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MANET Modeling and Simulation for Energy Efficient Routing

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ABSTRACT: Wireless industry has seen exponential growth in the last few years. The advancement in growing availability of wireless networks and the emergence of laptops, tablets, PDAs, smart phones is now playing a very important role in our daily routines. The ability to develop an on-demand, self-organizing wireless network without relying on any available fixed infrastructure is known as adhoc networks. Mobile Adhoc Network (MANET) applications can be seen in virtual classrooms, military communications, emergency search and rescue operations during flood/earthquake, data acquisition in hostile environments, communications set up in exhibitions, conferences and meetings, communication in battle field among soldiers to coordinate defense or attack, communication at airport terminals among workers to share files etc. Topology of the network changes frequently and unpredictably as the nodes move randomly in MANET. The nodes in an adhoc network are constrained by battery power for their operation. To route a packet from a source to a destination involves a sufficient number of intermediate nodes. Battery power of a node is a precious resource that must be used efficiently in order to avoid early termination of a node or a network. Efficient battery management, transmission power management and system power management are the major means of increasing the life of a node. Hence, the energy efficient routing in MANET is a critical issue due to mobility of nodes and limited battery power of mobile devices. In this paper, efforts have been made to study mobility models and simulation framework for energy efficient routing over MANET.

KEYWORDS: Adhoc, MANET, Model, Random Waypoint, Routing, Simulation

I. INTRODUCTION

An adhoc network [1,2] consists of hosts communicating among themselves with portable radios. This network can be deployed without any wired base station or infrastructure support where routes are mainly multi-hop because of the limited radio propagation range. Topology of the network changes frequently and unpredictably since its host moves randomly. Therefore, routing [3,4] is an integral part of Adhoc communication, and has received interests from many researchers. In traditional “on-demand” routing schemes like Adhoc On Demand Distance Vector Routing (AODV) scheme, when route disconnects, nodes of the broken route simply drop data packets because no alternate path to the destination is available until a new route is established [5]. When the network traffic requires real time delivery (voice, for instance), dropping data packets at the intermediate nodes can be costly. The Energy Efficient Adhoc routing [6] Protocol enables dynamic, self starting, multi hop routing between participating mobile nodes wishing to establish and maintain an Adhoc network. It allows mobile nodes to maintain routes to destinations with more stable route selection. One distinguishing feature of Energy Efficient routing protocol is its use of Power for each route entry. Given the choice between two routes to a destination, a requesting node is required to select one with better power status and more active. The nodes in an Adhoc network are constrained by battery power for their operation. To route a packet from a source to a destination involves a sufficient number of intermediate nodes. Battery power of a node is a precious resource that must be used efficiently in order to avoid early termination of a node or a network. Efficient battery management, transmission power management and system power management are the major means of increasing the life of a node. These management schemes deal in the management of energy resources by controlling the early depletion of the battery, adjust the transmission power to decide the proper power level of a node and incorporate low power consumption strategies into the protocols. Typical metrics used to evaluate adhoc routing protocols are shortest hop, shortest delay and locality stability. However, these metrics may have a negative effect in MANETs because they result in the over use of energy resources of a small set of nodes, decreasing nodes and network lifetime. The energy efficiency of a node is defined by the number of packets delivered by a node in a certain amount of energy. A few reasons for energy management [7] in MANETs are:



- Adhoc networks have been developed to provide communication for an environment where fixed infrastructure cannot be deployed. Nodes in adhoc networks have very limited energy resources as they are battery powered.
- In so many situations like hostile territory, it is very difficult or almost impossible to replace the battery or recharge it.
- There is no central coordinator in case of adhoc networks as a base station in cellular networks.

Therefore adhoc networks work on the concept of multi-hop routing in which intermediate nodes play the role of the relay nodes. If the relay traffic is very high, it leads to rapid depletion of a node and if the traffic is negligible upon a node that leads to the partitioning of a network. If the battery size is very small, it decreases the lifetime of a node and if battery size of a node is large, it increases the weight of the mobile node. So to keep the standard small size of a battery, energy management techniques are required to utilize it efficiently. Optimal value selection for transmitting a packet is difficult but as this transmission power increases, it increases the consumption of the battery but the connectivity increases. This increases the number of paths to the destination. Therefore selection of the transmission power should be done in order to reduce the consumption of the battery power so as to maximize the simultaneous packet transmission and preserve connectivity. Energy control algorithms are very useful for the systems in which the available bandwidth is shared among all the users. Reduction in transmission power increases frequency reuse, which leads to better channel reuse. Although developing battery efficient systems that have low cost and complexity, remains a crucial issue. Efficient battery aware protocol is the need of today's adhoc networks. Designing smart battery packs that can select appropriate battery discharge policies under different load conditions is a challenging problem. Other issues that exist at the physical layer includes efficient battery scheduling techniques selection of an optimal transmission power for the nodes and finding the appropriate time duration for switching off the nodes. Investigations at data link layer are; addressing the issues of relay traffic, such as finding an optimal strategy that decides the amount of allowable relay traffic for a node. Developing battery aware MAC algorithms for the nodes that increase the lifetime of the nodes is an important issue. Finally, at the network layer designing of an efficient routing algorithm that increases the network lifetime by selecting an optimal relay node. The network layer can aid in the conservation of energy by reducing the power consumed for two main operations, namely, communication and computation. The communication power consumption is mainly due to transmission and reception of bits. Whenever a node remains active, it consumes power. Even when the node is not actively participating in communication, but is in the listening mode waiting for the packets, the battery keeps discharging. The computation power consumption refers to the power spent in calculations that take place in the nodes for routing and other decisions. In general, a routing protocol which does not require large tables to be downloaded or greater number of calculations is preferable, the amount of data compression before transmission decreases the power consumed for communication although the number of computation tasks increases. Since the energy required per bit for communication is hundred times compared to computation, data compressed is preferred. MANETs allow anywhere, any time network connectivity with complete lack of control, ownership and regulatory influence. Each node in a MANET participates in the routing function. To establish communication among different nodes, the "death" of few nodes is possible due to energy exhaustion.

In traditional routing algorithms, routes are constructed on the basis of shortest path but these protocols are not aware of the energy consumed for the path setup or maintenance. Shortest path algorithm may result in a quick depletion of the energy of nodes along the heavily used routes. Designing energy aware and stable routing protocols has attracted a lot of attention for prolonged network operational time. Design objective of energy aware protocols [8] is to select energy efficient routes and simultaneously minimizing the overhead incurred in the selection of the routes. Some routing algorithms given by can optimize the energy use with a global perspective. But these algorithms incur expensive overheads for gathering, exchanging and storing the state information. These algorithms can be improvised in order to make them scalable. For this purpose a localized topology controlling algorithm or a distributed energy aware dominating set generating algorithm can be applied on nodes and a traditional base algorithm like AODV or DSR may be run in the network. This kind of protocol design can reduce the communication overheads consumed for route discovery. Implementation of this kind of approach requires the knowledge of one or two hop neighbours at the nodes. This requirement can consume bandwidth and use energy for gathering such information at nodes constantly in dynamic networks. Some algorithms work without assuming any topological knowledge at nodes and they can avoid the proactive overheads required for topological information. These kind of on demand approaches are required for energy efficient paths. Due to the reactive nature of on-demand routing protocols, one should choose on-demand routing protocol as the base protocol for energy efficient routing over MANET as it shall lead to find energy efficient paths. A lot of work has been carried in the direction of energy aware routing [6,7,8]. They modify either AODV or DSR, which are taken as the base protocol in their research.



II. MANET MODELING

Mobility models [9,10,12] are designed to represent the movements of mobile users, and how their location and acceleration change over time. They are used to evaluate the performance of adhoc network protocols. Since the performance of a protocol depends on the mobility model, it is important to choose a suitable model for the evaluated protocol. Various mobility models have been proposed so far, but the most common ones are random waypoint, random direction, and Gauss–Markov mobility models. These models are used for simulation purposes to evaluate new network protocols. Since mobility patterns may play a significant role in determining the protocol performance, it is desirable for mobility models to emulate the movement pattern of targeted real life applications in a reasonable way. Otherwise, the observations made and the conclusions drawn from the simulation studies may be misleading. Thus, when evaluating MANET Protocols, it is necessary to choose the proper underlying mobility model. For example, the nodes in Random Waypoint model behave quite differently as compared to nodes moving in groups. It is not appropriate to evaluate the applications where nodes tend to move together using Random Waypoint Model. Therefore, there is a real need for developing a deeper understanding of mobility models and their impact on protocol performance. One intuitive method to create realistic mobility patterns would be to construct trace-based mobility models, in which accurate information about the mobility traces of users could be provided. However, since MANETs have not been implemented and deployed on a wide scale, obtaining real mobility traces becomes a major challenge. Therefore, various researchers proposed different kinds of mobility models, attempting to capture various characteristics of mobility and represent mobility in a somewhat 'realistic' fashion. Much of the current research has focused on the so-called synthetic mobility models that are not trace-driven. In the previous studies on mobility patterns in wireless cellular networks, researchers mainly focus on the movement of users relative to a particular area (i.e., a cell) at a macroscopic level, such as cell change rate, handover traffic and blocking probability. However, to model and analyze the mobility models in MANET, we are more interested in the movement of individual nodes at the microscopic-level, including node location and velocity relative to other nodes, because these factors directly determine when the links are formed and broken since communication is peer-to-peer. One frequently used mobility model in MANET simulations is the Random Waypoint model, in which nodes move independently to a randomly chosen destination with a randomly selected velocity. The simplicity of Random Waypoint model may have been one reason for its widespread use in simulations. However, MANETs may be used in different applications where complex mobility patterns exist. Hence, recent research has started to focus on the alternative mobility models with different mobility characteristics. In these models, the movement of a node is more or less restricted by its history, or other nodes in the neighbourhood or the environment. In Figure 1, categorization for various mobility models into several classes has been provided based on their specific mobility characteristics. For some mobility models, the movement of a mobile node is likely to be affected by its movement history. We refer to this type of mobility model as mobility model with temporal dependency. In some mobility scenarios, the mobile nodes tend to travel in a correlated manner. We refer to such models as mobility models with spatial dependency. Another class is the mobility model with geographic restriction, where the movement of nodes is bounded by streets, freeways or obstacles.

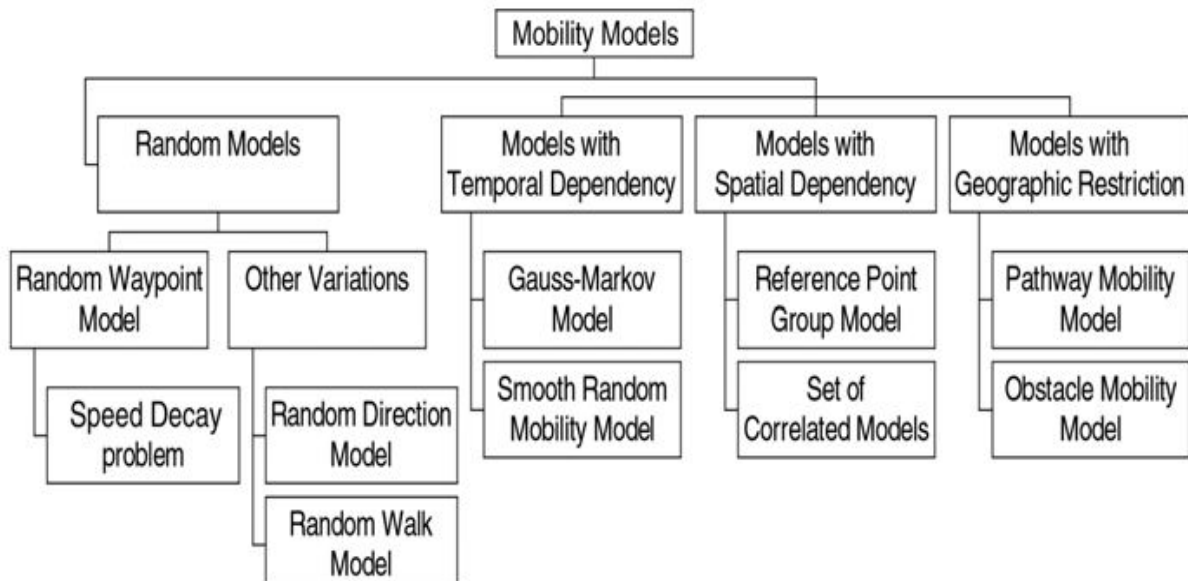


Figure 1: Categories of Mobility Models in MANET



The random waypoint model was first proposed by Johnson and Maltz. It is one of the most popular mobility models to evaluate MANET routing protocols, because of its simplicity and wide availability. In this model, the mobile nodes move randomly and freely without restrictions. To be more specific, the destination, speed and direction are all chosen randomly and independently of other nodes. Figure 2 shows pattern of a mobile node using the Random Waypoint Mobility Model.

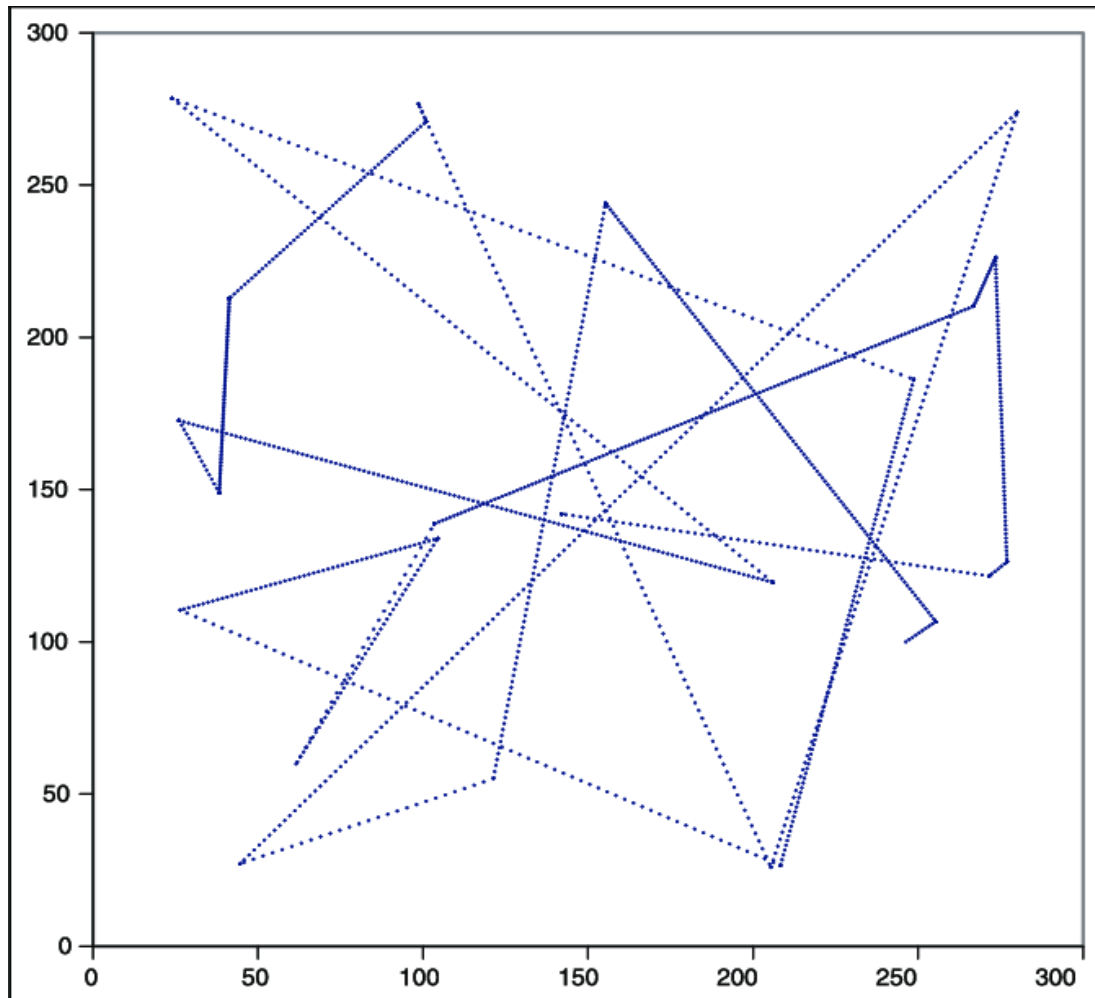


Figure 2: Mobility Patterns in Random Waypoint Mobility Model.

The random direction model is similar to the random waypoint model, but in the random direction model, the node randomly and uniformly selects a direction in which it travels until it reaches the boundary, instead of selecting a random destination. Upon reaching the boundary, the node waits for a designated time. Then, it randomly and uniformly selects another direction to travel. Therefore, a uniformly distributed mobility model is provided for evaluations.

The Gauss–Markov model is a different model from the random waypoint and direction models in terms of velocity management. In this model, the velocity of a mobile node is correlated over time and Gauss–Markov stochastic process. The Gauss–Markov stochastic process satisfies the requirements for both Gaussian processes and Markov processes. The velocity of a mobile node at time slot t is dependent on the velocity at time $t - 1$. Therefore, the Gauss–Markov model is a dependent mobility model, where dependency is determined by the parameter α , which affects the randomness of the Gauss–Markov process.



II. MANET SIMULATION

Wireless communication technology has become an essential framework for today's communication environments. This interest leads the researchers to improve the current wireless technology. In MANET, the nodes are dynamically moving without any boundary limitations. With the growth of the scale of today's MANETs, experimental studies become harder to implement in real environments. The implementation and testing of some applications in the real environment might not be possible due to practical constraints. To cope up with such problems, simulators [11,12] are widely used in today's research community. In this section, the different simulation environments and simulators have been discussed. Some metrics that are specifically used for MANET related applications while performing simulation analysis are given below:-

- Nodes Residual Energy
- Quality of Neighboring Nodes
- Communication Overhead
- Degree
- Node Trust
- Mobility Speed
- Direction etc.

Many researchers create their own simulation environment for many reasons. Table 1 depicts a sample of simulation environment for forthcoming research work in the field of energy efficient routing:-

Table 1: Simulation Environment

| | |
|-------------------------------|-------------------------------------|
| Simulator | NS-2.34 |
| Network Interface | WirelessPhy |
| Channel | WirelessChannel |
| Antenna type | OmniAntenna |
| Propagation | TwoRayGround |
| MAC Type | 802.11 |
| Mobility Model | Random Waypoint |
| Transmission Power | 1.65 W |
| Reception Power | 1.1 W |
| Transition Power | 0.6 W |
| Idle Power | 1 W |
| Sleep Power | 0.001 W |
| Initial Energy of Node | 1000 Joules |
| Data Rate | 1 mbps |
| Protocols | AODV and EER |
| Data Packet size | 512 byte |
| Transmission Range | 200 meter |
| Number of Nodes | 20, 60, 100 |
| Pause Time (Max.) | 500 Seconds |
| Queue Length | 150 |
| Area | 750 × 750, 1000 × 1000, 1500 × 1500 |
| Speed | 7 meter per second (fixed) |
| Traffic Agent | UDP |
| Traffic Model | CBR |

In today's research community, especially in distributed computing domain, simulators are highly utilized to test and evaluate studies. Each simulator tool has its own advantages and disadvantages in different aspects. Following are some



well known simulators:-

POSIX Thread-Based Simulator

In POSIX thread-based simulators, each node is represented by a thread. Protocols are coded into the thread's start routine, and communication between threads is handled by shared memory spaces such as globally defined arrays. The issue that must be taken into consideration in thread based simulators is the mutual exclusion problem. For this problem, an inter-process communication module is recommended to handle mutual exclusion between threads. Topology and scenario generation in such simulators can be developed explicitly from the simulator. Generally, the topology is stored in two-dimensional arrays, indicating the neighboring status of nodes. However, mobility scenarios can be realized by reasonably altering the neighbor matrix.

NS-2 Simulator

NS-2 (version 2.34) is a discrete event simulator that is developed at ISI, California. It provides substantial support for the simulation of transmission control protocol (TCP), routing, and multicast protocols over wired and wireless (local and satellite) networks. It is an object-oriented simulator written in C++, with an OTcl interpreter as a front end. NS-2 uses two languages: C++ and OTcl. Users implement their applications in C++, and simulation scenarios and setups are written in OTcl. Presently, the simulator is a single-threaded event-driven simulator, and only one event can be executed at a time. If more than one event is scheduled to execute at the same time, the built-in scheduler executes them in a first-come first-serve fashion and the next earliest event in the queue is executed to completion. Nodes in NS-2 are OTcl classes, which contain an address or id, a list of neighbors, a list of agents, a node type, and a routing module. Routing of messages is handled by five alternative ad hoc routing protocols: destination sequence distance vector, dynamic source routing, temporally ordered routing algorithm, ad hoc on-demand distance vector, and protocol for unified multicasting through announcements. By default, nodes in ns2 are constructed for unicast simulations. In order to enable multicast simulation, the simulation should be created with an option "multicast on."

TOSSIM Simulator

TinyOS is a sensor network operating system that runs on motes and TOSSIM is a discrete event simulator for TinyOS for wireless sensor networks. TOSSIM is designed considering four requirements, which are essential for efficient TinyOS simulation environment:-

- a) Scalability
- b) Completeness
- c) Fidelity
- d) Bridging

TOSSIM has visual components to improve its usefulness. The TOSSIM architecture is composed of five parts: a compilation support for simulation, a discrete event queue, a small number of hardware abstraction components, mechanisms for extensible radio and analog-digital converter (ADC) models, and communication services.

OPNET Simulator

OPNET is a high-level event-based network simulator. It is a commercial simulator, but there is free license for educational purposes. Originally, the simulator was developed for military operations. OPNET accelerates the R&D process for analyzing and designing communication networks and protocols. It is a very large and powerful network simulator with a variety of possibilities such as simulating entire heterogeneous networks with various protocols. It consists of user-friendly user interface, which is constructed from C and C++. The graphical user interface-based debugging and analysis simplify the simulation process. OPNET provides various tools for simulation including network model editor, node model editor, and process model editor. It has the fastest discrete event simulation engine among leading industry solutions. One of the significant features of OPNET is the supports grid computing for distributed simulations.

OMNeT++ Simulator

OMNeT++ is a modular object-oriented discrete event network simulator. OMNeT++ is the extended version of OMNET. It can perform various network simulations such as traffic modeling of telecommunication networks, protocol modeling, and modeling of queuing network, MANET etc. An OMNeT++ model consists of hierarchically nested modules that are managed with a highlevel script language (NED). These modules communicate through message passing. The modules can have their own parameters and they can be used to customize a module. The modules are programmed in C++ using the simulation library. OMNeT++ simulations can feature varying user interfaces for different purposes, including debugging, demonstration, and batch execution. The Eclipse-based Integrated Development Environment (IDE) provides an easy control over simulation execution. In addition, the IDE allows the



user development/debugging phase for the simulation project. User interfaces also facilitate demonstration of how a model works. The simulator as well as user interfaces and tools are portable: they are known to work on Windows and on several Unix flavors, using various C++ compilers. OMNeT++ also supports parallel and distributed simulation. OMNeT++ runs on Linux, Mac OS X, other Unix-like systems, and Windows, but the IDE runs only on Linux32/64, Mac OS X 10.5, or Windows XP. OMNEST is the commercially supported version of OMNeT++. OMNeT++ is free only for academic and nonprofit use, but for commercial purposes, OMNEST licenses have to be obtained from Omnest Global, Inc.

GloMoSim Simulator

GloMoSim is a scalable parallel discrete-event simulator for wired and wireless networks. The protocols are coded by Parsec, which is a C-based simulation language, developed in University of California, Los Angeles. GloMoSim has a layered approach like the OSI network architecture. Currently, GloMoSim supports protocols for a purely wireless network, but the wired and hybrid networks have not yet been accomplished.

Sinalgo Simulator

Sinalgo is a network simulator for testing and validating network protocols and algorithms. It was developed by the Distributed Computing Group at ETH Zurich and published under BSD license. It focuses on the verification of network algorithms. It tends to simulate the wireless networks and offers itself as a first test environment, prior to the deployment of the algorithm to the hardware. It provides a close environment to the real hardware devices. It has important features including quick prototyping of the network algorithms, many plug-ins, working over 100,000 nodes, 2D and 3D support, asynchronous and synchronous simulation, and customizable visualization of the network graph. Sinalgo contains the most frequently used modes such as UDG and QUDG.

As an illustration, the structure of MANET simulator can be depicted as in figure 3:-

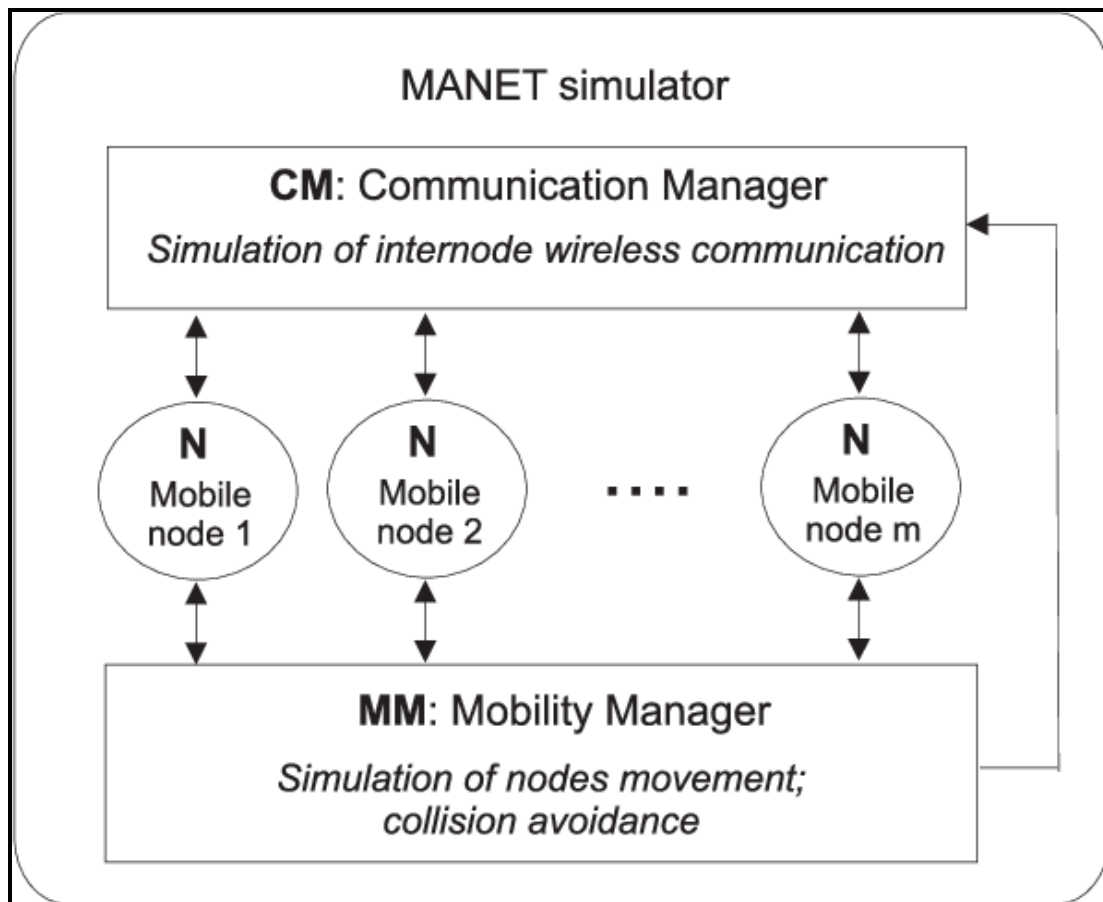


Figure 3: Structure of MANET Simulator

Out of above-mentioned simulators, the NS-2 simulator is a de facto standard simulator in experimenting wired and



wireless network applications, since it is an open source and powerful tool with vast functionalities in simulating networks.

IV. MANET SIMULATOR INPUT PARAMETERS

The input parameters for MANET Simulators are given below:-

- Mobility Models
- Group
- Grid/Road
- Random Direction
- Random Waypoint
- Steady-State Random Waypoint
- Range of Transmission
- Number of Nodes
- Mobility Model
- Coverage Area
- Packet Transmission Rate
- Average Pause Time (Node)
- Simulation Time
- Average Speed (Node)
- Number of Iterations (in Simulation)
- Average Pause Time Variation
- Traffic Type (e.g: Constant Bit Rate)
- Average Speed Variation

V. CONCLUSION

The simulation is a very challenging issue because of the complex nature of the MANET. Simulation lets the developers design and tests the network that is going to implement and deploy in the real world. This reduces the cost of implementation as well as easy to analyze the behaviour of moving nodes, routing protocol, models, and networks in advance. Further, it is also used to understand the actual working condition of the network and its operations. Numbers of network simulators have been discussed. Every individual simulator has unique functionalities to assess the network performance and algorithms/protocols used in the network. If an individual directly evaluate these processes in the real world, then it is very expensive to deploy. Simulation is the best way to overcome this drawback. Through this simulation, an individual can figure out the accuracy, scalability, efficiency, throughput, data rate and traffic delay of the network. An elaborative study has been carried out on modeling and simulation in order to implement energy efficient routing over MANET in forthcoming research. It has been concluded that Random Waypoint Mobility Model is the finest model and NS-2 is the best simulator to carry out further research work in the field of energy efficient routing over MANET.

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