Survey of Routing Protocols, Simulation, Testing Tools and Mobility Models in MANET

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ABSTRACT:

Developing categories of Wireless Networks are Cellular Networks, Mobile ad-hoc network, Wireless Sensor Networks, Vehicle Ad-hoc Networks, and Wireless Mesh Networks. With the advance of wireless communication technologies, small-size and high-performance computing and communication devices like commercial laptops and personal digital assistants are increasingly used in daily life. After the success of succeeding generation mobile system, more interest in wireless communication was started. This interest has led to two types of wireless networks: infrastructure wireless network and infrastructureless wireless network it is also called Mobile Ad-Hoc Network (MANET). In MANET all nodes are mobile, connected dynamically in an arbitrary manner and each node behaves like a router and it takes part in the discovery and maintenance of routes to other nodes in the network. The network structure changes dynamically due to node mobility. Essentially Mobile Adhoc Networks are suitable when infrastructure is not present or difficult or costly to set up or when network setup is to be done quickly within a short period. They are very attractive for tactical communication in the military and rescue missions (Natural disasters like earthquake, flood, tsunami, and fire). They are also expected to play an important role in civilian mediums such as convention centers, conferences, and electronic classrooms. This research paper surveys the three different areas of research fields, routing protocols, simulation tools, and mobility models, these fields are interrelated to each other. The previous research papers have not surveyed these areas of research fields collectively. Hence this paper is very useful to research community to propose and develop new routing protocols using the simulator in Mobile Adhoc Networks.

Keywords: MANET, Routing, Mobility Models, Simulators.

I. INTRODUCTION TO MOBILE AD HOC NETWORKS

Recently, we observe two kinds of wireless networks but the difference between them is not as obvious as it seems. The first kind and most used today is a wireless network built on top of a “wired” network and thus creates a reliable infrastructure wireless network. The wireless nodes are able to act as bridges in a wired network is shown in Fig.1. These kinds of wireless nodes are called base-stations. An example of this wireless network is the cellular-phone networks where a phone connects to the base station with the best signal quality. When the phone moves out of range of a base station, it does a “hand-off” and switches to a new base-station within reach. The “hand-off” should be fast enough to be seamless for the user of the network. The second approach, called ad-hoc, does not rely on any stationary infrastructure. All nodes in ad hoc networks are mobile and can be connected dynamically in an arbitrary manner. Each node in such networks behaves like a router and takes part in the discovery and maintenance of routes to other nodes. In the MANET every node can perform the role of host as well as a router, thus nodes, which are out of transmission range, can be accessed by routing through the intermediate nodes[1][2][3]. The network topology of MANET is always changing, as their mobile nodes are free to move around and can freely leave or join the networks shown in Fig 2.

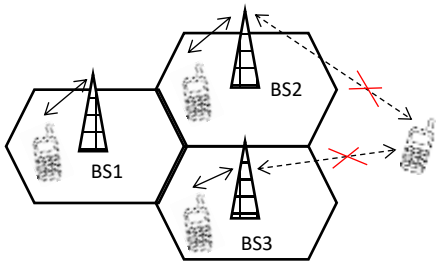

Fig.1.1: Illustration of the infrastructure network

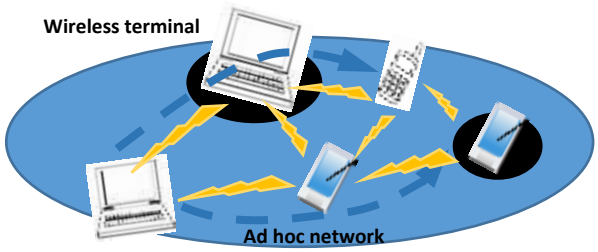

Fig. 1.2: Illustration of the infrastructure-less network

The history of Mobile Ad hoc Networks can be traced back to 1972 and the U.S Department of Defense (DOD) sponsored Packet Radio Network (PRNET), which evolved into the Survivable Adaptive Radio Networks (SURAN) program in the early 1980s [4]. ARPANET first introduced packet switching technology in the 1960s, it was not until the growth of the Internet infrastructure and the microcomputer revolution that packet radio network ideas became truly applicable and feasible. One of the original motivations for MANET is found in the military need for battlefield survivability. Soldiers must be able to move freely without any of the restrictions imposed by wired communication

devices. An additional motivation for MANET is that the military cannot rely on access to a fixed, pre-placed communications infrastructure in battlefield environments. Therefore, the goal of the DoD-sponsored programs was to provide packet-switched networking to mobile battlefield elements in an infrastructure less, hostile environment (such as soldiers, tanks, aircraft, etc.) forming the nodes in the network. The packet radio was the first implementation of an infrastructure less network where nodes are mobile devices. The MANET has played an important role in military applications and related research efforts, for example, the global mobile information systems (GloMo) program and the near-term digital radio (NTDR) program. Recent years have seen a new spate of industrial and commercial applications for wireless ad hoc networks, as many portable computers and personal digital assistants (PDAs) equipped with wireless ports are becoming more compact and inexpensive[4].

Characteristics of mobile ad-hoc networks [4] are dynamic topology, bandwidth constrained, variable capacity links, energy, and bandwidth constrained operation, limited physical security, quickly deployable. Well-known applications [1][2][4] of MANET are - Military (Automated battlefield, Special operations, Homeland defense), Civilian (Disaster - flood, fire, earthquakes etc, Law enforcement - crowd control, Search and rescue in remote areas, Environment monitoring - sensors, Space/Planet exploration), Commercial (Sport events, festivals, conventions), Patient monitoring, Ad hoc collaborative computing – Bluetooth, Sensors on cars (car navigation safety), Car to car communications, Networked video games at amusement parks, etc. Mobile Adhoc Networks (MANETs) has become one of the most widespread areas of research in recent years because of the challenges it poses to the routing protocols. Technology enables users to communicate without any physical infrastructure regardless of their geographical location. Research areas in the MANET[4] - Reliability, Routing, Scalability, Security, Internetworking, Multimedia, Energy consumption optimization, Quality Of Services, Multipath Routing, Cross-layer design, Unicast, Multicast, Broadcast, Geocast routing protocols design, MAC protocol design, Network layer Transport layer and Application layer design, Next generation hydride network protocols.

II ROUTING IN MOBILE AD HOC NETWORKS

MANETs are considered as autonomous, self-configured, multi-hop wireless networks. They don't rely on any stationary infrastructure; no centralized control and they are quickly deployable anywhere at any time. In the MANET, all nodes are mobile that cooperate in a friendly manner, they are connected dynamically and they have the ability to leave existing nodes from the network and enter new nodes into the network at any time, due to this, the topology of the MANET is highly dynamic and it frequently changes. In the MANET, every node performs the route discovery and route maintenance phase. The MANETs are widely used in military, civilian and commercial applications [1][2][4]. The routing is the most active research field in the MANET. The routing protocols, which are developed for wired networks are not suitable for wireless networks, due to the mobility. The routing problem becomes more serious in MANET, due - Highly dynamic topology due to node's mobility, No infrastructure for centralized administration, Bandwidth and Energy constrained, Hidden and exposed problem, Error-prone wireless channel, Poor wireless variable link capacity.

The routing protocols in MANET can be classified as follows : Pre-computed routing(table driven) vs. On-Demand Routing, Link State Routing vs. Distance Vector Routing, Periodical update vs. Event-Driven Up-Date, Flat structure vs. Hierarchical Structure, Decentralized Computation vs. Distributed Computation, Source routing vs. Hop-by-Hop Routing, Global Position Based Vs Global Position-Less Routing, Single Path Routing Vs Multipath Routing, Power aware routing Vs Power Unaware Routing, Security routing Vs Non Security Routing, Multicast routing Vs Uncast routing.

The routing protocols can be classified into in four different ways [1][2] - based on routing information update mechanism, based on topology information organization, based on the use of temporal information routing and based on utilization of the specific resource.

Based on the routing information update mechanism the routing protocols are classified into three categories [5, 6] - Proactive(Table-driven) routing protocols, reactive(On-demand) routing protocols, hybrid routing protocols. Depending on when the route is computed, routing protocols can be classified into three categories proactive routing protocols, reactive routing protocols, and hybrid routing protocols[5][6].

Table-Driven Routing: In this routing, the routes to all destinations are computed a priori. In order to compute routes in advance, nodes need to store the entire or partial information about link states and network topology. In order to keep the information up to date, nodes need to update their information periodically or whenever the link state or network topology changes. The advantage of pre-computed routing is that when a source needs to send packets to a destination, the route is already available, i.e., there is no latency. The disadvantage is that some routes may never be used. Another

problem is that the dissemination of routing information will consume a lot of the scarce wireless network bandwidth when the link state and network topology change fast. Some well-known table-driven protocols are [1,2,3,4,5,6] - Destination-Sequenced Distance-Vector Protocol (DSDV), Wireless Routing Protocol (WRP), Global State Routing (GSR), Hierarchical State Routing (HSR), Zone Based Hierarchical LSR Protocol (ZHLS), and Cluster Switch Gateway Routing (CGSR).

On-demand routing: In this method, the route to a destination may not exist in advance and it is computed only when the route is needed. The idea is as follows. When a source needs to send packets to a destination, it first finds a route or several routes to the destination. This process is called route discovery. After the route(s) are discovered, the source transmits packets along the route(s). During the transmission of packets, the route may be broken because the node(s) on the route move away or go down. The broken route needs to be rebuilt. The process of detecting route breakage and rebuilding the route is called route maintenance. The major advantage of on-demand routing is that the precious bandwidth of wireless ad hoc networks is greatly saved because it limits the amount of bandwidth consumed in the exchange of routing information by maintaining routes to only those destinations to which the routers need to forward data traffic. On-demand routing also obviates the need for disseminating routing information periodically or flooding such information whenever a link state changes. The primary problem with on-demand routing is the large latency at the beginning of the transmission caused by route discovery. Some well known on-demand routing protocols are [1,2,3,4,5,6] as follows - Dynamic Source Routing Protocol (DSR), Ad-hoc On-demand Distance Vector Routing Protocol (AODV), Temporally Ordered Routing Algorithm (TORA), Associativity Based Routing (ABR), and Signal Stability-Based Adaptive Routing (SSR).

Hydride Routing: uses both reactive and proactive schemes, it exhibits better performance. The disadvantage is hierarchical routing is used; the path to a destination may be suboptimal. [1,2,3,4,5,6] Some well known on-demand routing protocols are as follows - Zone-Based Routing Protocol, Fisheye State Routing (FSR) and Landmark Routing (LANMAR) Routing Protocol.

III MOBILITY MODELS

This section review the different mobility model Fig-4. Mobility is an important factor in wireless networks. It represents the movement of mobile nodes (MNs) and how their speed and direction are changed over time this section describes different mobility models. Mobility models represent or predict user's or wireless device’s movements. The movement pattern of MANET nodes is differentiated by mobility models and each routing protocols shows specific characteristics for these models. In order to find the most adaptive and effective routing protocol for dynamic MANET topologies, the behavior of routing protocols needs to be examined at changing node speeds, number of traffic nodes, network size, as well as node density. Mobility models can be simulated in two ways: using traces obtained through real experiments, or generating synthetic data using the statistical characteristics. Traces are real mobility patterns that exist in life. Synthetic is trying to realistically represent the movement of users in the absence of traces availability. There are many different ways to classify synthetic mobility models such as individual and group mobility models [7 , 8 ,9 ,10, 11]

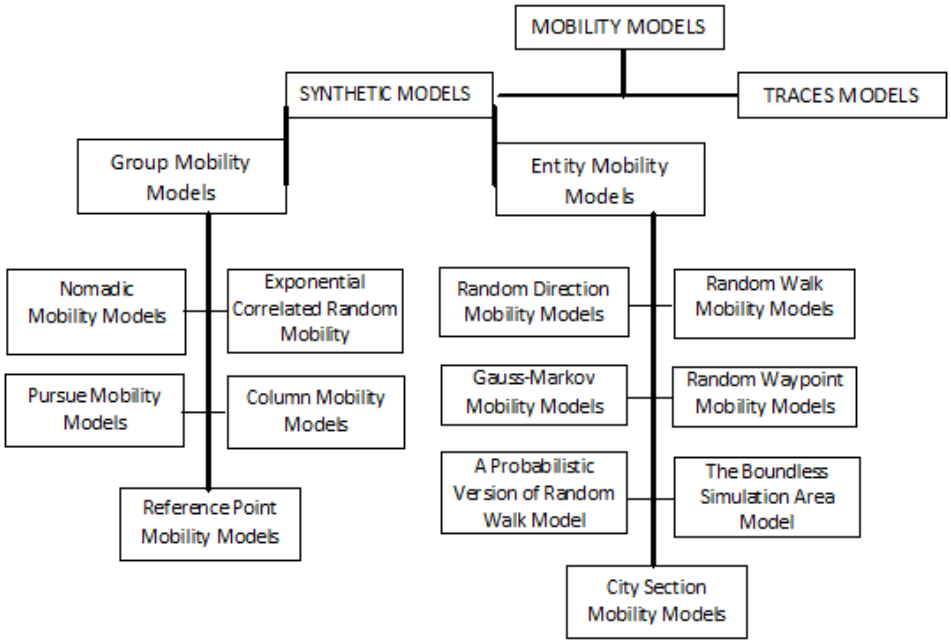

Fig-3.1: Mobility Model overview

IV SIMULATORS

To implement and measure the performance of protocols different simulates are used. Advantages and disadvantages *The characteristics of simulation include:* Study the behavior of a system without building it, results are accurate in general, compared to the analytical model, help to find un-expected phenomenon, behavior of the system, easy to perform "What-If" analysis and simulation experiment is low cost compared to practical experiment, and some limitations: expensive to build a simulation model, expensive to conduct simulation and sometimes it is difficult to interpret the simulation results.

MANET is a rapidly emerging mobile communication technology which offers fruitful services in various fields like a military battlefield, emergency services, entertainment, sensor networks, home and internetworking etc. It has mobile nodes with a decentralized administration. Experimentation on such network is time-consuming and cost-effective. To overcome this drawback various simulation tools are available to implement different protocols and measure their performance by using different qualitative performance metrics and using various parameters in Mobile Adhoc Networks. This section surveys and briefly describes the different Network Simulators that are used in MANETs and other Networks [12,13]

4.1 NETWORK SIMULATOR (NS2) - NS2 is one of the most popular and well known standard network simulation tools for implementing all types of network protocols. It was developed by the University of California at Berkeley and it is widely used by the research community. Statistics say about 70% of education purposes use NS2. It is open source, discrete event simulators for computer networks [14]. Ns2 code comprises of OTCL and C++. OTCL is an interpreter used to execute the commands. NS2 follows two levels of hierarchy namely C++ Hierarchy and the interpreted OTL, which is one to one correspondence [14]. Two languages are linked because to achieve efficiency. C++ Hierarchy allows faster execution and to achieve efficiency. This gives a detailed description, definition, and operation of protocols, packets and processing time. On the other hand, OTcL enables the user to define network topology, protocols, applications that user tend to simulate. OTcL can make use compiled C++ Object through an OTcL linkage. OTcL Linkage creates a matching between OTcL and C++ Objects. It defines the event discrete simulators, records the data for each millisecond and gives an output regarding packets send, received, dropped, initial energy of nodes, consumption of energy for transmitting, receiving, idle power, sleep power, denotes the traffic model, simulation packets, packet size, and mac address. Nam file is a visual graphical window which shows the node movements, radio range, and packet transfer including time.

4.2 NS-3 – NS-3is a discrete-event simulators primarily targeted for research and educational purposes. It was started in 2006 [15] and NS-3 is not an extension of NS2. NS3 is a new simulator. The similarity between NS2 and ns3 are

both written in C++ Codes but ns3 does not support NS2 API. In ns3 simulators is written in C++ and python. The new modules ns3 has when compared with NS2 are shown in the table as follows:

S.No	Property	NS2	NS3
1	Interface	Single interface	Multiple interface
2	Address	Single Addressing	Use of IP Addressing aligned
3	Portability	It can be ported to NS3	Not portable

Table 4.1: Property of NS2 and NS3

4.3 Qual Net - It is a discrete event simulator and mainly successor of GloMoSim. It was particularly built for large Scale networks. We can simulate wired, wireless and mixed networks. The main features of Qual Net [16] Robust set of wired and wireless network protocols which is useful for simulating networks. Qual Net executes equivalent networks 5-x times faster than other networks. Qual Net runs on all platforms like Linux, windows. Qual Net needs a single parameter, which sets up the experiment or network called a default configuration.

4.4 OPNET- OPNET is another network simulator, which again the best User Interface. It can be downloaded from the website. Test technology design in realistic conditions and evaluate enhancement to standard based protocols, develop new protocols and technologies [17]. OPNET supports four simulation technologies as 1. Discrete Event Simulator 2. Flow Analysis 3. Ace Quick Predict 4. Hybrid Simulation. Discrete event simulators provide models that explicitly simulate protocols and simulate messages [17]. It executes in same way as the production environment. Flow analysis provides analytical techniques and algorithms to model Stead state network behavior. ACE Quick Predict uses an analytical technique for studying the impact on an application response time of changing network parameters (e.g., bandwidth, latency, utilization, packet loss) this technique is supported within the OPNET Application Characterization Environment (ACE).

4.5 OMNET ++ - OMNeT++ is a discrete event simulation environment. Its primary application area is the simulation of communication networks, but because of its generic and flexible architecture, is successfully used in other areas like the simulation of complex IT systems, queuing networks or hardware architectures as well. OMNeT++ provides component architecture for models. Components (modules) are programmed in C++, and then assembled into larger components and models using a high-level language (NED). Reusability of models comes for free. OMNeT++ has extensive GUI support, and due to its modular architecture, the simulation kernel (and Models) can be embedded easily into your applications. Although OMNeT++ is not a network simulator itself, it is currently gaining widespread popularity as a network simulation platform in the scientific community as well as in industrial settings, and building up a large user community. The components of OMNeT++ are as follows simulation kernel library compiler for the NED topology description language, OMNeT++ IDE based on the Eclipse platform GUI for simulation execution, links into simulation executable (Tkenv) command-line user interface for simulation execution (Cmdenv) utilities (makefile creation tool, etc.) documentation, sample simulations.[18]

4.6 GloMoSim - GloMoSim [19] is a network simulator which tries to mimic the various layers of the OSI layers. In GloMoSim, each entity represents a geographical area of the simulation. Hence the network nodes which a particular entity represents are determined by the physical position of the nodes. Since GloMoSim implements different levels new protocols at various levels can be easily integrated. There are also various functions which can be used to send a message through different layers. GloMoSim runs only on Parsec compiler. New protocols should be added in Parsec and C language. Parsec code is used extensively in the GloMoSim kernel.

4.7 Agent J (Lan Taylor) - Agent J is a java based network simulator for NS2. AgentJ is essentially java virtual machine (JVM) [20] for the simulation environment. Agent J Consists of byte code subsystem that swaps used code on the use. It contains own implementation of network, threading, timing functions for NS2 [20].

4.8 SHARPE - Sharpe tool is an old network tool and well-known package in reliability and performability [21]. It is one of the important tool and modeling tool. It is a toolkit that provides a specification language and solution methods for most of the commonly used model types for performance, reliability and performability modelling. To increase the usability of this modelling tool, a graphical user interface (GUI) for SHARPE has been implemented. The SHARPE GUI implements eight interchangeable modelling description techniques for reliability engineering: fault trees, Markov chains, reliability block diagrams, reliability graphs, generalized stochastic Petri nets, product queuing networks, multi-chain product form queuing networks and task graphs. Future, all the modelling description techniques contained in SHARPE will be available in the GUI (phase mission, multi-components fault trees, and semi-Markov chains). The hierarchy feature is also implemented in the GUI. Java is the language chased for GUI implementation.

4.9 SPNP - This package was developed by Ciardo [22]. The model type used for input is a stochastic reward net (SRN). SRNs incorporate several structural extensions to GSPNs such as marking dependencies, marking dependent arc cardinalities, guards and allow reward rates to be associated with each marking. The reward function can be marking dependent as well [22]. They are specified using CSPL, C based SRN Language which is an extension of the C programing language with additional constructs for describing the SRN models. SRN specifications are automatically converted into a Markov reward model which is then solved to compute a variety of transient, steady-state, cumulative, and sensitivity measures.

4.10 SENSE - Sensor network Simulator and Emulator (SENSE) address the problem left by NS2 like object-oriented design that introduces much unnecessary interdependency between modules by binding functionalities with types. SENSE is designed to be an efficient and powerful sensor network simulator and ease of use. The three major factors of sense are Extensibility, scalability, usability G-SENSE is the first graphical user interface developed for SENSE Simulator. SENSE Simulator has been used to implement protocols like SSR (Self –Selective Routing), SHR (Self-Healing Routing), Self –Selective Reliable path (SSRP). [23] SENSE, has been developed for simulating wireless sensor networks. The primary design goal is to address three factors explained above like extensibility, reusability, and scalability, and to take into account the needs of different users. The recent progress in component-based simulation, namely the component-port model and the simulation component classification, provided a sound theoretical foundation for the simulator. Practical issues, such as efficient memory usage, sensor network specific models, were also considered. Consequent, SENSE becomes an ease-of-use and efficient simulator for sensor network research. [23]

4.11 Query Cycle - Query Cycle is a common file sharing simulators. It has realistic models for content distribution, query activity, and download behavior. [42]Content distribution is mainly based upon a model where each file belongs to one category and category is defined by the popularity of the file [24]. Simulations proceed in query cycle representing the time period between issuing a query and receiving a response [24]. The queries are passed out in First-In-First-Out basics and it is used for Simulating P2P Networks.

4.12 Maisie - Maisie is C- Based simulation language used for parallel and sequential execution of discrete-event simulation modules. It is used as a parallel programming language [25]. The Maisie Language begins describing the Maisie language constructs interactively building a small example program and advanced Maisie facilities a simulation model may be used to predict the behavior of a physical system under a variety of operating conditions. In the process-interaction approach to simulation, a physical system is assumed to consist of a set of physical processes that interact with each other at discrete points in time; these interactions are referred to as events. [25]In its simulation model, a logical process (LP) is used to model one or more physical processes (PP) [25] the events in the physical system are modeled by message exchanges among the corresponding logical processes in the model.

4.13 Neurogrid - Neurogrid [26] is a routing technique for peer-to-peer networks. Each node in a Neurogrid searches the network by forwarding queries to a subset of nodes that may be able to match the query. Neurogrid operates under the assumption that objects in the network (e.g. documents) are referenced by a number of 'keywords'. Each node maintains a knowledge base of keyword-node associations that are based on the nodes belief about the contents of remote nodes. So, for example, given that a node receives an incoming search consisting of keywords A, B, and C, the node will consult its knowledge base and retrieve any remote nodes that are associated with these keywords. When the nodes match to a degree it is ranked likewise. Neurogrid search results will help each node to update the knowledge database and thus facilitate better forwarding of the document throughout the network. Neurogrid nodes also utilize the results of searches in order to update their knowledge bases and add new connections to the nodes that provide results to search queries. When the search is successful then the nodes update their knowledge base and associates the remote node with the key works, this is the adaptive nature of Neurogrid. One major flaw of this is that all of the nodes in the system gradually become a little smarter, being able to route queries to more and more nodes.

4.14 Netsim - Netsim [27] is a stochastic discrete event simulator which allows for simulation of various networks including Wireless sensor networks, wirelesses LAN, WiMAX, TCP, IP networks. This simulator was first developed by Tectcos in association with Indian Institute of Science. Netsim is capable to simulate various levels of the network, the entire network, a sub-network, each node definition and also packet trace. The Netsim has a library of inbuilt protocols, which can be used directly or it can also be modified as it is in simple C code. The GUI of the Netsim is an inbuilt development environment which serves as an interface between the protocol library and the user code.

4.15 J-Sim - J-Sim [28] is a component-based network simulator which is developed in Java. *J-Sim* is built upon a software-based component architecture know as *autonomous component architecture (ACA).J-Sim* allows each individual component to be independently designed, implemented and tested. Components communicate with each other by sending and receiving data at ports. Since *J-Sim* is built upon ACA and is implemented in Java it becomes platform independent. It also has an extensible and reusable environment. *J-Sim* can be easily integrated with different

script languages such as Perl, TCL, and Python. *J-Sim* has the classes written in JAVA and this can be accessed using the TCL script just as done in NS2. Another salient feature of *J-Sim* is that public classes, methods and fields can directly be called from the TCL environment.

4.16 TrSim - Trust and Reputation Model simulators for Wireless sensor networks (TrSim) is java based simulator used to calculate the trust and reputation in Wireless sensor networks [29].

V MOBILITY SCENARIO GENERATION AND TRACE ANALYSIS

BonnMotion is a Java software which creates and analyzes mobility scenarios and is most commonly used as a tool for the investigation of mobile ad hoc network characteristics. The scenarios can also be exported for several network simulators, such as ns-2, ns-3, Glo-MoSim/QualNet, COOJA, MiXiM, and ONE. BonnMotion is being jointly developed by the Communication Systems group at the University of Bonn, Germany, the Toilers group at the Colorado School of Mines, Golden, CO, USA, and the Distributed Systems group at the University of Osnabruck, Germany.[30] There are two possibilities to feed input parameters into the BonnMotion scenario generation. The first one is to enter the parameters on the command line, and the second one is to have a file containing the parameters. These two methods can also be combined. BonnMotion supports (protocol independent) two classes of metrics: pure movement metrics and link-based metrics. As pure movement metrics, velocity, relative mobility, and dwell time are supported. As link-based metrics, BonnMotion support link duration, time to link break, node degree, partitions, and k-connectivity.

Trace-Based Mobility Models - Mobility models that are based on real datasets are called trace-based mobility models. Movement traces collected from several indoor/outdoor sites are available on CRAWDAD (http://crawdad.cs.dartmouth.edu/). While CRAWDAD is the largest repository for real datasets collected from diverse scenarios, other repositories can be found at UNC/FORTH (http://netserver.ics.forth.gr/datatraces/) and MobiLib (http://nile.cise.ufl.edu/MobiLib/). In [31], we provide a review of trace-based mobility models and the datasets that are available online. We categorize the traces using different criteria. For example, the traces are classified via the scenarios for which they were collected. The analysis of real datasets has helped researchers understand the statistical features present in human walks. We note, however, that different trace analysis techniques may lead to dissimilar movement patterns. Therefore, the results obtained from the analysis of one dataset may not be applicable to another dataset.

CONCLUSIONS

Emerging types of Wireless Networks are Cellular Networks, Mobile Ad hoc Networks, Wireless Sensor Networks, Vehicle Ad-hoc Networks, and Wireless Mesh Networks. The Mobile Ad hoc Networks are the latest trends in Mobile Wireless Networks and they have been attracting many research scholars due to a lot of research scope is presenting and a lot of research challenges are existing in MANETs. This research paper describes the three different areas of research fields routing protocols, simulation tools, and mobility models. These fields are interrelated to each other. Although the synthetic traces generated by mobility models are closer to real movement patterns, several challenges for future research still exist. Hence this survey is very useful to research community to suggest and progress new routing protocols using dissimilar simulators and carrying out research in Mobile Ad hoc Networks. Upcoming possibility in the Mobile Ad hoc Network is to address the routing protocols, mobility models and simulation performance collectively.

REFERENCES

[1] Murthy C.S.R. and Manoj B.S., 2004, “Ad hoc Wireless Networks: Architectures and Protocols”, Prentice Hall.

[2] Carlos de Morais Cordeiro and Dharma Prakash Agrawal, 2013 “Ad hoc and Sensor Networks, Theory and Applications”, 2nd edition, Cambridge university press India press Pvt.Ltd,

[3] Kumar Sunil, Manvi S., and Mahabaleshwar S.Kakkasageri, 2013 “Wireless and Mobile Networks Concepts and Protocols”, Jon Willy and Sons publication.

[4] Bheemalingaiah M., Venkataiah C., K. Vinay Kumar, Naidu M. M., D. Rao Sreenivasa, April 2016 “ Survey of Energy Aware On-demand Multipath Routing Protocols in Mobile ad-hoc networks”, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 6, Issue 4.

[5] Elzabeth M. Royer, Santa Barbara, Chui-Keong Toh, April,1999 “A Review of Current Routing Protocols for Ad hoc Mobile Wireless Networks”, in proceeding of IEEE personal communications.

[6] Xiaoyan Hong, Kaixin Xu, and Mario Gerla, July/August, 2002, “Scalable Routing Protocols for Mobile AdhocNetworks”, Journal of IEEE Network.

[7] Liang B., Haas Z. J., April 1999, "Predictive Distance-Based Mobility Management for PCS Networks," in Proceedings of IEEE Information Communications Conference (INFOCOM 1999).
[8] Camp T., Boleng J., and Davies V., 2002, "A Survey of Mobility Models for Ad Hoc Network Research, in Wireless Communication and Mobile Computing (WCMC): Special issue on Mobile Ad Hoc Networking: Research, Trends and Applications", Vol. 2, No. 5, pp. 483-502.
[9] Hong X., Gerla M., Pei G., and Chiang C., August 1999, "A group mobility model for ad hoc wireless networks". In Proceedings of the ACM International Workshop on Modeling and Simulation of Wireless and Mobile Systems (MSWiM).
[10] Liang B. and Haas Z., March 1999, "Predictive distance-based mobility management for PCS networks." In Proceedings of the Joint Conference of the IEEE Computer and Communications Societies (INFOCOM).
[11] Davies V., 2000, "Evaluating mobility models within an Ad Hoc Network", MS thesis, Colorado School of Mines.
[12] Hayder Majid Abdulhameed Alash, 2016 on "Impact of Mobility Models on Routing Protocols for Various Traffic Classes in Mobile Ad Hoc Networks", Kent State University.
[13] Siraj M Saba, Gupta Ajay Kumar, and Rinku Badgujar, June 2012, "Network Simulation Tools Survey", International Journal of Advanced Research in Computer and Communication Engineering Vol. 1, Issue 4, PP: 201-210.
[14] Issariyakul Teerawat and Hossain Ekram, 2012, "Text book on Introduction to Network Simulator NS2", Second Edition, Springer.
[15] NS-3 Simulator, NS-3 Tutorial Release November 13, 2012, NS-3.15, NS-3 project.
[16] QualNet official site, http://www.scalable-networks.com/products/
[17] OPNET Modeler, http://www.opnet.com/
[18] OMNeT++ official website, http://www.omnetpp.org
[19] pcl.cs.ucla.edu/projects/glomosim/GloMoSimManual.html
[20] Taylor Ian, A PROTEAN Research Group Project Naval Research Laboratory, Code 5522. "AgentJ Java Network Simulations in NS-2 -An Installation and User Manual"
[21] C.Hirel, R. Sahner, X. Zang, K. Trivedi, Department *of electrical and computer engineering* "Reliability and Perform ability Modelling using SHARPE2000".
[22] http://www.ee.duke.edu/~chirel/IRISA/spnp.html
[23] Gilbert Chen, Joel Branch, Michael J. Pflug, Lijuan Zhu, and Boleslaw K. Szymanski Department of Computer Science, *Advances in Pervasive Computing and Networking , Springer ,NewYork* "SENSE"- A Wireless Sensor Network Simulator
[24] Niko Kotilainen, Mikko Vapa , Teemu Keltanen, Annemari Auvinen and Jarkko Vuori, P2PRealm – Peer-to-Peer Network Simulator.
[25] http://may.cs.ucla.edu/projects/maisie/tutorial/simulation/
[26] Sam Joseph Ph.D., NeuroGrid, http://www.neurogrid.net/publications/publications.html
[27] en.wikipedia.org/wiki/NetSim
[28] Ahmed Sobeih, Wei-Peng Chen, Jennifer C. Hou, Lu-Chuan Kung , Ning Li , Hyuk Lim , Hung-Ying Tyan , and Honghai Zhang " JSim: A Simulation Environment forWireless Sensor Networks" Proceedings of the 38th Annual Simulation Symposium (ANSS'05) 2005 IEEE
[29] http://ants.dif.um.es/~felixgm/research/trmsim-wsn/
[30] www. Bonnmotion.net
[31] N. Aschenbruck, A. Munjal, and T. Camp, 2011, "Trace-based mobility modeling for multi-hop wireless networks," Computer Communications, vol. 34, no. 6, pp. 704–714.