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A GA-Based Simulation System for WMNs: Performance Analysis for Different WMN Architectures Considering Transmission Rate and OLSR Protocol

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***Abstract*—In this paper, we evaluate the performance of two WMN architectures considering throughput, delay, jitter and fairness index metrics. For simulations, we used ns-3. We compare the performance for two architectures considering transmission rate and OLSR protocol. The simulation results show that for transmission rate 600 and 1200 [kbps], the throughput of Hybrid WMN is higher than I/B WMN. For transmission rate 600 and 1200 [kbps], the delay and jitter of Hybrid WMN is lower than I/B WMN. For transmission rate 600 and 1200 [kbps], the fairness index of I/B WMN is higher than Hybrid WMN.**

***Keywords*-Genetic Algorithms, Wireless Mesh Networks, NS-3, Network Architecture, OLSR, DCF, SGC, NCMC, Normal Distribution, Transmission rate.**

I. Introduction

Wireless Mesh Networks (WMNs) [1] are important networking infrastructures. These networks are made up of wireless nodes, organized in a mesh topology, where mesh routers are interconnected by wireless links and provide Internet connectivity to mesh clients.

The main issue of WMNs is to achieve network connectivity and stability as well as QoS in terms of user coverage. This problem is very closely related to the family of node placement problems in WMNs [2]–[5], among them, the mesh router mesh nodes placement. We consider the version of the mesh router nodes placement problem in which we are given a grid area where to deploy a number of mesh router nodes and a number of mesh client nodes of fixed positions (of an arbitrary distribution) in the grid area. The objective is to find a location assignment for the mesh routers to the cells of the grid area that maximizes the network connectivity and client coverage.

As node placement problems are known to be computationally hard to solve for most of the formulations [6], [7], Genetic Algorithms (GAs) has been recently investigated as effective resolution method.

In our previous work [8]–[10], we used mesh router nodes placement system that is based on Genetic Algorithms (GAs) to find an optimal location assignment for mesh routers in the grid area in order to maximize the network connectivity and client coverage.

In this work, we use the topology generated by WMN-GA system and evaluate by simulations the performance of normal distribution of mesh clients considering two architectures and transmission rate by sending multiple Constant Bit Rate (CBR) flows in the network. For simulations, we use ns-3 and Optimized Link State Routing (OLSR). As evaluation metrics we considered throughput, delay, jitter and fairness.

The rest of the paper is organized as follows. Architectures of WMNs are presented in Section II. In Section III, we show the description and design of the simulation system. In Section IV, we discuss the simulation results. Finally, conclusions and future work are given in Section V.

II. Architectures of WMNs

In this section, we describe the architectures of WMN. The architecture of the nodes in WMNs [11]–[14] can be classified according to the functionalities they offer as follows:

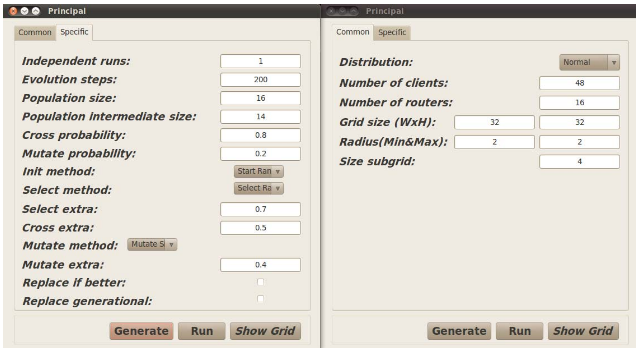


Figure 1. GUI tool for WMN-GA system.

Table I
INPUT PARAMETERS OF WMN-GA SYSTEM.

Parameters	Values
Number of clients	48
Number of routers	16, 20, 24, 28, 32
Grid width	32 [units]
Grid height	32 [units]
Independent runs	10
Number of generations (NG)	200
Population size	64
Selection method	Linear Ranking
Crossover rate	80 [%]
Mutate method	Single
Mutate rate	20 [%]
Distribution of clients	Normal

Infrastructure/Backbone WMNs: This type of architecture (also known as infrastructure meshing) is the most used and consists of a grid of mesh routers which are connected to different clients. Moreover, routers have gateway functionality thus allowing Internet access for clients. This architecture enables integration with other existing wireless networks and is widely used in neighboring communities.

Client WMNs: Client meshing architecture provides a communications network based on peer-to-peer over client devices (there is no the role of mesh router). In this case we have a network of mesh nodes which provide routing functionality and configuration as well as end-user applications, so that when a packet is sent from one node to another, the packet will jump from node to node in the mesh of nodes to reach the destination.

Hybrid WMNs: This architecture combines the two previous ones, so that mesh clients are able to access the network through mesh routers as well as through direct connection with other mesh clients. Benefiting from the advantages of the two architectures, Hybrid WMNs can connect to other networks (Internet, Wi-Fi, and sensor networks) and enhance the connectivity and coverage due to the fact that mesh clients can act as mesh routers.

III. SIMULATION DESCRIPTION AND DESIGN

A. GUI of WMN-GA System

The WMN-GA system can generate instances of the problem using different distributions of client and mesh routers.

The GUI interface of WMN-GA is shown in Fig. 1. The left site of the interface shows the GA parameters configuration and on the right side are shown the network configuration parameters.

For the network configuration, we use: distribution, number of clients, number of mesh routers, grid size, radius of transmission distance and the size of subgrid.

For the GA parameter configuration, we use: number of independent runs, GA evolution steps, population size, population intermediate size, crossover probability, mutation probability, initial methods, select method.

B. Positioning of mesh routers by WMN-GA system

We use WMN-GA system for node placement problem in WMNs. A bi-objective optimization is used to solve this problem by first maximizing the number of connected routers in the network and then the client coverage. The input parameters of WMN-GA system are shown in Table I. In Fig. 2, we show the location of mesh routers and clients for first generations and the optimized topologies generated by WMN-GA system for normal distribution.

In Fig. 3 are shown the simulation results of Size of Giant Component (SGC) and Number of Covered Mesh Clients (NCMC) vs. number of generations. After few generations, all routers are connected with each other.

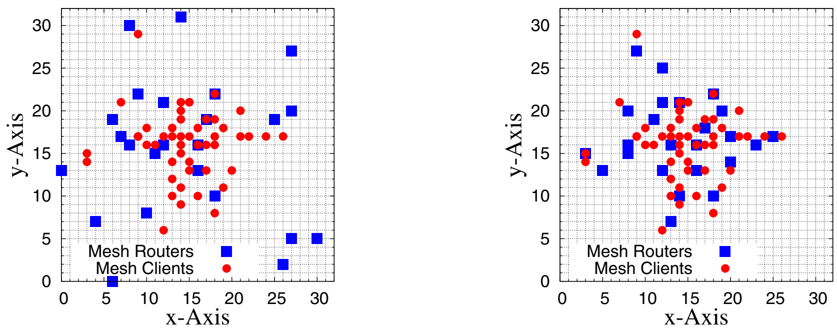
Then, we optimize the position of routers in order to cover as many mesh clients as possible. We consider normal distribution of mesh clients. The simulation results of SGC and NCMC are shown in Table II.

C. Simulation Description

We conduct simulations using ns-3 simulator. The simulations in ns-3 are done for number of generations 1 and 200. The area size is considered 640 [m]$\times$640 [m] (or 32 [units]$\times$32 [units]) and the number of mesh routers is from 16 to 32. We used transmission rate, DCF and OLSR routing protocol and sent multiple CBR flows over UDP. The pairs source-destination are the same for all simulation scenarios. Log-distance path loss model and constant speed delay model are used for the simulation and other parameters are shown in Table III.

D. NS-3

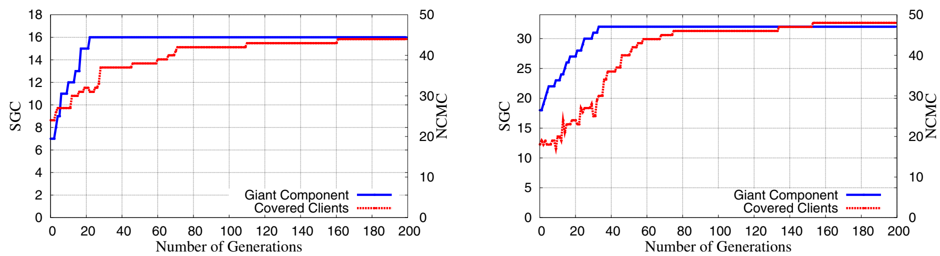
The ns-3 simulator [15] is developed and distributed completely in the C++ programming language, because it better facilitated the inclusion of C-based implementation code. The ns-3 architecture is similar to Linux computers, with internal interface and application interfaces such as network interfaces, device drivers and sockets. The goals



(a) Number of generations: 1 (8, 12)

(b) Number of generations: 200 (24, 47)

Figure 2. $(m,\ n)$: m is SGC, n is NCMC for normal distribution.



(a) Number of mesh routers: 16

(b) Number of mesh routers: 32

Figure 3. SGC and NCMC vs. number of generations for normal distribution.

Table II
EVALUATION OF WMN-GA SYSTEM.

Number of mesh routers	Normal Distribution SGC	NCMC
16	16	44
20	20	46
24	24	47
28	28	48
32	32	48

Table III
SIMULATION PARAMETERS FOR NS-3.

Parameters	Values
Area Size	640[m]×640[m]
Distributions of mesh clients	Normal distribution
Number of mesh routers	16
Number of mesh clients	48
PHY protocol	IEEE 802.11b
Propagation loss model	Log-distance Path Loss Model
Propagation delay model	Constant Speed Model
MAC protocols	DCF
Routing protocol	OLSR
Transport protocol	UDP
Application type	CBR
Packet size	1024 [Bytes]
Transmission rates	100, 600, 1200 [kbps]
Number of source nodes	10
Number of destination node	1
Transmission current	17.4 [mA]
Receiving current	19.7 [mA]
Simulation time	600 [sec]

of ns-3 are set very high: to create a new network simulator aligned with modern research needs and develop it in an open source community. Users of ns-3 are free to write their simulation scripts as either *C++ main()* programs or *Python* programs. The ns-3's low-level API is oriented towards the power-user but more accessible "helper" APIs are overlaid on top of the low-level API.

In order to achieve scalability of a very large number of simulated network elements, the ns-3 simulation tools also support distributed simulation. The ns-3 support standardized output formats for trace data, such as the pcap format used by network packet analyzing tools such as tcpdump, and a standardized input format such as importing mobility trace files from ns-2 [16].

The ns-3 simulator is equipped with *Pyviz* visualizer, which has been integrated into mainline ns-3, starting with version 3.10. It can be most useful for debugging purposes, i.e. to figure out if mobility models are what you expect, where packets are being dropped. It is mostly written in Python and it works both with Python and pure C++ simulations. The function of ns-3 visualizer is more powerful than network animator (*nam*) of ns-2 simulator.

The ns-3 simulator has models for all network elements that comprise a computer network. For example, network devices represent the physical device that connects a node to the communication channel. This might be a simple Ethernet network interface card or a more complex wireless IEEE 802.11 device.

The ns-3 is intended as an eventual replacement for popular ns-2 simulator. The ns-3's wifi models a wireless network interface controller based on the IEEE 802.11 standard [17]. The ns-3 provides models for these aspects of 802.11:

1) Basic 802.11 DCF with infrastructure and ad hoc modes.
2) 802.11a, 802.11b, 802.11g and 802.11s physical layers.
3) QoS-based EDCA and queueing extensions of 802.11e.
4) Various propagation loss models including Nakagami, Rayleigh, Friis, LogDistance, FixedRss, and so on.
5) Two propagation delay models, a distance-based and random model.
6) Various rate control algorithms including Aarf, Arf, Cara, Onoe, Rraa, ConstantRate, and Minstrel.

E. Overview of OLSR Routing Protocol

The OLSR protocol [18] is a pro-active routing protocol, which builds up a route for data transmission by maintaining a routing table inside every node of the network. The routing table is computed upon the knowledge of topology information, which is exchanged by means of Topology Control (TC) packets.

OLSR makes use of HELLO messages to find its one hop neighbours and its two hop neighbours through their responses. The sender can then select its Multi Point Relays (MPR) based on the one hop node which offer the best routes to the two hop nodes. By this way, the amount of control traffic can be reduced. Each node has also an MPR selector set which enumerates nodes that have selected it as an MPR node. OLSR uses TC messages along with MPR forwarding to disseminate neighbour information throughout the network. Host Network Address (HNA) messages are used by OLSR to disseminate network route advertisements in the same way TC messages advertise host routes.

IV. Simulation Results

We used the throughput, delay, jitter and fairness index metrics to evaluate the performance of WMNs for two architectures considering transmission rate and normal distribution.

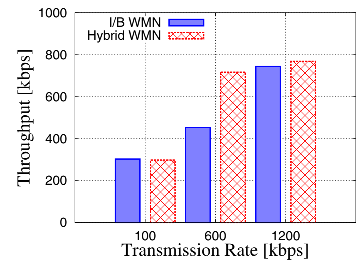


Figure 4. Results of average throughput.

In Fig. 4, we show the simulation results of throughput. For transmission rate 600 and 1200 [kbps], the throughput of Hybrid WMN is higher than I/B WMN. However, for transmission rate 100 [kbps], the throughput of I/B WMN is a little bit higher than Hybrid WMN.

In Fig. 5 and Fig. 6, for transmission rate 600 and 1200 [kbps], the delay and jitter of Hybrid WMN is lower than I/B WMN. However, for transmission rate 100 [kbps], the delay and jitter of I/B WMN is lower compared with Hybrid WMN.

In Fig. 7, we show the fairness index. For transmission rate 600 and 1200 [kbps], the fairness index of I/B WMN is higher than Hybrid WMN. However, for transmission rate 100 [kbps], the fairness index of Hybrid WMN is higher compared with I/B WMN.

V. Conclusions

In this work, we presented WMN-GA system and applied it for node placement problem in WMNs. We evaluated the performance of WMN-GA system for normal distribution of mesh clients considering transmission rate and OLSR protocols.

From the simulations we found that:

- For transmission rate 600 and 1200 [kbps], the throughput of Hybrid WMN is higher than I/B WMN. However, for transmission rate 100 [kbps], the throughput of I/B WMN is a little bit higher than Hybrid WMN.
- For transmission rate 600 and 1200 [kbps], the delay and jitter of Hybrid WMN is lower than I/B WMN. However, for transmission rate 100 [kbps], the delay and jitter of I/B WMN is lower compared with Hybrid WMN.
- For transmission rate 600 and 1200 [kbps], the fairness index of I/B WMN is higher than Hybrid WMN. However, for transmission rate 100 [kbps], the fairness index of Hybrid WMN is higher compared with I/B WMN.

In the future work, we would like to implement other systems and compare the performance with proposed system.

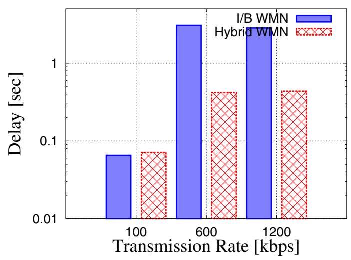


Figure 5. Results of average delay.

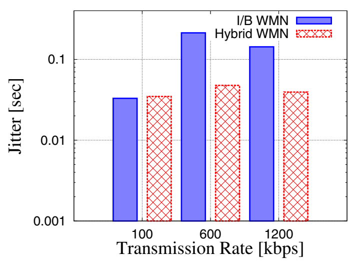


Figure 6. Results of average jitter.

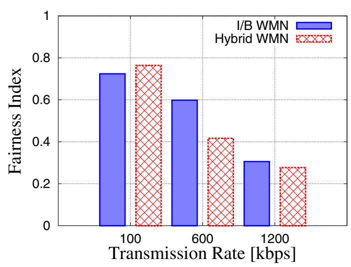


Figure 7. Results of fairness index.

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