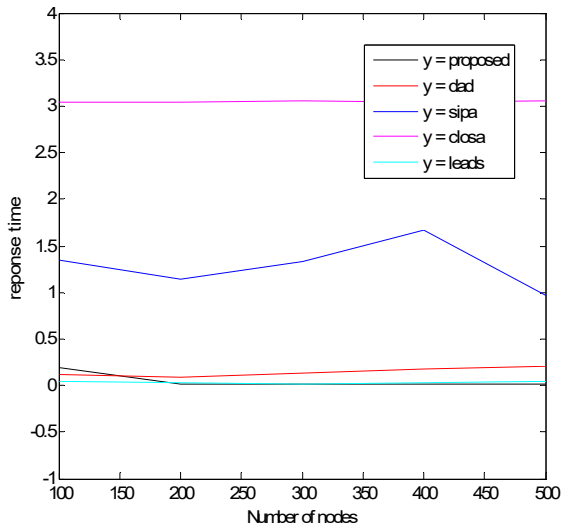Fig. 3 Communication overhead for five addressing scheme

Fig. 4 Response time for five addressing algorithms

VI. CONCLUSION

During this work, we have presented an addressing scheme for an IoT network using the clock skew of each device and converting it into a single IPV6 address, compared it with four other addressing schemes and presenting the different results. The simulation confirms that the presented scheme provides reductions in terms of total energy consumption and communication overhead as well as response time compared to the four other algorithms.

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