TOPOLOGY MANAGEMENT FOR WIRELESS MESH NETWORK

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ABSTRACT: This research formulated and simulated a topology management scheme for wireless mesh network (WMN) in areas of scalability and reliability; considering its vast present limitations in commercialization in many application areas. WMNs framework was devised and OMNeT++network simulator was used to simulate the WMNs model. A research method structure was devised that showed clearly how the project is carried out. An improved model for WMNs that use better approach To Mobile Adhoc Network routing protocol over the existing model was designed and formulated. Pearson Product Moment Correlation (PPMC) was used to find out the correlation between the Scenarios. PPMC produced 0.923 coefficients which showed a high positive correlation between the scenarios indicating that WMNs is reliable and scalable even with additional gateways.
KEYWORDS: Correlation, Mesh, Scalability, Simulator, Topology, Wireless router.

1. INTRODUCTION

A wireless mesh network (WMN) is made up of two or more wireless access points, working in harmony with each other. It is a self-organized wireless networks in which component parts (nodes) can all connect to each other via multiple hops. The wireless routers are normally fixed in position, but some may be mobile. In many cases, several network links are not needed for establishing efficient sharing of the channel among neighbouring nodes or the routing of data packets ([AT05]). Weeding out redundant and unnecessary topology information is usually called topology control or topology management. Other than the routing capability for gateway/bridge functions as in a conventional wireless router, a mesh router contains additional routing functions to support mesh networking ([DPZ04]). Mesh routers have minimal mobility and form the mesh backbone for mesh clients. Thus, WMNs will greatly help users to be always-on-line anywhere, anytime. Consequently, instead of being another type of ad-hoc networking, WMNs diversify the capabilities of ad-hoc networks.

The problem in network topology management is that WMNs are not scalable; throughput drops significantly as the number of nodes or hops in WMNs increases. This paper proffers a possible solution to scalability and reliability in WMNs topology problems before effective standards are established.

2. LITERATURE REVIEW

2.1 Types of Wireless Mesh Topology

There are two types of mesh topologies: full mesh and partial mesh.
Full Wireless Mesh Topology: It occurs when every node in a realm is connected to every other node in a network. Full mesh yields the greatest amount of redundancy, so in the event that one of those nodes fails; network traffic can be directed to any of the other nodes. **Partial Mesh Topology:** With partial mesh, some nodes are organized in a full mesh scheme but others are only connected to one or more nodes in the network realm. It yields less redundancy than full mesh topology.
There are 4 main types of partial wireless mesh nodes topologies:
1. Point-to-Point nodes topology: A point-to-point network is the simplest form of wireless network, composed of two radio and two high gain antennas in direct communication with each other, as shown in Figure 1. Client used these nodes in a site-to-site configuration, ([LAC01])).
2. Point-To-Multipoint: A point-to-multipoint or a Multipoint to point nodes share link between an uplink node with omni-directional antenna and repeater nodes or downlink nodes with high gain directional antennas, as shown in Figure 2. This type of network is easier to deploy than Point to point network because adding a new subscriber only requires equipment deployment at the subscriber site, not at the uplink node. The problem with point to Multipoint node topology is that they are not

design to mesh with other nodes due to the directional antenna ([LAC01]).

3. Multipoint to Multipoint Networks: Multipoint to multipoint networks creates a routed mesh topology that mirrors the structure of a wired Internet. Additional access routers are then deployed throughout the coverage area until a maximum density is achieved as shown in Figure 3.

4. Metropolitan Nodes Topology: Metropolitan nodes topology uses the two mesh type networks: Backhaul and Last Mile, shown in Figure 4.

i. Backhaul is either a Point-to-Point or Point-to-Multipoint topology. It designs is to provide a backbone to the uplink nodes. The nodes use dual antennas one being directional to the uplink the other providing connection to the last mile.

ii. Last Mile is a Multipoint-to-Multipoint topology; its nodes have single radio cards with Omni-antennas and are linked to the backhauls Omni-antenna.

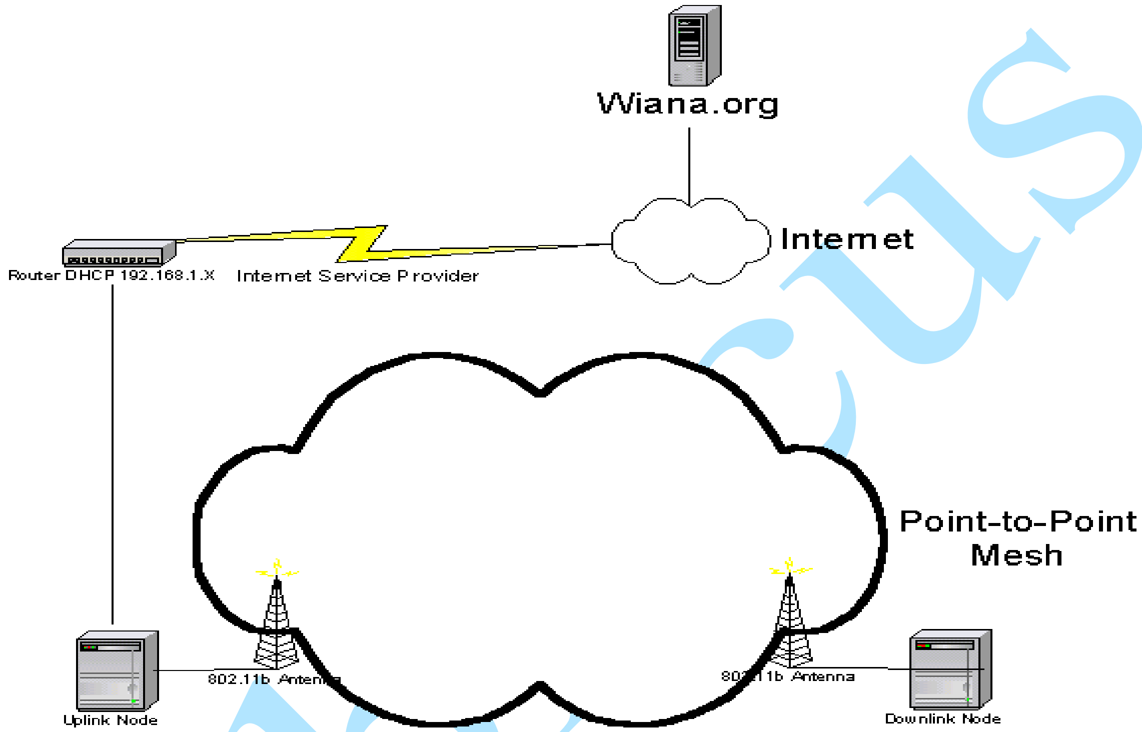

Fig. 1. Point to point nodes topology ([LAC01])

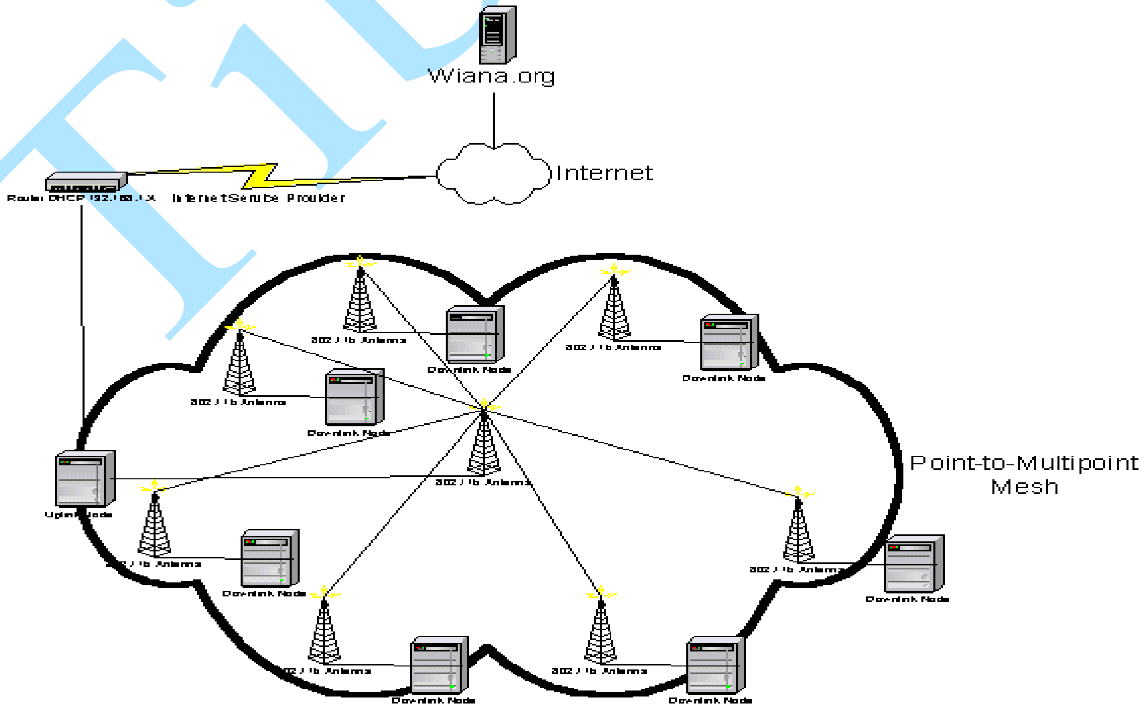

Fig 2: Point-to-multipoint nodes topology (]LAC01])

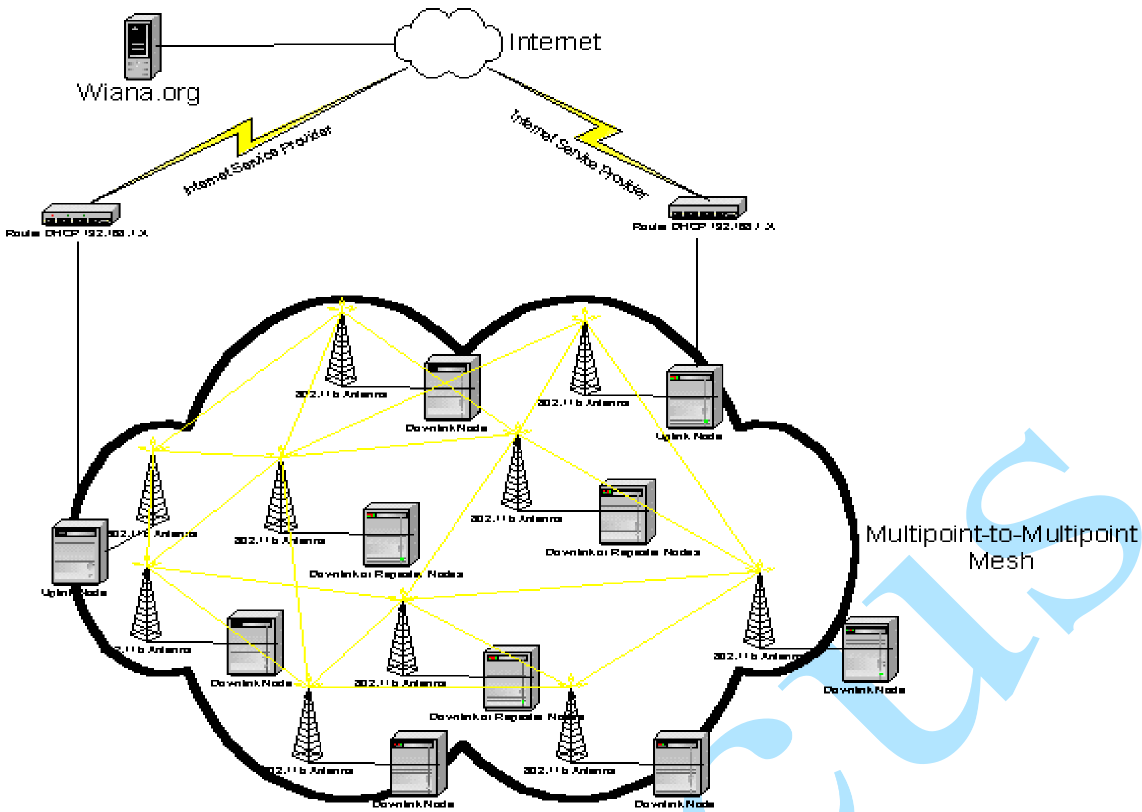

Fig 3: Multipoint to Multipoint Networks ([LAC01])

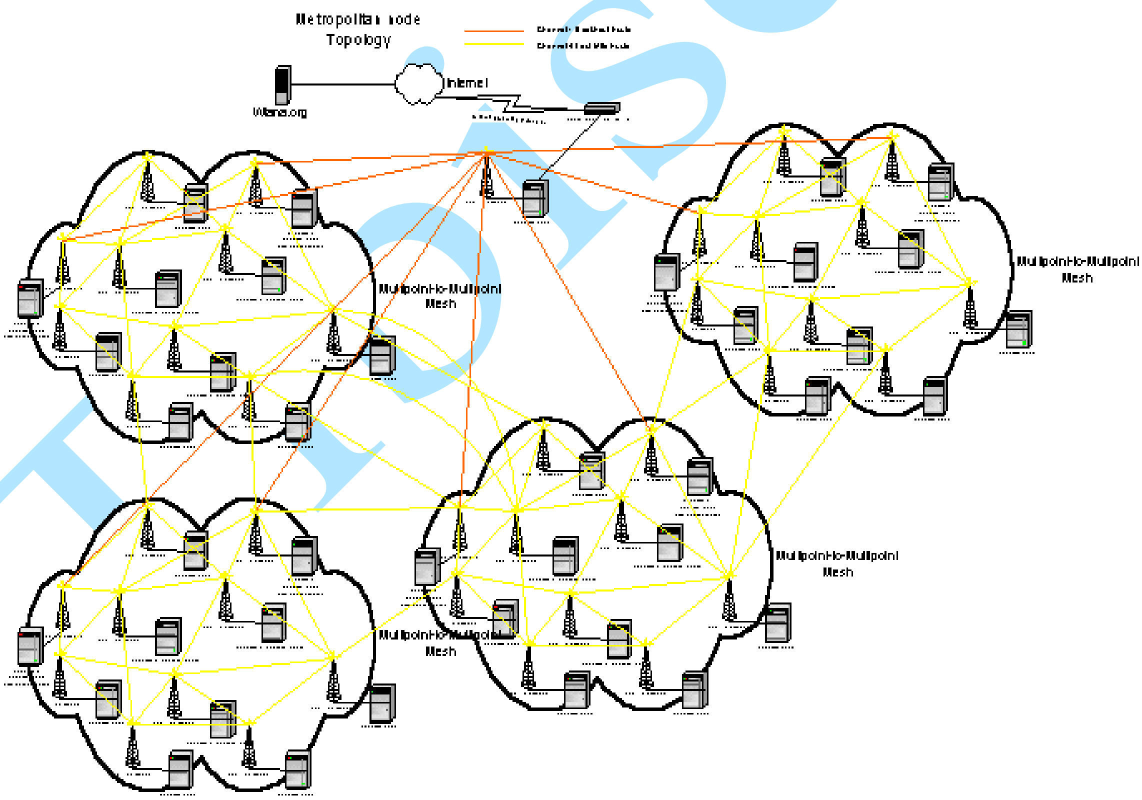

Fig 4: Metropolitan nodes topology [LAC01])

The difference between Last Mile and Multipoint-to-Multipoint topology is that Internet connection does not come from a wired router but through the backhaul mesh via a central point.

The complexity increases when adding a second wireless radio card to a node and adding different types of antennas ([LAC01]).

2.2 Critical Design Factors

The critical factors influencing the performance of WMNs are summarized as follows:

A. Radio Techniques: Many approaches have been proposed to increase capacity and flexibility of wireless systems in recent years. Typical examples include directional and smart antennas, multiple input multiple output (MIMO) systems, and multi-radio/multi-channel systems. To further improve the performance of a wireless radio and control by higher layer protocols, more advanced radio technologies, such as reconfigurable radios, frequency agile/cognitive radios, and even software radios, have been used for wireless communication. Although these radio technologies are still in their infancy, they are expected to be the future platform for wireless networks due to their dynamic control capability. These advanced wireless radio technologies all require a revolutionary design in higher-layer protocols, especially MAC and routing protocols ([DZ04]).

B. Scalability: Scalability is a critical requirement of WMNs. Without support of this feature, the network performance degrades significantly as the network size increases. For example, routing protocols may not be able to find a reliable routing path, transport protocols may lose connections, and MAC protocols may experience significant throughput reduction ([DZ04]). To ensure scalability in WMNs, all protocols from the MAC layer to the application layer need to be scalable.

C. Mesh Connectivity: Many advantages of WMNs originate from mesh connectivity. To ensure reliable mesh connectivity, network self-organization and topology control algorithms are needed. Topology aware MAC and routing protocols can significantly improve the performance of WMNs ([L+03]).

3. METHODOLOGY

In this paper, the major research approaches used are:

- Research Method Structure: It is the structure or steps followed in solving the research problems, from identification of problem through Simulation to Assumption and Conclusion.
- OMNeT ++ (Objective Modular Network in C++) network simulator non-commercial network simulator was used. OMNeT++ itself is not a simulator of anything concrete, but rather provides infrastructure and tools for writing simulations.
- Wireless Mesh Network model that use BATMAN(Better Approach To Mobile Adhoc Network) routing protocol
- Statistical tools using Pearson Product Moment Correlation

3.1 The Model

A model for simulating wireless mesh networks formulated is composed primarily of two classes of network devices or nodes viz: the mesh router and the mesh client ([NZ11]). Some of the mesh routers provide access to the internet via a wired interface thereby performing the role of a gateway. The model comprised of network nodes which was modelled as a collection of modules as shown in Figure 5.

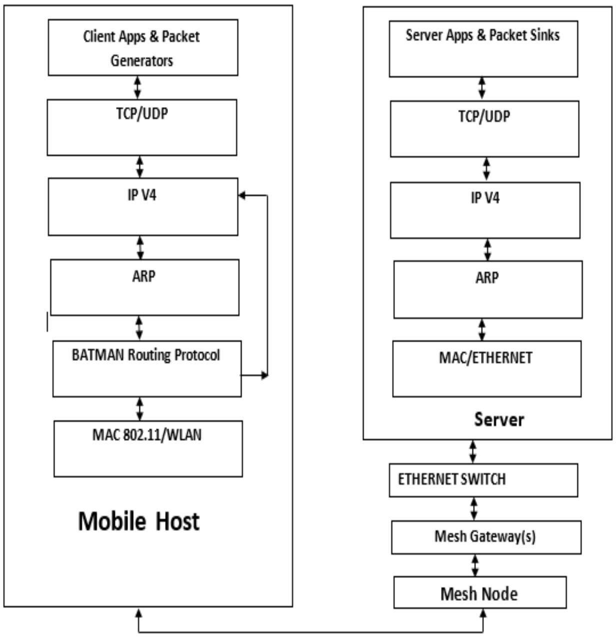

Figure 5: The Formulated Model

The Modelling Parameters

Various simulations were performed using the formulated model for wireless mesh network that use the BATMAN routing protocol. The area covered by the network (i.e the size of the space within which mobile hosts can move) is 550m by 500m. The Simulation was run for 600s (10 minutes). Three different scenarios were used to test the scalability, performance and significance of the number of mesh gateways. Scenarios 1 and 2 were used to test for scalability and performance of the model with no mobility there was increased in number of gateway in senario2. Scenario 3 was used to test reliability with mobility.

NIC Reliability: This is the probability that at a specific point in time, the NIC will be in an "UP" state i.e. NIC is with 99% reliability.

Session Throughput in Kbps: This is the rate at which data sent by the server is received at the various mobile hosts (Mesh Clients).

Gateway Metric: This is the number of hops required to reach a gateway from a mobile host

SCENARIOS

Three scenarios were considered and in each, three parameters: reliability, session throughput and gateway metric were tested and analyzed using Pearson Product Moment Correlation. Also, in all the three scenarios the topology consisted of:

Mesh Clients: The Mesh Client (Mobile Host) comprise of the following Simple Modules: Notification Board, Interface Table, Routing Table, Mobility, Ping Application, UDP, TCP, TCP Application and UDP Application. Also, it comprises of the following Compound Modules: Addressable IEEE802.11 Nic Adhoc and BATMAN Network Layer For Clients. Its attributes are: ThinkTime: 3seconds, IdleInterval: 5seconds, Requested Video Size: 1048576Bytes (1MB), Packet Lenght: 200Bytes, Wait Interval: 1second.

Mesh Routers: The Mesh Router comprise of the following Simple Modules: Notification Board, Interface Table, Routing Table and Mobility. Also, comprises of the following Compound Modules: Addressable IEEE80211 Nic Adhoc and BATMAN Network Layer for routers. Its attribute are: ThinkTime: 2seconds, IdleInterval: 1second, Reconnect Interval: 2seconds, MAC Bitrate: 2Mbps (Mega Bits Per Second), Max Queuesize: 14 Frames, Radio Bitrate: 54Mbps, Transmitter Power: 20mW, Sensitivity: -70mW.

Mesh Gateway: The Mesh Gateway comprise of the following Simple Modules: Notification Board, Interface Table, Routing Table and mobility. Also, it comprises of the following Compound Modules: Addressable IEEE802.11 NicAdhoc, BATMAN Network layer for gateways and addressable Ethernet Interface. It uses wireless interface to connect to the mesh clients and Ethernet Interface through Switch to connect to the server. Its attributes are: ThinkTime: 2seconds, IdleInterval: 1second, Reconnect Interval: 2seconds.

Server (Destination): Pentium IV 3.0 GHz board, 120g Hard disk, 512MB RAM configuration was used with Windows operating system. The gateway was connected to it through the Switch from the Ethernet interface.

Scenario 1

This scenario topology is consisted of: 6 Mesh Clients, 7 Mesh Routers, 1 Mesh Gateway, 1 Server (Destination). There is 99% Reliability for all nodes i.e the NIC is at “UP” state throughout and there is no mobility.

Scenario 2

This scenario topology is consisted of: 6 Mesh Clients, 7 Mesh Routers, 2 Mesh Gateways, 1 Server (Destination). There is 99% Reliability for all nodes i.e the NIC is at “UP” state throughout and there is no mobility.

Scenario 3

This scenario topology is consisted of: 6 Mesh Clients (Mobile host) (2 metres per second mobility), 7 Mesh Routers (no mobility i.e static in position), 2 Mesh Gateways (no mobility i.e static in position), 1 Server (Destination). There is 50% Reliability for Mobile Hosts WLAN NICs, 60% Reliability for Mesh Routers WLAN NICs, 80% Reliability for Mesh Gateway Ethernet NICs, 70% Reliability for Mesh Gateway WLAN NICs, 99% reliability for Server Ethernet NIC.

4. RESULTS AND DISCUSSIONS

The research employed the use of Pearson Product Moment Correlation (PPMC) to show if there exist a positive or negative correlation between Scenarios 1 and 2, also between Scenarios 2 and 3. If the coefficient obtained is negative, it implies there is negative correlation between the variables which means the correlation is statistically not significant. If the coefficient obtained is positive, it shows there is positive correlation between the variables which means the correlation is statistically significant. The positive correlation is said to be WEAK if the coefficient is between 0.0 and 0.4, it is MODERATE if the coefficient is between 0.4 and 0.7 inclusive, and it is HIGH positive correlation if the coefficient is between 0.7 and 1.0.

Table 1 is a contingency table for calculating the PPMC for Average TCP Throughput between scenario 1 (X) and scenario 2 (Y). The Average TCP throughputs were rounded up to whole number. The PPMC was used to find the correlation between scenario 1 (X) and Scenario 2 (Y) to determine if addition of more gateway to scenario 2 from scenario 1 has effort on the number of throughput received by the mobile hosts. The PPMC produced a coefficient of 0.6017 which shows a moderate positive correlation which is statistically significant, indicating that increase in number of gateway increased the performance and number of TCP throughput received by each mobile host in scenario 2 than scenario 1.

Table 2 is a contingency table for calculating PPMC for Average Gateway Metrics between scenario 2 (X) and scenario 3 (Y). The PPMC was used to test if there is correlation between scenario 2 and scenario 3 with equal number of gateways. Mobile hosts in scenario 2 are static and NIC reliability in all nodes remain at “UP” state throughout the simulation, whereas they are mobile in scenario 3 and NIC reliability in each Node varies.

The correlation between the two scenarios was calculated and 0.923 coefficients were obtained. It shows a high positive correlation which is statistically significant. The result showed that WMNs are reliable and scalable with additional gateway.

Table 1: A Contingency Table for calculating the PPMC for AverageTCP Throughput between Scenario 1 (X) and Scenario 2 (Y)

	Scenario 1 (X)	Scenario 2 (Y)	X^2	Y^2	XY
Mobile Host 0	23	74	529	5476	1702
Mobile Host 1	23	7	529	49	161
Mobile Host 2	69	55	4761	3025	3795
Mobile Host 3	0	0	0	0	0
Mobile Host 4	12	29	144	841	348
Mobile Host 5	0	44	0	0	0
	$\sum X = 127$	$\sum Y = 209$	$\sum X^2 = 5963$	$\sum Y^2 = 9391$	$\sum XY = 6006$

Table 2: A Contingency Table for calculating the Pearson Product Moment Correlation (PPMC) for Gateway Metrics between Scenario 2 (X) and Scenario 3 (Y)

	Scenario 2 (X)	Scenario 3 (Y)	X^2	Y^2	XY
Mobile Host 0	1	1	1	1	1
Mobile Host 1	4	3	16	9	12
Mobile Host 2	2	2	4	4	4
Mobile Host 3	4	3	16	9	12
Mobile Host 4	3	2	9	4	6
Mobile Host 5	2	1	4	1	2
	$\sum X = 16$	$\sum Y = 12$	$\sum X^2 = 50$	$\sum Y^2 = 28$	$\sum XY = 37$

5. CONCLUSIONS

This work simulated topology management for wireless mesh network characterized with reliability and flexibilitys. Wireless Mesh Networks (WMN) are self-organized wireless networks in which component parts (nodes) can all connect to each other via multiple hops. The wireless routers are normally fixed in position, but some may be mobile.

The Pearson Product Moment Correlation (PPMC) was used to find the correlation between scenarios 1 (X) and 2 (Y) to determine if addition of more gateway to scenario 2 from scenario 1 has effort on the number of throughput received by the mobile hosts. The PPMC produced a coefficient of 0.6017 which shows a moderate positive correlation which is statistically significant, indicating that increase in number of gateway increased the performance and number of TCP throughput received by each mobile host in scenario 2 than scenario 1. Also, PPMC was used to test if there is correlation between scenario 2 and scenario 3 with equal number of gateways. Mobile hosts in scenario 2 are static and NIC reliability in all nodes remain at “UP” state throughout the simulation, whereas they are mobile in scenario 3 and NIC reliability in each Node varies. The correlation between the two scenarios was calculated and 0.923 coefficients were obtained. It shows a high positive correlation which is statistically significant. The result showed that WMNs is reliable and scalable even with additional gateway. The variety of testing topologies in wireless is limited and mobility tests are impracticable, consequently, this formulated simulation model that provides more flexibility and a controllable environment is therefore recommended for testing purposes on various parameters.

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