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Research paper

Simulation Technique of Steady-State Network based on AODV Routing Protocol

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Abstract

Wireless network refers to any characteristic of a computer network that does not depend on line connectors or physical connections. One of the outstanding characteristic of wireless Mobile Ad hoc Network (MANET) that is significantly different compared to the traditional wired networks is mobility. A user i.e. typically represented by a mobile station or nodes can freely move, whilst being connected to the network. Generally, MANET is a collection of wireless mobile nodes that possess the ability to intercommunicate with one another without any predefined infrastructure or centralized administration support [1]. They are self-organized, autonomous and decentralized multi-hop wireless system of mobile nodes [2]. As such, a reliable MANET routing protocol is needed to enable data to be propagated multi-hops. An example of such routing protocol is Ad hoc On Demand Distance Vector (AODV). Using AODV as the basis of this work, this research paper discusses the best approach to conduct simulation experiment particularly for discrete-event based simulator such as Network Simulator. The underlying principle in MANET simulation is to ensure results are as credible to the empirical experiment. Therefore, iteration of experiment is essential to determine the final result. Much research work also fails to identify the existence of transient phase in simulation work. Failure to address the issue may cause inconsistent result. In addition, a validation methodology based on comparison method is also presented. Although such technique is fairly common, it is one of the most effective method to assess the reliability of the simulation tool.

Keywords: *AODV; MANET; NS-2 simulator; Routing Protocol; Wireless network.*

1. Introduction

The speedy evolution of devices such as laptops, smart phones, satellite navigation systems for vehicles and other widgets utilizing wireless communication has attracted many research activities in wireless networking technology. The existing Internet of Things (IoTs) technology requires substantial improvement in the area of wireless connectivity. There are many benefits of wireless networks that make it useful for diverse functions. These features made it possible to easily deploy the network for emergency requirements, short term needs and coverages in special areas where a wired network infrastructure may be damaged or unsuitable due to reasons such as cost or convenience. Therefore, the network finds application helpful in fields like disaster relief operations, tactical communications, environmental monitoring, etc.

In MANETs, each node can individually act as a router or a host for data transmission and relies on the establishment of multi-hop routes to overcome the limitations of their communication range. These networks are so flexible that nodes can join and leave the network easily and are free to move independently in any direction. The flexibility of the mobile nodes results in a dynamic topology, which poses a great challenge in maintaining consistent network connectivity. To support the connectivity between mobile nodes in MANETs, routing protocols such as Ad hoc On-demand Distance Vector (AODV) [3], Dynamic Source Routing (DSR) [4], Destination Sequence Distance Vector (DSDV) [5] etc., are used to establish paths in which packets are forwarded to and from the nodes in the network. However, due to the absence of fixed infrastructure support, the nodes in MANETs have to collaborate with each other to offer the necessary network functionalities. In this paradigm, some pairs of nodes may not be able to communicate directly with each other and have to rely on some other nodes (i.e., intermediate nodes) to convey data from source to destination. This communication model presumes that the intermediate nodes are willing to carry traffic other than their own, and so, nodes exchange data and control packages based on mutual trust.

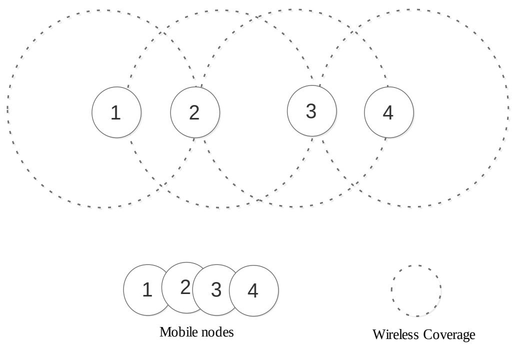

Fig. 1: MANET of 4 nodes

Based on the scenario shown by Figure 1, there are four nodes in the network. Node 1 is connected to node 4 through node 2 and node 3. To enable such communication, node 1 communicates with node 4 with the assistance of node 2 and 3, which relay the packets based on the computed path by the routing protocol. Figure 1 is a chain topology and the path formed what is known as synchronous multi-hop wireless communication. Routing path that is used to propagate the packets to the destination is in return employed to carry the reply packet back to the source.

1.1. Wireless network

Unlike the traditional wired network that interconnects networks devices to the internet via cables; wireless networks connect devices using radio waves. Both networks are formed by routers and host where the routers are in charge of packet forwarding in the network and the host are either the source or sinks of data flow. The distinct difference between wireless and wired network is in the way the individual network component communicates. In a wired network, communication is made possible by the use of physical cables, while in wireless network; communication is enabled using modulated data carried over the air using radio wave. Unlike wired network, wireless network is not tied down by the constraints of physical cables; thus, provide freedom of mobility to the host. In wireless networks, components communicate with other network component via wireless channels using distinctive radio frequencies ranges of the spectrum. Wireless signal attenuates as the signal travel away from the point of generation. Therefore when radio signal travels sufficiently far and reaches to the point where the signal reception is no longer possible, the distance from the point of generation to the point where the signal ends i.e. can no longer be received is called the radio range for that signal. Hence, a user or mobile node can only communicates and relay messages when they are within the radio range [6] of its neighbors.

1.2. Advantages of wireless network

Flexibility: wireless networks are flexible in the sense that it doesn't need any form of physical connection like cables, so it can be easily expanded and scalable.

Mobility: data can be accessed by users anywhere as long as they are within the radio range, this ease movement.

Ease and speed of deployment: Issues may arise as a result of laying cables in places that are hazardous and remote which cannot be accessed easily or effectively such as mountains or even in over-populated area where installation will be difficult.

Cost: implementation cost of wireless is substantially cheaper as compared to wired networks.

1.3. Wireless Network Classification

Wireless network can be classified into two major categories based on the mode of operation, which are infrastructure and infrastructure-less or ad hoc mode.

Infrastructure or Basic Service Set (BSS): are wireless networks, which are made up of access point through which wireless stations can communicate. Infrastructure mode requires the use of a wireless access point (AP). Wireless enabled devices such as laptops and smart phones, typically uses the infrastructure to connect to wireless network, which are often connected to a backbone or internet through an access point. Since the devices in this mode access a network through an access point, their connectivity is restricted within the coverage areas of the access points. Figure 2 illustrates an infrastructure mode of wireless network [7].

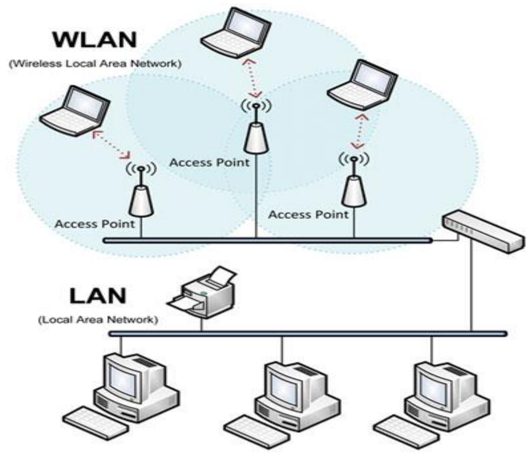

Fig. 2: Infrastructure mode wireless network

Infrastructure-less wireless network: also known as an ad hoc network or peer-to-peer network is a type of wireless network mode that does not rely on AP to operate. An instance of an ad hoc network is shown in Figure 3. In ad hoc network, wireless nodes communicate with one another spontaneously and do not depend on AP as a gateway to propagate packets via different network. Ad hoc networks also support communications between mobile nodes that are not directly connected. Such communication is possible by using routing information computed by each node in the network.

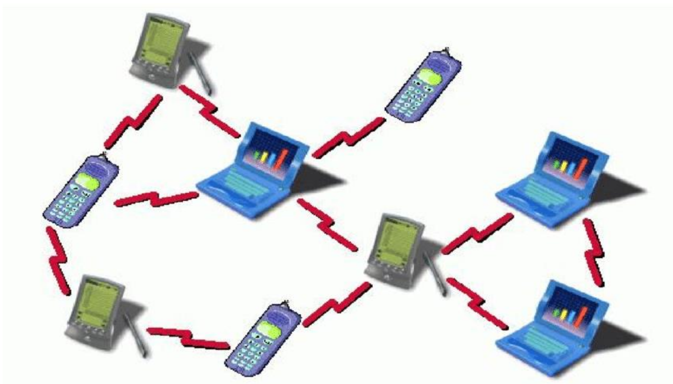

Fig. 3: Infrastructure less wireless network

1.4. Mobile Ad Hoc network (MANET)

MANET is a network of autonomous devices, which communicate via wireless medium. A MANET has distributed multi-hop network architecture, which do not require nor depend on any pre-existing network infrastructure for its deployment. In MANET, the network topology frequently changes and can be unpredictable, due to the manner in which node moves freely and independently. Obviously, a node in MANET can only send packets to their respective neighbors. Therefore MANET nodes must use a multi-hop route formed by cooperative nodes, which relays packets on behalf of other nodes to its final destination [8].

MANETs are entirely different from fixed networks while quite similar to other wireless networks such as wireless mesh networks and wireless sensor networks. Some of the key characteristics of MANET are shown by the below points [9][10][11]:e wireless networks, which are made up of access point through which wireless stations can communicate.

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Characteristics of MANET

1. Lack of centralized management
2. Fast deployment
3. Self-configuration
4. Limited resources
5. Dynamic topology
6. Limited bandwidth
7. Limited physical security
8. Multi-hop communication

2. Ad-Hoc on Demand Distance Vector (AODV) Routing Protocol

Ad Hoc on Demand Distance Vector (AODV) [12], is a MANET routing protocol that is built upon the DSDV routing protocol. It inherits the use of sequence numbers and distance vector algorithm from DSDV. However, AODV differs from DSDV in that it does not maintain a complete list of routes in the network; rather it discovers routes only when they are needed. With AODV, a route discovery process is initiated when two nodes in the network want to communicate to each other without any known route between them. The process makes use of two types of control packets; Route Request (RREQ) packets and Route Reply (RREP) packets. The source node initiates the process by transmitting a RREQ packet that will be relayed by intermediate nodes until it reaches the destination node that responds with a RREP packet. AODV uses a route error (RERR) packet for route maintenance to cope with dynamic network topology changes. Once a mobile node detects a broken link, the node propagates an unsolicited RERR packet to all the nodes already involved in the route discovery process. The RERR packet will be relayed until all active source nodes are notified. Upon receiving the notification of a broken link, the source node may reestablish another path discovery process if a path to the destination node is still required.

In contrast to the DSDV routing protocol that advertises for route discoveries periodically, AODV initiates a route discovery process only when the route is needed. Therefore, overhead and unnecessary control traffic injected into the underlying network as the result of the periodical route advertisements is prevented when there are no topological changes in the MANET. However, AODV has a larger initial latency compared to DSDV. This is because AODV does not obtain the route to destination when needed; it has to initiate a route discovery which introduces more delay before the communication begins.

The IETF MANETs working group has proposed some improvements to AODV, mostly in the area of route discovery and this AODV enhanced version has been called Dynamic MANET on Demand (DYMO) routing protocol [13]. The standard specification for DYMO is expected to be the main body of the IETF reactive MANET protocol (RMP) which is currently under development.

Routing functions in MANETs can be explained in three main phases [14]: route discovery, route maintenance and data forwarding as shown in Figure 4. It starts with the route discovery phase where a node starts to find a route when it needs to communicate with another node. Once a route is found, the data forwarding phase begins. During the course of communication, if a link becomes unavailable, e.g., due to reason, such as node mobility (i.e., node moving out of the transmission range) or battery blackout, an alternative route should be sought for communication to continue. The route maintenance phase deals with broken route. In this stage, a node which detects a broken route will try to find an alternative route from the local cache. If there is no other route in the cache, the node which detects the broken route will initiate another route discovery phase to find another route to the same destination node.

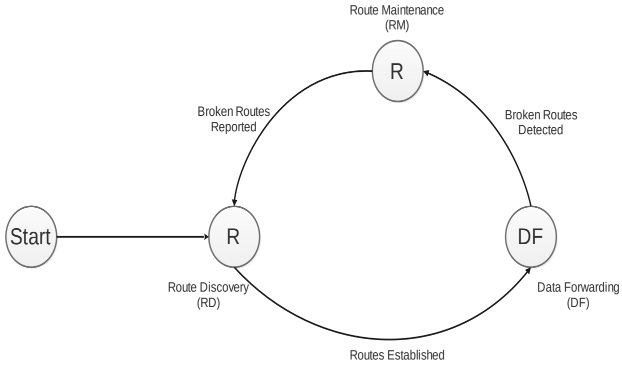

Fig. 4: MANET Routing Operation Cycle Model

As previously mentioned, the first phase of routing process which is the route discovery is the mechanism by which a node finds a route to another node in the network. This process is initiated when a node joins a network or whenever a node i.e., a source node wishes to communicate with another node i.e., a destination node. The source node inquires its neighbors to seek routes to the destination node. It typically does so by broadcasting a RREQ packet into the network. The RREQ packet is set to Time-to-Live (TTL) equals to 1 to avoid repeated broadcast of the same RREQ. The routing protocol also controls the broadcast using expanded ring search algorithm that limits the amount of RREQ generated in to the network.

As shown by Figure 5, the source node S broadcast the RREQ packet. The downstream node then rebroadcast this packet until the packet is received by the destination node. The destination node D as shown in Figure 6 responds with a RREP, which conclude the route discovery process. Upon the execution of the route discovery stage, as shown in Figure 7, more than one route may be found in the network. If this is the case, the source node will select the best one from the available routes based on the routing algorithm used. For instance, some routing protocols select the best route based on hop counts. In other words, these protocols select a route using a combination of packet attributes, which are the lowest hop count and the highest sequence number to the destination node. Other type of routing protocol may select route based on the different criterion e.g. highest available bandwidth to the destination.

In Figure 7, two routes are found, S will choose route 1 because the path has lower hop count compared to route 2. Once the route is determined, the routing path will be established. The data forwarding stage will then commence. In this process, node communicates with one another using the established routing path. However, if a mobile node detects a failure of an active link, the transmission will be suspended. The upstream node then reports the broken route to all mobile nodes pointing to the source node from the current node. Once the source node is notified, it can initiate another route discovery process. In other word, the likelihood of broken route is higher with more frequent network topology changes, particularly in mobile network. The complete process of RREQ freshness inspection is shown by Figure 8.

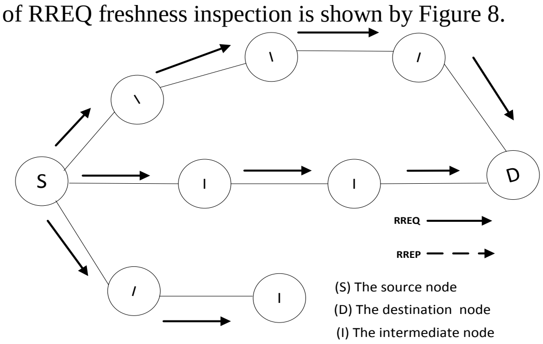

Fig. 5: Broadcasting of RREQ packet

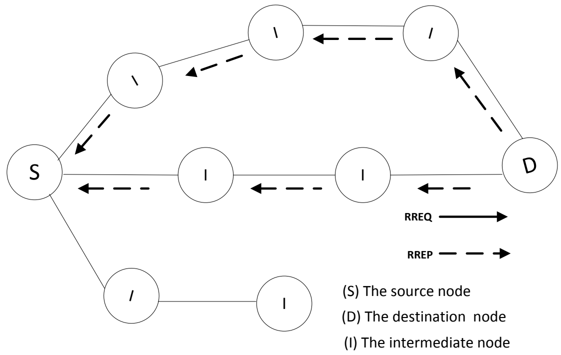

Fig. 6: RREP of an acknowledgement packet

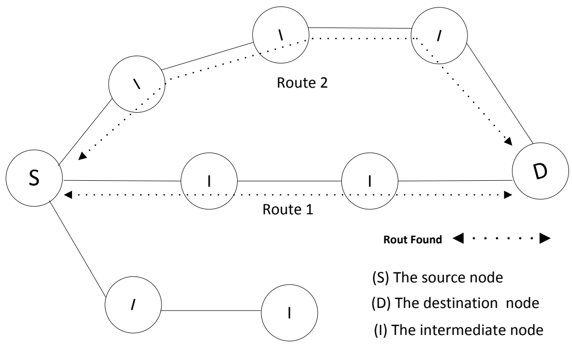

Fig. 7: Routes found by the source node S

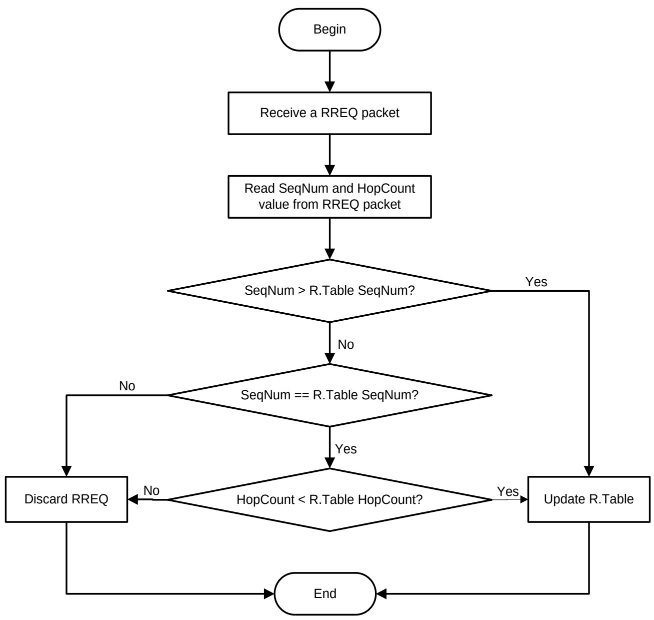

Fig. 8: RREQ route freshness inspection procedure

3. Network simulator

Throughout the years, network simulator-2 (NS2) is one of the most commonly used open source tools for network research. The existing NS2 tool is now not actively maintained by the open source community. However, many research works are still depends on NS-2 due to its credibility as compared to other open source tools. Although the current NS-3 tool is not backward compatible with NS-3, the framework and some codes are inherited by NS3 from NS2. The tool is developed by University California Berkeley. It is an object oriented tool, designed for discrete event driven networks. It includes the support for simulation of wired and wireless network functions and protocols such as physical layer, link layer and routing. Generally, NS-2 users are allowed to simulate a network by specifying the features included in the tools. In addition, the modular structure of NS-2 enable users the ability to focus the study on a specific protocol by simulating their corresponding behaviors. NS-2 supports various network protocols such as Transport Control Protocol (TCP), User Datagram Protocol (UDP), File Transfer Protocol (FTP) and traffic sources such as Constant Bit Rate (CBR) and Variable Bit Rate (VBR). Results of the simulations are provided within a trace files that contains the entire scheduled event driven simulation. The output of simulation can be visualized through Nam (Network Animator) [15]. In addition to the C++ object oriented programming language, NS-2 includes the Massachusetts Institute of Technology (MIT)'s Object extension to Tool command language (OTcl) [16]. The tool is intended to assists users for simulation, which allows them to specify values for parameters that can be passed to the C++ object. The main purpose of OTcl is to enable rapid parsing of parameters to expedite the simulation process. It reduces the time required to build and recompile the code after every changes made to the simulation parameter. In this way, the core structure of the protocol, i.e., coded in C++, is retained and various results can be output much faster. In general, the implementation and simulation of NS-2 can be summarized by Figure 9.

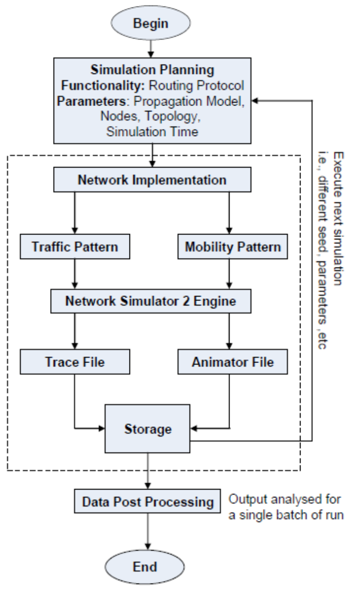

Fig. 9: Simulation process [17]

A review over a five-year-period of wireless network research papers [18] indicates that 76% of the works are based on network simulation. The extensive application of network simulation for wireless research continues to grow with Network Simulator 2 (NS-2) as the most popular simulation tools for such research. NS-2 includes a properly built model and debugging package that ensure output obtained is credible and can support various conditions and network scenarios. There are several simulation tools that can be used for the simulation of MANETs such as NS-2 [19][20], GloMoSim [21], QualNet [22], OPNET [23] and OMNeT++ [24]. Previous studies [25][26] have also present a detail comparison between these tools. Some of the characteristics of NS-2 are listed below:

1. Open source
2. Free license
3. Well established with complete manuals and community support
4. Widely used for research in MANETs domain
5. Support cross platform installation
6. Easy access to new extensions and modifications can be easily included

3.1. Mobile Nodes Model

Nodes are the most fundamental element among all other components of NS-2. They are modelled to perform the basic functionality of network-enabled devices; including processing and forwarding of packets. The internal architecture of a node differs, depending on whether the node is mobile or stationary. NS-2 supports two types of nodes; wired and mobile. Typically, a mobile node is a wired node equipped with extra functionality to model the behaviors of mobile networking. In addition, mobile nodes are allowed to move within a certain area of the network, as opposed to wired nodes which remain stationary. The mobile node itself is a compound object, built from the several components. Figure 10 shows the internal structure of such node:

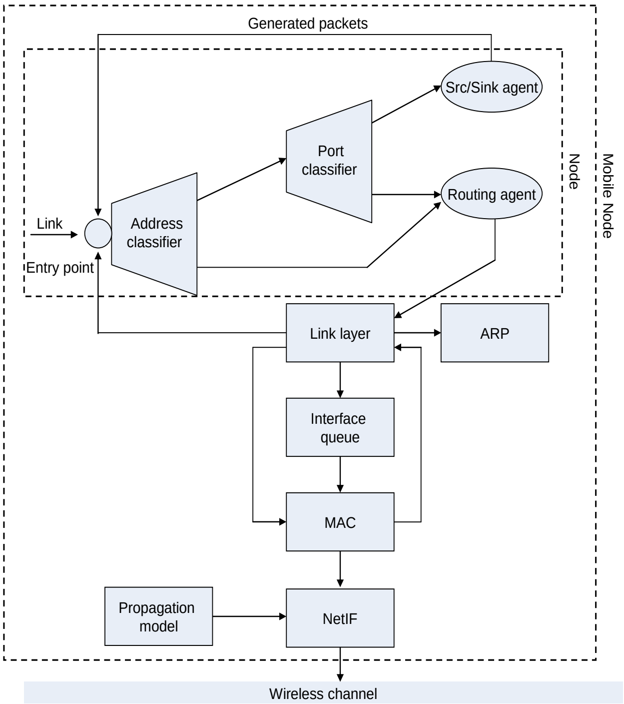

Fig. 10: Components of mobile node model in NS-2

Src/Sink agent: every packet that is sent by the source node (Src) is handled at the entry point, which is then forwarded either to the unicast or multicast classifier. Consequently, the packet is relayed through the routing agent before being sent to the immediate lower layers. The sink agent only receives packets through the classifier if the packet is addressed to the node.

Routing agent: the main function of this agent is to perform routing. An incoming packet from an application is processed using the specified routing algorithm and forwarded to the entry point. The classifier appends an address and the packet is sent to the link, which is then received by the receiver node's entry point. In the event that the incoming packet is not for the mobile node itself, the packet is handed to the routing agent, which assigns the routing information and sends it down to the link layer (LL). A port number of 255 is set by the receiver's classifier to attach the routing agent to a mobile node.

Link layer and ARP module: the function of LL class is to simulate the data link protocol. Similar to the IEEE 802.3 standard specification [27], the LL class employs the Address Resolution Protocol (ARP) to determine the hardware address of neighbouring nodes and map Internet Protocol (IP) addresses to their correct interfaces.

Interface Queue class: prior to transmission, all outbound packets are queued using the interface queue (IFq) class. Although the IFq has been defined by default to hold a maximum size of 50 packets, it is possible to change the value. Packets are placed according to their priority before being delivered to the MAC. Basically, there are four different priority queues available, in which packets are stored in accordance to priority level.

MAC module: this module is an implementation of the IEEE 802.11 standard. It is a common protocol used by the MANET's modelling community and, as such, an appropriate candidate protocol to be used in this analysis.

Radio propagation model: the two-ray ground reflection model [28] and the log-normal shadowing model are selected for the simulation in this work. The log-normal shadowing model is crucial for the study of routing protocol that highly depends on the channel condition for routing path construction. The omni-directional antenna's gain is assumed unity, i.e., 0 dBm, which used for the transmitters and receivers. Node's antenna is placed at an equal height of 1.5 m above the ground.

Network interface model: In the evaluation work, the wireless network interface (NetIF) is set to follow the specification of the Cisco Aironet 350 Client Adapter [29], operating at 2.4 GHz. However, for the purpose of the model validation, the Lucent WaveLAN [30] is used. This is consistent with the previous studies. The WaveLAN is a shared media radio with nominal bit rate of 2 Mbps and nominal radio range of 250 m. Table 1 shows the detail configuration parameters for the WaveLAN network interface.

4. Simulation Controls and Independent Replications

In the terminating simulation model, the starting and stopping conditions of the simulation are specified as a natural reflection of the target system's operation. The system's flow is terminating according to some conditions, where all operations occur within the pre-determined start and stop time. On the other hand, the steady state simulation is a method where the system's performance is measured in a theoretically infinite time frame. The initial parameter conditions and simulation time period is pre-determined and the measure of interest is defined within a specified time frame, as the simulation theoretically run to infinity.

Table 1: Lucent WaveLAN network interface parameters

Parameter Name	Parameter variable	Parameter Value
Raw bit rate (bps)	Rb_	2*1e6
Power of transmission (W)	Pt_	0.2818
Frequency (Hz)	freq_	914e+6
System loss factor	L_	1.0
Carrier sense threshold (W): min power required to detect another node's transmission	CSThresh_	1.559e-11
Receive threshold (W): min power required to receive a packet	RXThresh_	3.652e-10
Capture threshold (dBm): signal ratio required to maintain receiver capture of incoming packet in face of collision	CPThresh_	10.0

In this research work, the latter approach is adopted for the simulation experiment since it enables the performance of routing protocol to be observed in long-run. Essentially, two typical issues arises in the steady-state simulation; first the detection of initial transient period and second, the analysis of concurrent data. An important attribute of steady-state simulation is the time period between the start of the simulation until the time the simulation enter a stationary state. Such period is defined as the transient period or the warm-up period, where the system converges to a stable state. The simulation output obtained during such period is inconsistent and therefore, is not of use. As such, the data need to be discarded because it can severely affect the analysis of the routing performance. The following section discusses the methods to determine the initial transient period and subsequently the data elimination process.

4.1. Initial data deletion

The initial data deletion (IDD) [31] method requires analysis of the overall average after some of the initial output is deleted from the sample. A steady state is achieved when the average output of the simulation shows only a small variation. Nevertheless, due to the randomness of the simulation, which may be caused by random seeds, the average can slightly change during the steady state. To reduce the effect of randomness, it is essential that the simulation output is averaged across several replications. Each replication is run using the same parameter settings, which differs only in terms of the seed values used in the random-number generators. The averaging technique causes the simulation to produce a smoother trajectory. The left side of Figure 11 shows the result of several simulation runs with different seeds, whereas the average run in right side of Figure 11 shows a smooth curve.

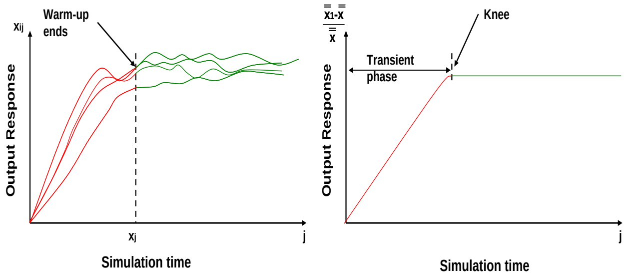

Fig. 11: Initial data deletions method result in smoother average runs

4.2. Batch-means test

The Batch-Means Test (BMT) is a simulation test [32] on running a simulation over a long period of time. Subsequently, the simulation is divided into several partitions, each of equal duration known as batch. Each batch is computed for its individual batch mean. The variance of the batch means is then analyzed as a function of the batch size. As shown in Figure 12, N number of observations is divided into m batch, each with n size, where m = N/n. Similar to the IDD method, let xij denote the jth observation in the ith batch.

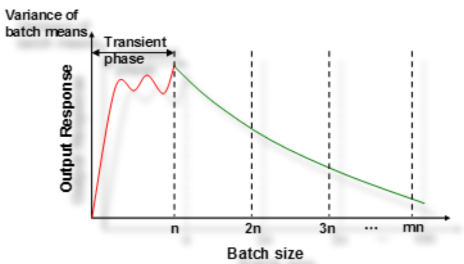

Fig. 12: Initial data deletions method result in smoother average

The advantage of BMT is that only one transient interval needs to be removed. On the contrary, the IDD requires multiple transient intervals, l, to be deleted prior to output stabilization (knee). Another issue with IDD is that randomness can cause some fluctuations during steady state. This may lead to unexpected deletion of steady state data. Multiple runs with high variations of seed can reduce such problem. On the other hand, the BMT approach requires large batch sizes to ensure output is significantly correlated between successive batches. Nevertheless, the BMT technique is adopted in this paper and is used with the confidence estimation measures. On the other hand, the IDD is employed to determine the cut-off point, for which the nodal movement stabilizes in each mobility model. The cut-off point for each simulation is set at 1100 seconds.

4.3. Independent replication

The other aspect of the simulation control in simulation work is the replications method [33]. To produce a credible simulations output, a sufficient number of independent replications must be made for the analysis of the correlated data. It is important that the number of replications is carefully chosen to produce simulation output that can guarantee the accuracy of the final results. Based on the methods previously discussed, the transient output can be effectively discarded, and the remaining results are sufficient for the analysis. However, the method does not specify the number of independent repetitions needed for a particular simulation. Therefore, the following points outline the steps required to achieve a confidence interval of 95%:

1. The same set of initial parameters is set for each replication.

2. The initial transient detection scheme is applied for each replication

3. The simulation is repeated with different random number generator seed value for each replication. A total of 25 replications is considered with the size of each replication is m – l, where l is the size of discarded observations due to transient state.

4. Each replication is run over a long simulation time to ensure the number of observations is significantly larger than the portion that is discarded due to transient period. If the simulation is too short, the results may be highly variable.

5. The overall mean is calculated across the replications. Based on the variance of the replicated means, the confidence intervals can be computed. The upper and lower bound of the confidence interval are identified by the vertical bars across the mean value. The confidence interval limits can be found by using the Student's t-distribution table [33][34]. In this work, the simulation output has been set to a confidence interval of 95%, i.e. a confidence level α of 0.05.

5. Validation Methodology

This section discusses the validation methodology. The comparison method is selected for validation, which is one of the techniques presented by Sargent [35]. Simulation results of the base routing protocols are reproduced and compared against the results obtained by previous researchers. To do this, similar network scenarios are recreated with parameters set to match as close as possible to the studies [36][37][38]. In order to ensure that the results obtained are credible, the simulation control and replications method as previously discussed are applied. For this reason, the simulation outputs in this validation may not be identical to the compared simulation results. A slight difference is observed, as shown by the results in subsequent section.

5.1. Initial data deletion

A comparison to a benchmark results from a 'valid' simulation work is the approach used to validate the simulation model in this research. Based on the comparison, a degree of similarity can be observed, which may indicate that the simulation settings and network scenarios are valid in comparison to other research work. The baseline results [36][37][38], which is run by authors of the routing protocol are considered faithful. Similar network parameters settings are followed and the value is summarized in Table 2. Naturally, the output of the simulation results may not be identical to the compared work. This is due to undocumented parameters and for that reason, some simulation settings are assumed similar to the parameters commonly used in earlier NS-2 simulation work. The NS-2 simulation software models all network layers in great detail, and may results in complex calculations and high resource consumptions, i.e., memory and computing time.

5.2. AODV model validation

The AODV model is validated using NS2, which follows most of the parameters stated by Broch and Perkins. Table 2 shows the parameters used in this validation. Generally, the simulation parameters in Perkins's work are identical to Broch's except for the packet size and the number of repetitions. The differences can slightly affect the results, which can be observed in Figure 13 specifically at 300 and 600 seconds.

Basically, Figure 13 and Figure 14 shows the packet delivery ratio (the ratio of number of data packets delivered to destination to those generated by the sources) and routing overhead (the total number of routing packets sent and forwarded) as a function of pause time, with maximum node speed of 20 m/s. Each point on the graphs represents a repetition of 25 independent simulation runs, varied only by the node movement patterns. The results of AODV, obtained from the simulation (represented by the square symbol) are nearly identical to Broch's and Perkins's (represented by the bar charts). There are some slight differences, particularly when compared to the Perkins's result.

Parameter	Perkins **Error! Reference source not found.**	Marina **Error! Reference source not found.**
Physical and Data Link Model		
Propagation model	Two-Ray Ground	Two-Ray Ground
Radio frequency	914MHz	914MHz
Transmission range	250 meters	250 and 150 meters
Data bit rate	2Mb/s	2Mb/s
Antenna height	1.5 meter	1.5 meters
Interface queue	50	50
Link layer	IEEE802.11 standard	IEEE802.11 standard
Routing Model		
Link breakage detection	MAC layer feedback	MAC layer feedback
Active route time	300 seconds	300 seconds
Route reply lifetime	600 seconds	600 seconds
Route request attempt	3	3
Route request timeout	6 seconds	6 seconds
Broadcast ID timeout	3 seconds	3 seconds
Reverse route timeout	3 seconds	3 seconds
Broken link timeout	3 seconds	3 seconds
Movement Model		
Mobility model	Random Way-point	Random Way-point
Number of nodes	50	100
Pause time	0 to 900 seconds	0 second
Network area	1500 x 300 m/sq	575 x 575 m/sq
Maximum node speed	20 m/s	0 to 20 m/s
Simulation time	900 seconds	500 seconds
Ave. runs for each data point	25	50
Traffic Model		
Traffic source	Constant Bit Rate	Constant Bit Rate
Traffic load	4 packets/sec	4 packets/sec
Number of sources	20	20
Packet size	512 bytesi	512 bytes

As indicated by Table 2, the average number of runs on Perkin's is small, i.e. 5, which can be the reason for the small discrepancy. Nonetheless, as expected, at a pause time of 900, the packet delivery ratio for every result is nearly identical. Nodes set with such pause time are virtually stationary for the entire time period of simulation. Figure 14 shows the routing overhead output obtained by simulation compared to the results reported by Broch. At pause time 0, the routing overhead shown obtained by the simulation is the highest, which slowly decreasing as the pause time increases towards 900. Again, there are some slight differences in the results, which may be due to the fact the packet size used in Broch's work is much smaller, i.e. 64 bytes. Figure 15, shows the normalised routing load (the number of routing packets sent and forwarded to the number of data packets received). It shows a similar trend to Figure 14, where each point on the graphs slowly decreasing as the pause time increases.

5.3. Conclusion

This paper discusses the simulation tool that is frequently used by researchers i.e. NS2. Based on the literature, 76% of the research paper employed NS2 and therefore it is imperative that essential components of NS2 are pointed out. This paper utilizes AODV routing protocol to show the quantification of routing protocol using the network simulator. A detailed account of the process of simulation tool and AODV has been explained. To measure the performance of AODV, different performance metrics are used. The values are obtained from the trace file generated after simulation by NS2. The data is processed using the AWK and Perl script and result produced are used to measure the performance of AODV protocol.
The results as shown in this paper illustrate the typical performance of the networks. This paper also presents several performance evaluation methodology employed for simulation experiment. In addition, the simulation modelling is also described, including network model and node model. An important element in any simulation experiment, which is the simulation control, is also discussed. Finally, this paper also presents the validation process, where results obtained by simulation are compared to the benchmark results reported by other authors. Such is essential to increase the credibility of the simulation model used.

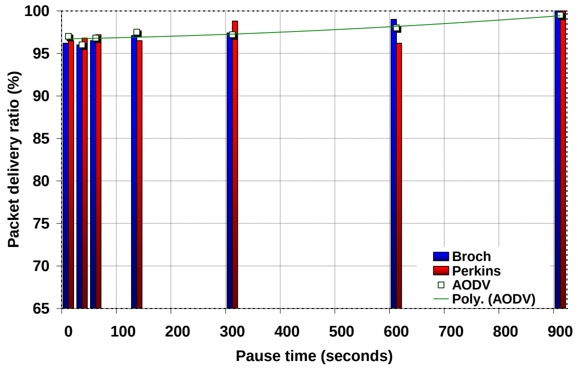

Fig. 13: Packet delivery ratio

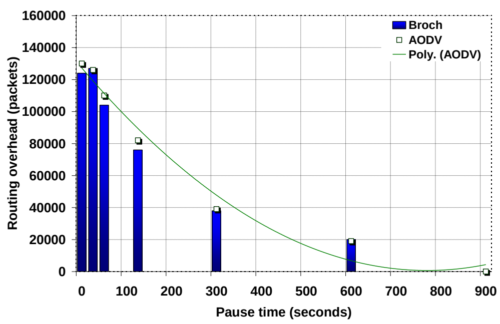

Fig. 14: Routing overhead

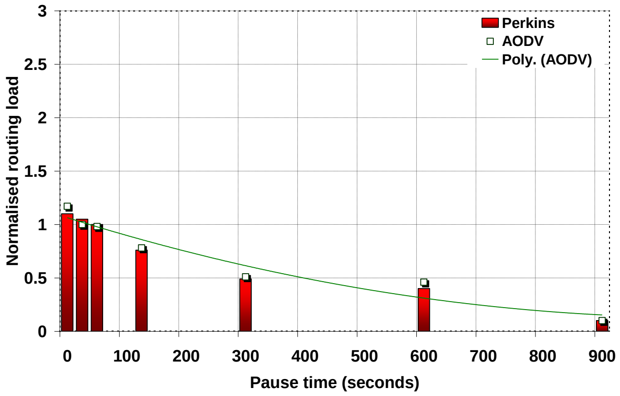

Fig. 15: Normalised routing load

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