A SIMULATION-BASED PERFORMANCE COMPARISON OF MANETS CDS CREATION ALGORITHMS USING IDEAL MAC AND IEEE 802.11 MAC

Khalid A. Almahorg[1], Mohamed S. Elbuni[2], Elmahdi M. Abousetta[3], Ahmed Arara[4]

[1]Department of Computer Engineering, University of Tripoli, Tripoli-Libya
khalid.almahrog@gmail.com
[2]Department of Computer Engineering, University of Tripoli, Tripoli-Libya
mselbuni@gmail.com
[3]Department of Computer Engineering, University of Tripoli, Tripoli-Libya
drelmahdiabousetta@gmail.com
[4]Department of Computer Engineering, University of Tripoli, Tripoli-Libya
ahmedarara@yahoo.fr

ABSTRACT

Mobile Ad Hoc networks (MANETs) are gaining increased interest due to their wide range of potential applications in civilian and military sectors. The self-control, self-organization, topology dynamism, and bandwidth limitation of the wireless communication channel make implementation of MANETs a challenging task. The Connected Dominating Set (CDS) has been proposed to facilitate MANETs realization. Minimizing the CDS size has several advantages; however, this minimization is NP complete problem; therefore, approximation algorithms are used to tackle this problem. The fastest CDS creation algorithm is Wu and Li algorithm; however, it generates a relatively high signaling overhead. Utilizing the location information of network members reduces the signaling overhead of Wu and Li algorithm. In this paper, we compare the performance of Wu and Li algorithm with its Location-Information-Based version under two types of Medium Access Control protocols, and several network sizes. The MAC protocols used are: a virtual ideal MAC protocol, and the IEEE 802.11 MAC protocol. The use of a virtual ideal MAC enables us to investigate how the real-world performance of these algorithms deviates from their ideal-conditions counterpart. The simulator used in this research is the ns-2 network simulator.

KEYWORDS

Network Protocols, Ad Hoc Networks, Mobile Networks, Network Simulator

1. INTRODUCTION

The multi-hop radio packet networks, also known as mobile Ad Hoc networks (MANETs), are proposed by researchers to allow for the instantaneous creation of reconfigurable temporary wireless communications networks. As the name implies, MANETs are created by the mobile hosts, a.k.a. nodes, on an Ad Hoc basis without any support or administration provided by any

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fixed or pre-installed communications infrastructure. The self-control, self-organization, and Ad Hoc properties make MANETs applicable in both civilian and military sectors. Their applications range from providing temporary and instantly deployable communications networks in conference rooms, class rooms, and exhibitions to providing reliable inter-vehicle communications, and communications networks in rural areas, devastated areas, and battle fields [1].

Along with their attractive properties, MANETs have other properties that make their realization a challenging task. Due to the mobile nature and the limited transmission ranges of MANETs' nodes, communication links between nodes are established and torn down in unpredictable fashion; therefore, MANETs are characterized by dynamic topologies. The self- control property, a powerful feature of MANETs, obliges nodes to perform routing and other network administrative tasks cooperatively. The routing algorithms used in traditional wired networks generate a huge amount of overhead traffic in order to discover and maintain routes in such dynamic topologies. The limited bandwidth of the wireless channel renders all these algorithms non-feasible for MANETs routing.

The Connected Dominating Set (CDS), a.k.a. virtual backbone or spine, is a proposed solution for routing, broadcasting, and establishing a dynamic infrastructure for distributed location databases in MANETs [5], [8], [11], [12]. Minimizing the CDS cardinality simplifies the MANET's abstracted topology, allows for using shorter routes, and reduces the total number of retransmissions in broadcasting scenarios. It is proven that finding the minimum CDS (MCDS) in general graphs is NP-complete [7]; therefore, approximation algorithms and heuristics are used to tackle this problem.

The literature is rich of many CDS approximation algorithms competing in terms of CDS size, running time, and signaling overhead [3], [6], [9], [10], [12], [14], [16]. It has been reported that, among all competing algorithms, localized CDS creation algorithms are the fastest and the lightest in terms of signaling overhead [2]. Examples of these algorithms are Wu and Li algorithm [9], the MPR algorithm [13], and Alzoubi algorithm [4]. The simplest and the fastest among all these algorithms is Wu and Li algorithm; however, this algorithm has a relatively high signalling overhead. To reduce the signaling overhead, proposals were made that are based on utilizing nodes' location information [11], [20].

In this paper we compare the performance of the original Wu and Li algorithm [9] with that of its Location-Information-Based version given in [20] under two different types of Medium Access Control protocols (MAC protocols) and several network sizes. The MAC protocols used are: a virtual ideal MAC protocol, and the IEEE 802.11 MAC protocol [21]. While the ideal MAC protocol adheres to the design assumption made by the algorithms designers regarding the guaranteed delivery of broadcasted packets, the IEEE 802.11 MAC violates this assumption since broadcasted packets may not be correctly delivered due to packet collisions. The use of a virtual ideal MAC gives us the ability to investigate how the real-world performance of these algorithms deviates from their ideal-conditions counterpart.

The rest of this paper is organized as follows: Section 2 gives a description of the working mechanics of Wu and Li algorithm [9] and its Location-Information-Based version [20]. Section 3 deals with the experiment setup. In section 4, the results are presented and discussed. Finally, section 5 concludes this paper.

2. ALGORITHMS DESCRIPTION

This section gives a description of the CDS creation and maintenance mechanisms of the studied algorithms.

2.1. Wu and Li Algorithm

Initially the CDS is empty. Every node starts by broadcasting a list that contains the identities of its 1-hop neighbors. Exchanging this information with neighbors allows every node to know the identities of all nodes in its 2-hop neighborhood and the connections among its 1-hop neighbors. Based on this knowledge, every node decides whether to join the CDS or not and it informs its neighbors about this decision. A node, v, joins the CDS if it has at least two neighbors that are not directly connected to each other. After receiving the decisions of all its neighbors, a CDS member, υ, makes its final decision regarding whether to withdraw from the CDS or not, and it informs its neighbors about this decision. υ withdraws from the CDS in one of two cases; the first case is when υ has a neighbor u such that $N[\upsilon] \subseteq N[u]$ and $id(\upsilon) < id(u)$, where $N[\upsilon]$ is the closed 1-hop neighborhood of node υ and $id(\upsilon)$ is υ's ID; the other case is when υ has two neighbors u and w such that u and w are directly connected and $N[\upsilon] \subseteq N[u] \cup N[w]$ and $id(\upsilon) = min(id(\upsilon), id(u), id(w))$. To maintain the CDS in face of topology changes, every node, v, exchanges its 1-hop neighborhood information with its neighbors whenever it discovers a topology change. Every node $u \in N[v]$ updates its role according to the connectivity of its current 1-hop neighborhood by applying the rules explained above.

2.2. Location-Information-Based Wu and Li Algorithm

To reduce the signaling overhead of Wu and Li algorithm, Stojmenovic et al. proposed that nodes have to broadcast their location information, i.e. X and Y coordinates, instead of broadcasting their lists of neighbors [11]. Using the location information of its neighbors, a node, v, can discover if any two of its neighbors are directly connected or not; nodes u and w are directly connected if the Euclidean distance between them is shorter than the transmission range; otherwise, they are not connected; however, in [20], it was shown that utilizing the location information does not guarantee the reduction of signaling overhead. The argument made in [20] is that since the node ID is a four-byte integer number while its location information, i.e. its X and Y coordinates, is two eight-byte floating point numbers, broadcasting the location information of a given node is more costly, in terms of signaling overhead, than broadcasting its list of neighbors if this node has three neighbors or less. Based on this argument, it was shown that in order to reduce the signaling overhead of Wu and Li algorithm every node has to broadcast its X and Y coordinates only if it has more than four neighbors; otherwise, it must broadcast its neighbors list.

3. EXPERIMENT SETUP

The simulator used in this study is the **ns-2** network simulator [17], a widely used discrete event simulator targeted at network research. Nodes use Hello messages to discover their neighborhood; every node broadcasts a Hello message every second. The transmission range of every node is set to 250 meters. To reduce the effect of the short-live connections that are formed when fast moving nodes come into the transmission range of each other for very short periods of time, node υ does not add node u to its neighbors list until it receives the third consecutive Hello message from u.

The network sizes simulated range from 30 nodes to 100 nodes with increments of 10. The mobility model used is the Random Waypoint mobility model [18] and a field of 2000 m × 2000 m was used with this model. The speed of movement was uniformly distributed between 20 and

25 m/s. For every network size, two different MAC protocols were used: a virtual ideal MAC protocol, and the IEEE 802.11 MAC protocol. For every network size and MAC protocol, fifteen different movement scenarios were simulated. Every simulation lasted for 300 seconds. The average of the results of every set of fifteen simulations is calculated and used to represent the algorithm’s performance under the given network size and MAC protocol.

4. EXPERIMENT RESULTS

The results obtained from the conducted simulations are presented in the following figures. These results include the CDS size, the unicast signaling overhead, the broadcast signaling overhead, the CDS establishment time, and the total running time.

4.1. The CDS size

The average size of the CDS produced by each algorithm as a function of the network size for each MAC protocol is given in figures 1 and 2. It can be seen that, in both algorithms, using the IEEE 802.11 MAC leads to creating smaller CDS compared to that created by using the virtual ideal MAC. The fact that in broadcasting scenarios the IEEE 802.11 MAC does not eliminate collisions is the reason for this decrease in CDS size. Losing packets due to collisions prevents nodes from having accurate knowledge about changes in their 1-hop neighborhood and this inaccurate knowledge prevents nodes that are supposed to join the CDS from joining it and decreases the CDS size.

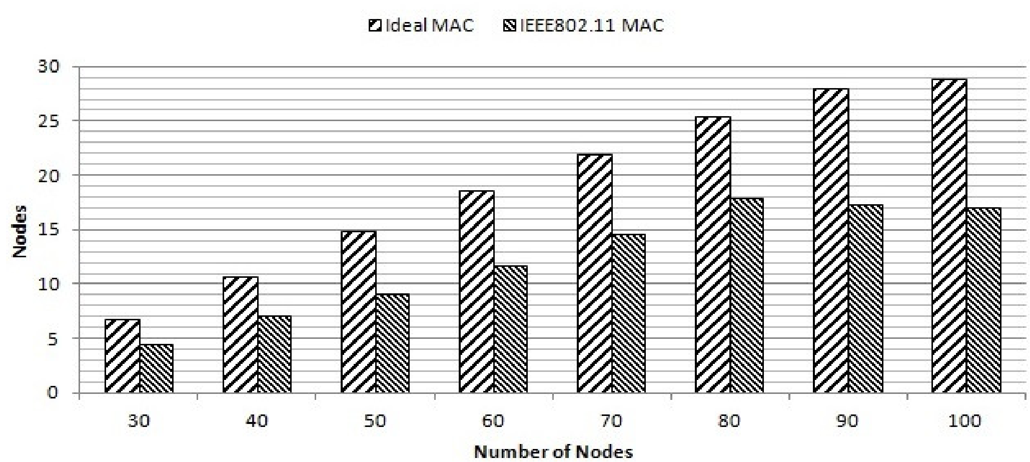

Figure 1. Size of the CDS created by Wu and Li algorithm for different number of nodes and MAC protocols.

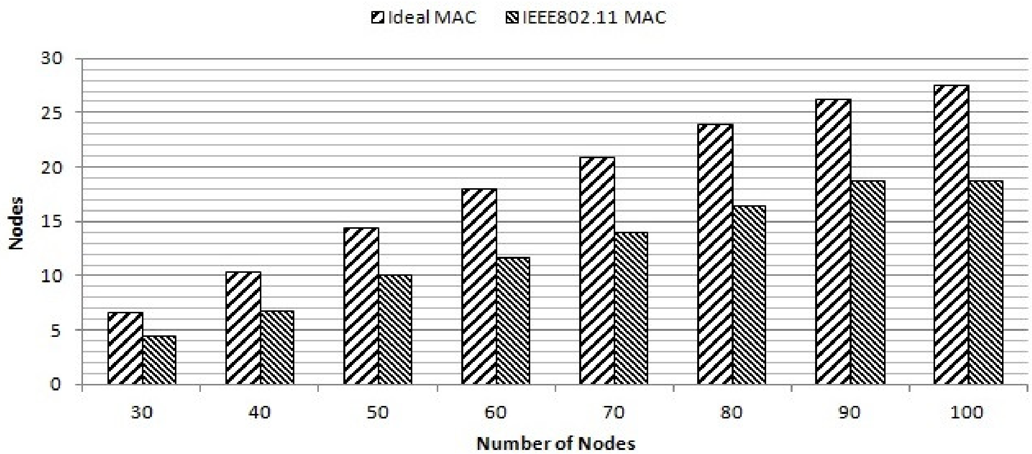

Figure 2. Size of the CDS created by Location-Information-Based Wu and Li algorithm for different number of nodes and MAC protocols.

4.2. Unicast Signaling Overhead

Unicast signaling refers to messages sent from a sender to a specific receiver. In this type of signaling, the IEEE 802.11 MAC uses a handshaking mechanism between the sender and the receiver to avoid collisions; however, this handshaking mechanism does not eliminate collisions completely, since unicasted packets may collide with packets broadcasted by hidden nodes [19]. Figures 3 and 4 show the average number of bytes unicasted by every node during the CDS creation and maintenance phases of each algorithm as a function of the network size for each MAC protocol. It can be noticed that, in both algorithms, using the IEEE 802.11 MAC leads to generating less unicast signaling compared to that generated by using the virtual ideal MAC. The fact that the IEEE 802.11 MAC does not eliminate collisions completely is the reason for this decrease in unicast signaling. Due to collisions, nodes may not get updated about changes in their 1-hop neighborhood; therefore, they do not react to these changes and this leads to generating less unicast signaling overhead.

4.3. Broadcast Signaling Overhead

Broadcast signaling refers to messages sent from a sender to all its neighbors. In this type of signaling, the IEEE 802.11 MAC does not use a handshaking mechanism between the sender and the receiver so that the chances of collisions are high; hence, broadcast signaling is considered a problematic type of signaling. Figures 5 and 6 show the average number of bytes broadcasted by every node during the CDS creation and maintenance phases of each algorithm as a function of the network size for each MAC protocol. It can be noticed that, in both algorithms, using the IEEE 802.11 MAC leads to generating less broadcast signaling compared to that generated by using the virtual ideal MAC. This decrease in broadcast signaling overhead is due to lack of updates about neighborhood changes that results from losing of packets because of collisions.

5. THE CDS ESTABLISHMENT TIME

The CDS establishment time is the time at which every node knows whether it is a CDS member or not. Figures 7 and 8 show the average CDS establishment time for each algorithm as a function of network size for each MAC protocol. It can be noticed from these figures that, in both algorithms, using the IEEE 802.11 MAC leads to longer CDS establishment time compared to the time spent in CDS establishment by using the virtual ideal MAC. Losing of packets due to collisions forces nodes to keep waiting for retransmissions of the lost packets and this results in longer CDS establishment time.

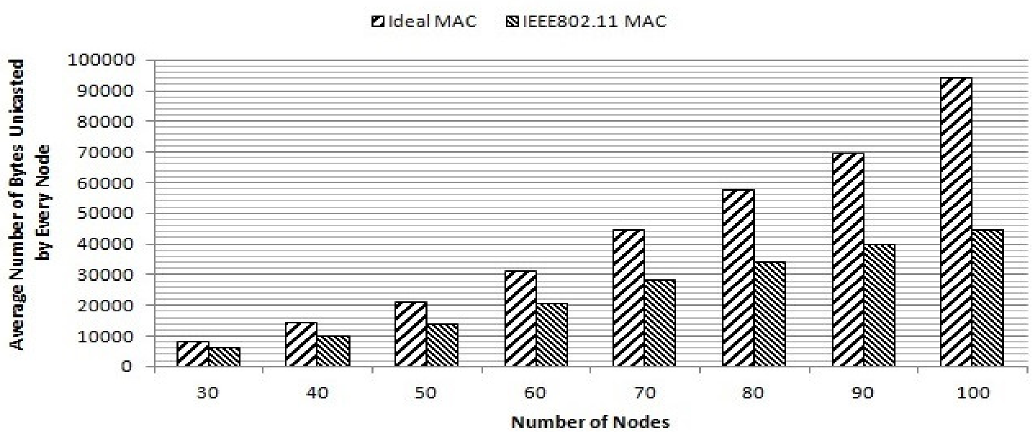

Figure 3. Unicast signaling overhead generated by Wu and Li algorithm for different number of nodes and MAC protocols.

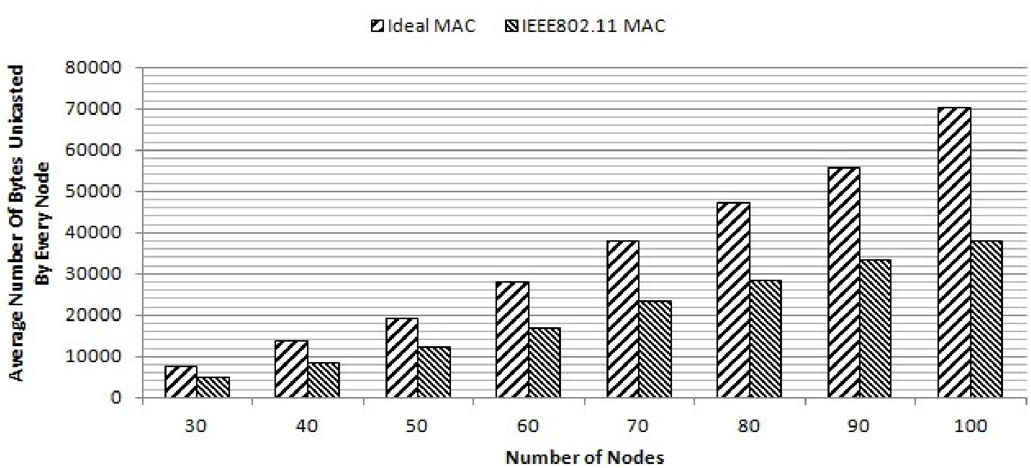

Figure 4. Unicast signaling generated by Location-Information-Based Wu and Li algorithm for different network sizes and MAC protocols.

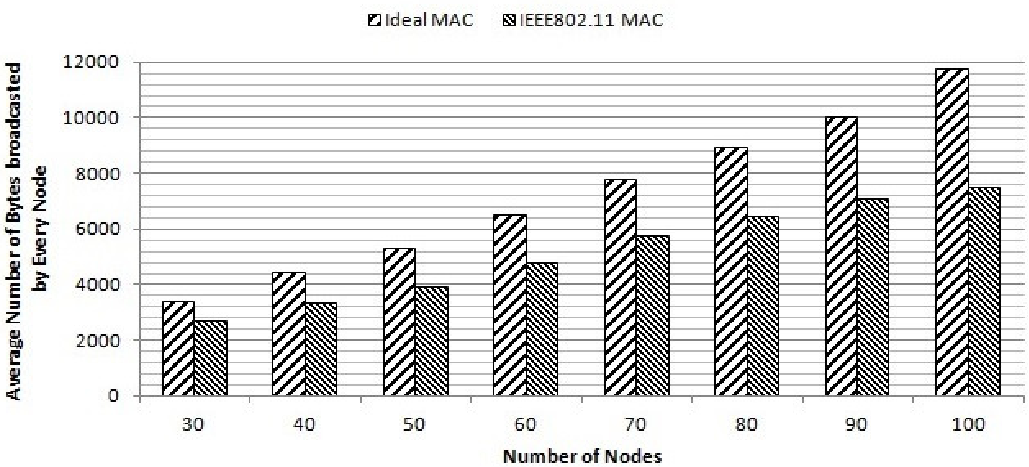

Figure 5. Broadcast signaling overhead generated by Wu and Li algorithm for different number of nodes and MAC protocols.

6. THE TOTAL RUNNING TIME

The total running time is the time spent during CDS creation and maintenance phases. The average total time of each algorithm as a function of the network size for each MAC protocol is shown in figures 9 and 10. Again, we notice that using the IEEE 802.11 MAC leads to longer total time compared to the time spent by using the virtual ideal MAC, and the reason for this is the loss of packets due to collisions that keeps nodes waiting for retransmissions of the lost packets.

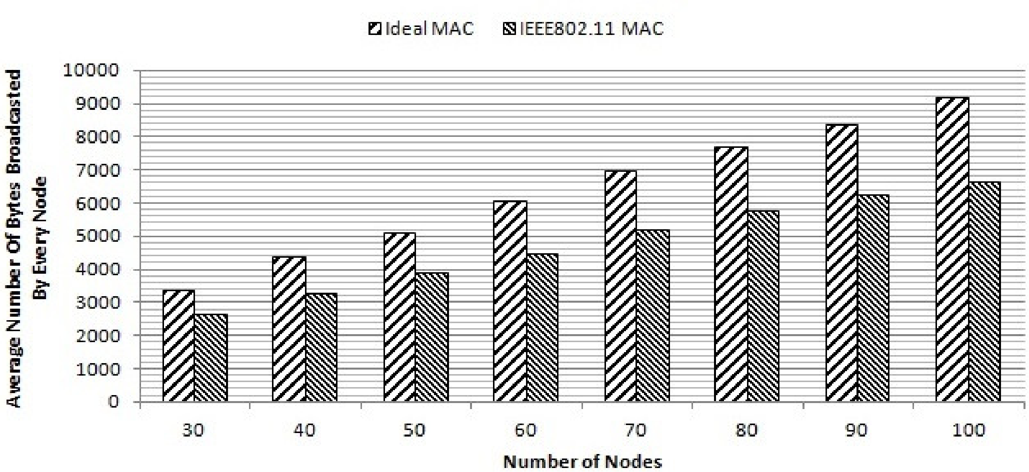

Figure 6. Broadcast signaling generated by Location-Information-Based Wu and Li algorithm for different network sizes and MAC protocols.

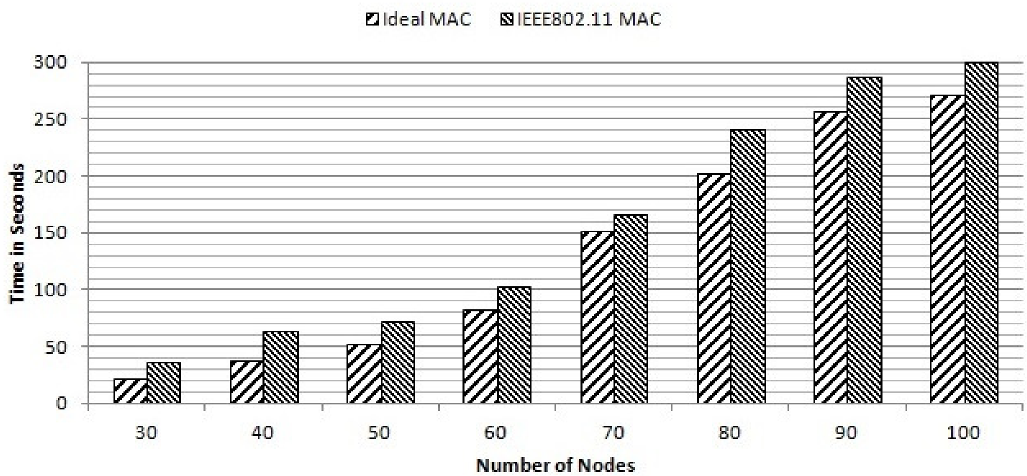

Figure 7. Time to establish the CDS by Wu and Li algorithm for different number of nodes and MAC protocols.

7. CONCLUSION

In this paper the performance of the original Wu and Li algorithm is compared with that of its Location-Information-Based version under a virtual ideal MAC protocol and the IEEE 802.11 MAC protocol. The performance is measured in terms of CDS size, signaling overhead, and run time. The results obtained showed that using the IEEE 802.11 MAC protocol leads to smaller CDS size, lighter signaling overhead, and longer run times compared to those obtained by using the virtual ideal MAC protocol. The reason of these deviations is the loss of packets due to collisions. This loss of packets deprives nodes of acquiring accurate knowledge and fast updates about changes of their 1-hop neighborhoods, this lack of accurate and up-to-date information may lead nodes to refrain from joining the CDS erroneously, not broadcast information unaware of neighborhood changes, and spend longer time waiting for information.

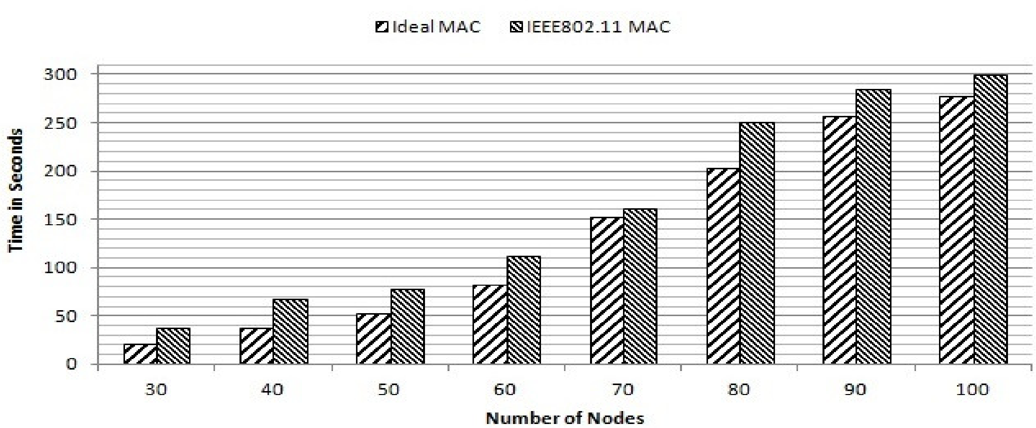

Figure 8. Time to establish the CDS by Location-Information-Based Wu and Li algorithm for different number of nodes and MAC protocols.

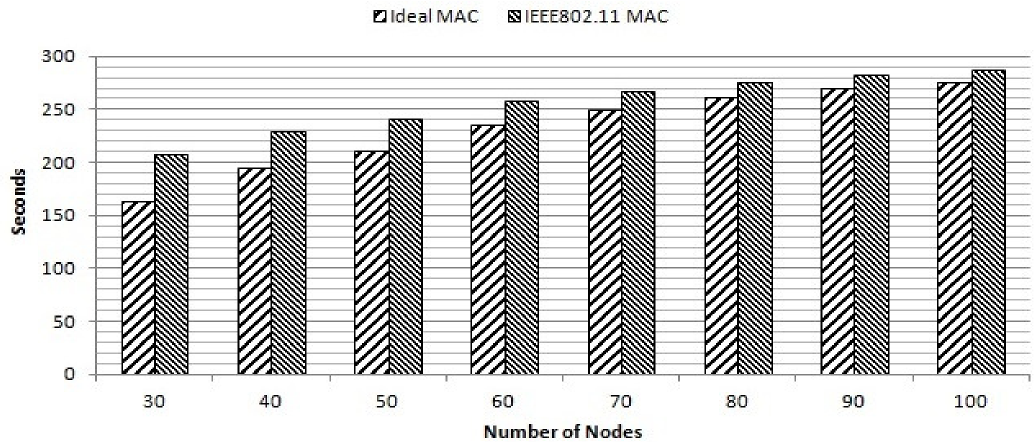

Figure 9. Total running time by Wu and Li algorithm for different number of nodes and MAC protocols.

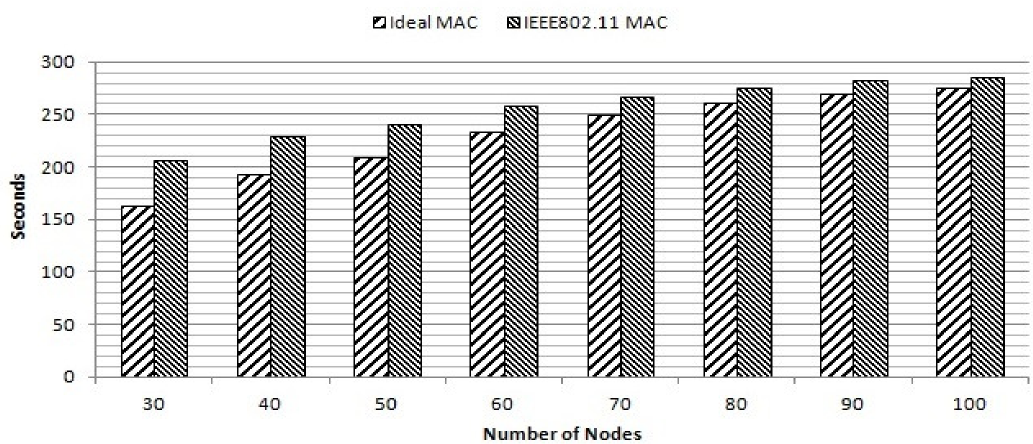

Figure 10. Total running time by Location-Information-Based Wu and Li algorithm for different number of nodes and MAC protocols.

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