IMPROVING THE UNDERSTANDING OF THE DYNAMIC PROPERTIES OF ADVANCED COMMUNICATION NETWORKS BY USING AGENT-BASED MODELING APPROACH

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UNIVERSITI SAINS MALAYSIA

2018

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by

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Thesis submitted in partial fulfillment of the

Requirements for the degree of

Bachelor of Engineering (Electronic Engineering)

JUNE 2018

ACKNOWLEDGEMENT

This dissertation is dedicated to everyone in the field of advanced and complex communication network who embarks on the journey of expanding the collection of knowledge and transcendent passion for the advanced and complex communication network.

First and foremost, I am very grateful to the School of Electrical and Electronic Engineering of Universiti Sains Malaysia engineering campus for providing me the opportunity to undertake and complete this fascinating project. The resource and facilities provided by the school are important in accomplishing the project.

Besides that, I am grateful to Dr. Mohd Nazri b Mahmud my thesis advisor and project supervisor, for seeing the promise of this thesis and achieving research conducted under his watchful eyes. His guide and patience throughout the tumultuous time of conducting methodical analysis related to this project are much appreciated. In addition, his invaluable support and insightful suggestions, not to mention all the hard work and extra time poured in has resulted in the completion of this project.

In addition, I wish to thank my respected project examiner, Dr. Intan Sorfina bt Zainal Abidin for her positive feedback and suggestions in providing a deeper understanding. Besides that, I would like to express my gratitude to the officers and staffs of the School of Electric and Electronic Engineering of Universiti Sains Malaysia who provide their support and cooperation to me in completing the project.

Last but not least, I offer my best regards and blessing to my friends and beloved family who also serve as an inspiration and support me in any aspect of the completion of this project.

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LIST OF ABBREVIATIONS

ABMS	Agent-Based Modeling and Simulation
API	Application Programming Interface
CCL	Center for Connected Learning
GUI	Graphical User Interface
IDE	Integrated Development Environment
MANET	Mobile Ad-Hoc Sensor Network
MASON	Multi-Agent Simulator of Network
MSN	Mobile Social Networks
P2P	Peer-To-Peer
ZRP	Zone Routing Protocol

MEMPERBAIKI PEMAHAMAN TENTANG CIRI-CIRI DINAMIK RANGKAIAN KOMUNIKASI MAJU MENGGUNAKAN PENDEKATAN PEMODELAN BERASASKAN AGEN

ABSTRAK

Rangkaian komunikasi moden semakin maju dan kompleks. Oleh itu, sistem kompleks menjadi bidang baru bagi penyelidik untuk meneroka bagaimana aspek sistem menimbulkan tingkah laku kolektif sistem dan bagaimana sistem berinteraksi dengan persekitarannya. Tingkah laku sistem yang kompleks adalah bagaimana konstituen rangkaian bertindak bersama untuk membentuk tingkah laku keseluruhan, bukan hanya tingkah laku aspek konstituen. Kerumitan sedemikian dapat dilihat dalam banyak jenis rangkaian komunikasi yang canggih seperti rangkaian ad-hoc tanpa wayar, rangkaian sensor mudah alih dan rangkaian radio kognitif. Dalam rangkaian ini, kerumitan yang tidak dapat diramal adalah timbul daripada mobiliti, jalur lebar terhad, latensi, gangguan dari rangkaian jiran dan perubahan tipologi. Di samping itu, stesen mudah alih dalam rangkaian ad-hoc dijangka akan menjadi autonomi dalam membuat keputusan mereka sendiri dan untuk bekerjasama dengan stesen bergerak lain dalam mengatur rangkaian. Kerumitan rangkaian komunikasi yang semakin meningkat ini mempunyai implikasi yang mendalam untuk pemodelan dan simulasi. Oleh kerana rangkaian menjadi lebih kompleks, ujian dan penilaian reka bentuk dan pelaksanaan menjadi lebih sukar. Terdapat banyak model sedia ada yang digunakan untuk menggambarkan rangkaian yang rumit. Projek ini cuba menggunakan model pemodelan dan simulasi baru, iaitu pendekatan pemodelan berasaskan ejen. Oleh itu, projek ini menggunakan model perisian bernama Netlogo untuk membantu memahami dan mengonsepkan projek ini. Keputusan menunjukkan bahawa pemodelan berasaskan agen

adalah model yang lebih baik berbanding dengan model tradisional seperti Swarm dan MASON, terutamanya ketika memodelkan rangkaian komunikasi rumit.

IMPROVING THE UNDERSTANDING OF THE DYNAMIC PROPERTIES OF ADVANCED COMMUNICATION NETWORKS BY USING AGENT-BASED MODELING APPROACH

ABSTRACT

Modern communication networks are getting more advanced and complex. Therefore, complex systems become a new field for researchers to explore how aspects of a system give rise to the collective behaviors of the system and how the system interacts with its environment. The behavior of a complex system is how network constituent act together to form the behavior of the whole, not only the behavior of the constituent aspects. Such a complexity can be seen in the many types of advanced communication networks such as wireless ad-hoc network, mobile sensor network, and cognitive radio networks. In these networks, complexity and unpredictable arise from the mobility, limited bandwidth, latency, interference from neighboring networks, and typological changes. In addition, mobile stations in ad-hoc networks are expected to be autonomous in making their own decision and to cooperate with other mobile stations in organizing the network. This rising complexity of the communication networks has a profound implication for modeling and simulation. As the networks are becoming more complex, testing and evaluation of the design and implementation are becoming more difficult. There are many existing models used to depict complex networks. This project use new modeling and simulation approach, which is the agent-based modeling approach. Thus, this project will go through a software model named as Netlogo to aid in understanding and conceptualizing about this project. The results show that agent-based modeling is a better model compared to traditional models such as Swarm and MASON, especially when modeling complex communication networks.

CHAPTER 1- INTRODUCTION

1.1 Background

A network is a set of organizations that are connected by a set of relationships. The formation, evolution, and utilization of networks become more important because of increasing the interest and usage of networks in people's lifestyle [1].

Advanced and complex communication networks refer to how the people can retrieve the various types of information and communicate with distant people quickly and easily even though many people are moving and communicating at the same time [2]. The communication network becomes more complex because of their interaction. In addition, modern communication networks, such as cognitive radio network are made of autonomous components, which mean that these complex adaptive systems have the additional capability for agents to adapt at the individual or population levels. The emergence of these advanced networks has resulted in the search for a new approach to modeling and simulating them so that their design and implementation can be tested and evaluated more efficiently and effectively. This project had considered one of the great algorithms known as the clustering algorithm.

Clustering is an extraction of closely joined groups from a set of nodes. It benefits from the advanced and complex communication network. It is also considered an important algorithm for efficient communication in the mobile ad-hoc sensor network. Clustering is particularly useful for applications that need scalability to multiple of nodes. The neighborhood of a node consists of the set of nodes to which it is connected. The clustering coefficient of a node is the ratio of the number of links to the

total possible number of links among the nodes in its neighborhood. Compared with traditional clustering algorithms, the proposed algorithm in this project can form more stable and reasonable cluster structure. Eventually, their capability of self-organizing becomes an important role.

Self-organization is one of the most attractive concepts of many natural systems. Self-organization also is a great concept for building scalable systems consisting of some numbers of subsystems. Each subsystem must perform completely autonomous. In common, self-organized communication networks are reliable, flexible, robust, and cost-effective. Self-organization is a set of devices to produce a large-scale and stable state of a system from the interaction of different units without any interaction to the outside environment [2]. For this reason, this communication in the self-organized network needs a technique for more systematic modeling. Therefore, this project proposed a technique which is mobile ad-hoc sensor network technique to combine with the self-organization algorithm.

A mobile ad-hoc sensor network (MANET) is included in several mobile devices connected by short-range of links which are each device is a router for other devices. The mobile ad-hoc sensor networks are no centralized server. MANET provides a very flexible environment for users which mean each device is free to organize itself independently. In addition, the nodes are free to move randomly and organize themselves arbitrarily. Therefore, the network's topology may change rapidly and unpredictably because the network can be created, combined, and divided into separated networks depending on the requirements of the network [3]. MANET algorithm design has many challenges due to the actual state of MANET depends upon the considerable quantity of various parameters like a number of nodes and mobility of

nodes [1]. It is through modeling and simulation of a MANET that one can understand its limitations and explore its flexibility. In addition, one of the problems addressed by this project is the need to model large-scale networks, such as those with hundreds of agent. It is because the larger and more complex the network, the harder it becomes to test and evaluate its design and eventual implementation. Therefore, this project seeks to utilize the new emerging approach called the agent-based modeling and simulation (ABMS).

Agent-based modeling and simulation approach refers to modeling systems comprised of autonomous, interacting agents [4]. Today, network become much larger and far more complex than it is harder to test and evaluate its design and implementation the modeling and simulation. Agent-based modeling and simulation is an easy and yet best method. This project has been shown why the ABMS is a best and even better than many traditional modeling approaches in many systems especially when modeling complex communication networks. In addition, this project shows how ABMS is becoming a problem-solving to solve practical problems such as when the modeler wants to use a large number of agents in their model. ABMS has relations with many other fields including complexity science, systems science, systems dynamic, computer science, several branches of the social sciences, and traditional modeling and simulation [5]. The key issues of modeling agent interaction are who is connected to who and the device leading the nature of the interactions. In this project, the Netlogo software had been used as a tool for modeling and simulation.

Netlogo is the most proficient platform based on Java. Netlogo is major designed for modeling and simulation of natural and social phenomena by using a high-level programming language. In addition, Netlogo is a multi-agent programming

language and included modeling environment. It is mainly well suited for modeling complex systems growing over time. Some advantages of Netlogo over traditional simulators in area MANET are direct addressability of individual nodes in the network, ease of application, and evaluation of self-organization. Next, the possibility of effective and simple modeling of interaction protocols with individual agents. Netlogo is extensively familiar as an efficient platform for agent-based simulation. It lets modelers including both beginner and knowledge ones to move quickly through the design, programming, testing platforms, and on to using models for analysis and developing methodical understanding [6].

1.2 Problem Statement

Agent-based modeling and simulation are still new in the modeling and simulation of communication networks. Hence, there have yet to be many people using this system despite its reported advantages. So that why this a new challenging try to research and learning new things to improve the understanding of the dynamic properties of this advanced and complex communication networks. Agent-based modeling and simulation appear to solve the problem when systems become more complex composed of interacting, autonomous ‘agents’. In addition, simulation of MANET in Netlogo is a new paradigm in MANET simulation [6]. Therefore, this project had been applied to mobile ad-hoc sensor network technique, specifically for USM engineering campus.

The authors of the paper [1] stated that the accuracy of the technique needs more work and suggested add some systematic technique to improve the systems. This is because the relation between users and skill requires being measured in order to differentiate normal users from advanced systems. The new approaches to this problem

were added some algorithms and techniques, such as clustering algorithm, self-organization algorithm, agent-based modeling and simulation technique and mobile ad-hoc sensor network technique.

Lastly, the authors of the paper [7] stated that the benefits of agent-based modeling and simulation created many technical and conceptual challenges because of their complex and advanced communication network. Agent-based modeling and simulation become the one challenge when putting the high numbers of agents in agent-based modeling. Therefore, this project had been tried to model more than a hundred of agents by using agent-based modeling and simulation technique. In addition, the Netlogo software had been used as a great tool for agent-based modeling and simulating.

1.3 Objectives

The main objectives of this research are:

1) To model and simulate the mobile ad-hoc sensor network for USM engineering campus area by using Netlogo.
2) To demonstrate the effectiveness of the agent-based modeling approach in improving the understanding of self-organization and clustering in a mobile ad-hoc sensor network.

1.4 Scope of Research

Agent-based modeling approached model and simulates the advanced and complex communication networks had been developed. The mobile ad-hoc sensor network is selected as the main model in this project. A great concept of self-

organization had been applied for building a scalable system consisting of a huge number of subsystems. This project used Netlogo software to implement the model to achieve the objective that had been decided. The source of the mobile sensor will detect the message to be transmitted to others sensor in their own group. The message obtained from the source sensor will send to the other sensors based on links connection among them. Lastly, the number of sensors that detected the message had been displayed on the monitor through Graphical User Interface (GUI).

1.5 Report Outline

This thesis consists of five main chapters which explain the full details and specification from the beginning to the conclusion of this project.

Chapter 1 describes the introduction of this project. The project background, problem statement, project objectives, and research scopes are described clearly in this chapter. The ideas, concepts, and reasons to conduct this project are stated. The objectives and research scopes ease the reader in understanding the aims and goals of this project.

Chapter 2 describes the literature review. It contains common concepts, previous related works and the description of software considered to be used in this project.

Chapter 3 explains the methodology of this project. The software used to implement the project is described in detail at this session. Some of the algorithms and techniques that used in the model are discussed.

Chapter 4 explains the results and discussion of the project. The model and simulation of the communication networks define to be organized by the system are

shown. The programming of the system is evaluated and discussed. The method to display the result of the system is also described.

Lastly, chapter 5 described the conclusion and future works. It summarizes the overall project work and achievement. The future work to solve the limitation of this project and the improvement that can be done is covered in this session.

CHAPTER 2 - LITERATURE REVIEW

2.1 Chapter Introduction

This chapter begins with the review of approaches and modeling of how the modern communication network becomes more advanced and complex. Different ways of modeling have been proposed for obtaining necessary information for agent-based modeling and simulation. The acquired information is interpreted and analyzed by the model and simulation to improve the communication networks, such as mobile ad-hoc sensor network, self-organization, and clustering algorithms. The Netlogo software is used in this project. Thus, the agent-based modeling and simulation are implemented to improve the advanced and complex communication networks. Therefore, some organization algorithms are discussed and analyzed. This pattern organization algorithm is used to construct the best model and design from the acquired information. This organization algorithm system is affected by the appropriate selection of features parameters and suitable organization algorithms. Hence, the review of difference organization algorithms is done to select the best-suited organization algorithms to be implemented in this project. Difference organization algorithms approached in the previous information related research work will be discussed and analyzed. Lastly, the complete classification model and algorithms have considered being used in this project is described.

2.2 Agent-based Modeling and Simulation (ABMS)

The paper [5] covers eighty-five agent-based of concepts and formulates toolkits that may support the system for designers and developers with common tasks, such as creating agent-based models and representing the real-time simulation outputs in

graphical or tabular formats and illustration recordings. This paper is to help engineers, researchers, learners, programmers, and academicians as a reference to select the most suitable agent-based modeling and simulation toolkit for designing and developing the system models. In this survey, this paper has taken into consideration the most important characteristics of each ABMS tool such as license categories, software availability, source code specification, type of agent implementation, and domain coverage of each ABMS toolkit. One of the ABMS software tools is Netlogo. Netlogo software can be applied in several application domains such as dynamic computational systems, business, marketing, economics, ecology, healthcare, traffic situation, and especially in education and teaching. This paper provided the definition of a model where the model can represent as a phenomenon or predict future phenomena. In addition, this paper also gave the meaning of simulation as referring to the computing algorithms, equations, and mathematical expressions that provided impending about the system and relevance under analysis. Based on this survey, the most suitable ABMS software tool to apply in this project is Netlogo software because the application domain is the most related to this project which is dynamic system and organizational behavior. Moreover, this software also has the advantage in the field of education and teaching. Therefore, this is very suitable for use in this project as a beginner.

The author in the paper [8] concentrated on what the agent-based modeling and simulation tool can offer is, and its limitations in modeling and simulating communication networks. Most of the model simulators like Swarm, MASON, and Netlogo are platform independent because they are Java Based. Then, they can run in fundamental all the platforms and can make the best use of rich Java libraries. Java is not the best candidate for selection unlike languages like C and C++ if the system is time critical and required lower level programming. One example that this paper used to

implement in their thesis is Netlogo. The adaptive behavior among the agents can be easily programmed in Netlogo. In addition, this paper provided the classification of agents in common as in Figure 2.1. One type of agent is ‘reactive’ agents who have no goal at all but still runs an important role in the simulation. Another type of agents is ‘proactive’ agent which means agent have a simple goal in a model which required the basic calculation and programming. Lastly is ‘cognitive’ agent where the agent in complex condition combines with the environment. Environment means the structured that platform used by the agents to perform its goal. Limitation of no support for complex system which has been stated in this paper makes this project to try overcoming this limitation by using the agent-based modeling.

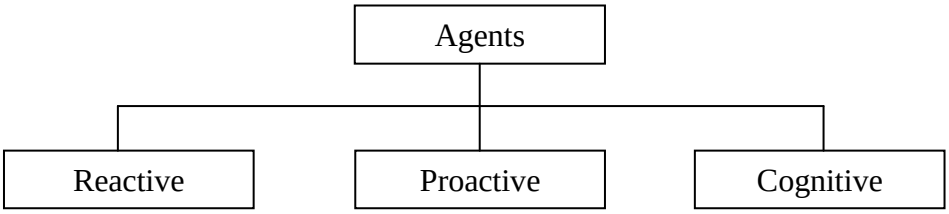

Figure 2.1: General classification of agents [8]

Authors in the paper [7] gave the definition of agent-based modeling and simulation. The simulation of interacting agents in agent-based modeling can be easily understood in a social system. Social systems of the agent-based modeling and simulation can understood through simulation of the interaction among the agents. One of the potential of ABMS approaches to controlling the complicated modeling and analysis system described in this paper is through a simulation using an autonomous utility-based agent. Based on this paper, the project tries to explore and deepen the understanding of complex systems by using an agent-based modeling since the ABMS is still new approaches.

Authors in the paper [9] stated that agent-based modeling becomes a useful complement to more traditional model illustration using a system of ABMS. The difficult thing to describe in traditional approaches can be easily implement by using agent-based modeling such as:

1) The agents transform to the network dynamically when model networks of agents,
2) Model agent learning and evolution,
3) The different types of agents and agents behavior to capture in a large range between them,
4) Investigate non-linear interactions between agents.

These points provide many ideas on how to implement ABMS to overcome the traditional approaches in implemented for this project.

2.2.1 ABMS in Web Service Selection

Authors in the paper [10] had models of complex and advanced individual agents utilizing complicated internal mechanisms to models of large-scale societies of relatively simple agents that focus more on the interactions between agents. This is because today's interconnected society is performed an increasingly important role in social simulation. In addition, ABMS promises to have an important role in research and education scopes. Their main goal of wide varieties ABMS applications and simulation tools are to assist model building. Their tool selection depends on design, availability of functions for scientific field modeling, visualization of results, and support of modeling process. The different action of agents over traditionally is executed within some environment to allocate for the observation of their effect. This is because the individual agents themselves become fixed to the environment that

surrounds them added with other nearby agents. Lastly, this paper also suggested Netlogo for the future work as an efficient platform for modeling and simulating similar problems. That is why this project tried to use Netlogo software for modeling and simulating the similar problems to this paper which is the mobile ad-hoc sensor network.

2.2.2 Introductory Tutorial for Agent-Based Modeling Simulation

Authors in the paper [4] gave some purposes for practical modeling that agent must have with certain properties and attributes, as follows (Figure 2.2):

1) Autonomy. An agent is autonomous and self-directed. As example, an agent can operated independently in its environment and in its interaction among the agents.
2) Modularity. Agents are self-contained or modular.
3) Sociality. An agent is social that means an agent can interact with other agents.
4) Conditionality. An agent has a state that different over time.

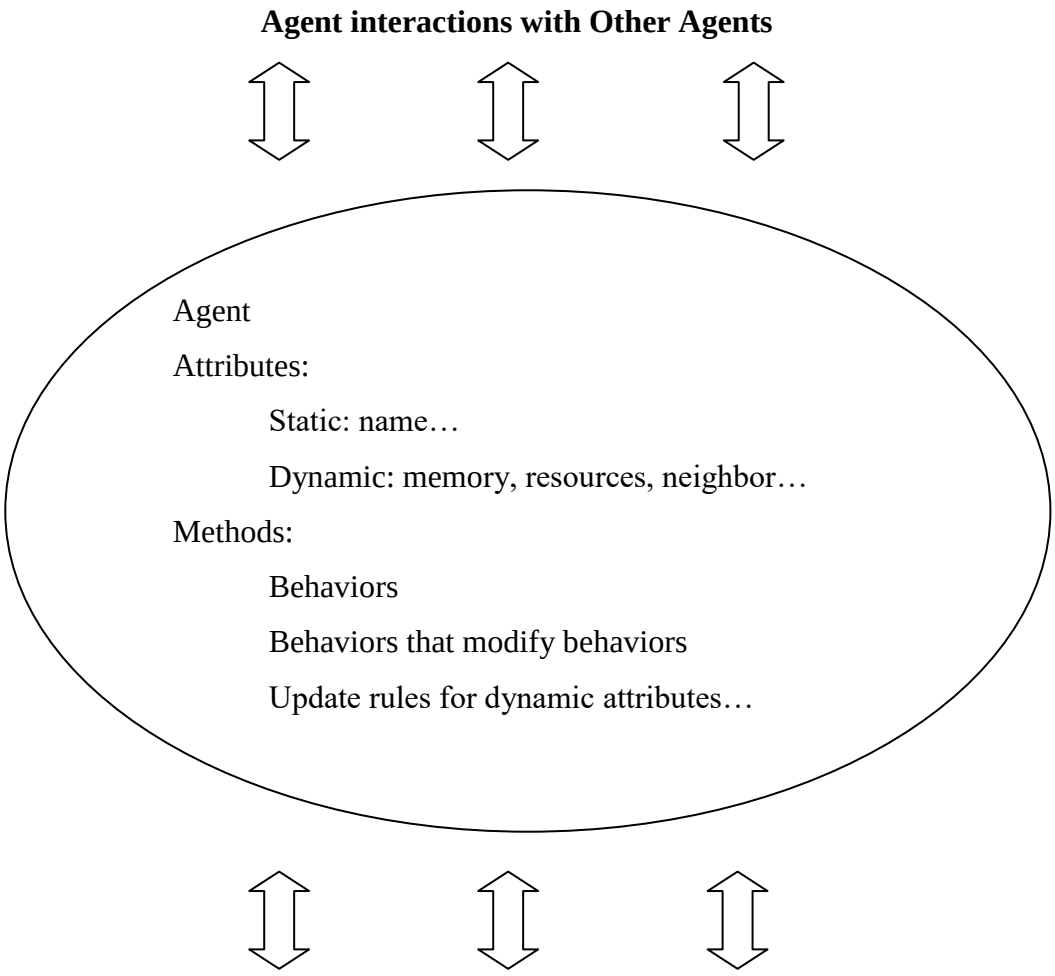

Figure 2.2: A typical agent [4]

This paper [4] also help how to organize this project before developing an agent-based model. This paper has given some questions to the modeler for developing the idea before building a model. Therefore, this paper is very helpful for getting ideas especially the ABMS before starting this project.

The authors in the paper [10] stated some main issues of modeling agent interaction like who is connected to who, and the mechanisms principal the nature of the interactions. In addition, this paper also listed the features of agents as follows. This list is used as a reference to construct the sensors properties of the agents in this project:

1) Problem-solving entities with well-defined limitations and interfaces.
2) Situated in a specific environment as example, agents receive inputs related to the state of their environment through sensors and then act on the environment through effectors.
3) Design to complete a specific requirement that means agents have specific objectives or goals to achieve.
4) Autonomous. That means agents have to organize both of their internal state and their own behavior.
5) Ability to exhibiting flexible problem-solving behavior in the detection of their design objectives.

2.3 Netlogo

The authors in the paper [11] proposed the use of Netlogo for simulating high level portion of mobile ad-hoc sensor network (MANET). In this paper used Netlogo for simulating and evaluating security criteria of various public key infrastructure approaches in MANET. One of advantages of used Netlogo over traditional simulators is direct addressability of individual nodes in network and ease of completion and evaluation of self-organization. In addition, this paper have designed and applied practical model of mobile ad-hoc sensor network in Netlogo and then demonstrated applicability of Netlogo in mobile ad-hoc sensor network modeling and simulation. This paper already mentions that this paper needs more comparison of different model in order to demonstrate Netlogo applicability for modeling and simulating high level aspects of mobile ad hoc sensor networks. That is why this time the project was built in the different model by adding some algorithms which is clustering algorithm and self-

organization algorithm in order to demonstrate Netlogo applicability for modeling and simulating high level aspects of mobile ad-hoc sensor networks.

2.3.1 Improving Execution Speed of Models Implemented in Netlogo

The authors in the paper [6] suggests the five-step process for quantifying execution speed, identifying slow parts of the code, and writing faster code. Netlogo has become not suitable for large and complex models because of slow execution when running the codes. But, this paper not supports that statement due to simple and easily tested changes can almost always produce major increases in execution speed. Speed improvements can often produce dramatic by avoiding or improving agents filtering statements. The number of model runs and the effort to set up for parameterization and sensitivity analysis can reduce by using NetLogo. Slow models can be executed thousands of times by using Netlogo's BehaviorSpace tool. This tool makes easy to conduct multiple-model-run experiments in parallel on either desktop or high-performance cluster computers. That is why this project used the latest version of Netlogo which is 6.02 versions because the code arrangement is very effective for speed improvement.

2.4 Modeling Complex Wireless Sensor Network

A social network is a collection of organizations for other social creature attached to a set of social relationships. It can be shown as a model with users symbolized as a node, which is connected by edges that symbolize relationships. In addition, the social networks had some general problems with many issues systems like scalability, transparency, and fault tolerance. This is one of the specific problems based on its sociality nature when creates the user and relationships model in social networks. The mobile social network has some extra problems compared to a traditional social

network such as the networks must consider the geographic location of users, and neighborhood relations at the same time, not just the user's relationship [1]. This project used self-organization algorithm to decrease the problems with neighborhood relationship that had been mentions in this paper.

The traditional system allows researcher more focus on having the entire system to complete its goals than how to make the individual nodes survive. Communication network's simulation must have at least two important things which are network deployment strategies and network routing strategies. The idea from [12] presented some different types of complex network models; there are small-world, scale-free and lattice sensor networks.

2.4.1 Random Sensor Networks

The random sensor network can be model by connecting nodes with each other in a random approach. Figure 2.3 shows the complete model of how the random network looks like. It can be observed that there are about 15 nodes with a degree of 1, 21 nodes with a degree of 2, 13 nodes with a degree of 3, and only one node with a degree of 4. This proves randomness in link formation of 50 nodes in the networks.

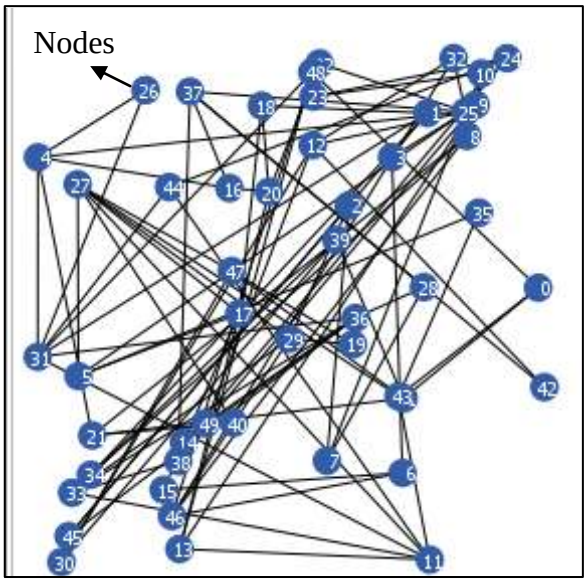

Figure 2.3: Random Network Model [12]

Sensors typically performed by some functions such as detection of a target inside the inspection area, an approximation of target position, monitoring of the target kinematic performance, and classification of the target. Sensors are randomly spread out over a two dimensional (2D) and squared inspection area. It is acceptable to assume that they will be consistently distributed over it. The sensor network consists of two types of sensors which is the simple sensors and complex sensors. Simple sensors have only the ability to sense their coverage area, computer binary information, and transmit data to complex sensors. Another type is the complex sensors that mean have computation capabilities and these sensors are able to locate the target by applying the maximum likelihood estimation algorithm (A. Farina, G. Golino et al, 2005).

2.4.2 Small-World Networks

The Small-World possessions can be seen in many actual world graphs such as social networks biological networks, road maps, food chains, and electric power grids. The small-world network is a small distance in term of links between any two nodes,

where the most of nodes are not neighbors of each other. Mathematically, it is fulfilled by the following formula (2.1):

$$\mathrm{l} \propto \log\ (N) \tag{2.1}$$

Where:

N is the number of nodes.

Figure 2.4 shows there are 50 nodes, which is 49 nodes have a degree of 4 and 1 node with a degree of 5. That is means a small-world network posses some properties like clustering coefficient and mean shortest path length.

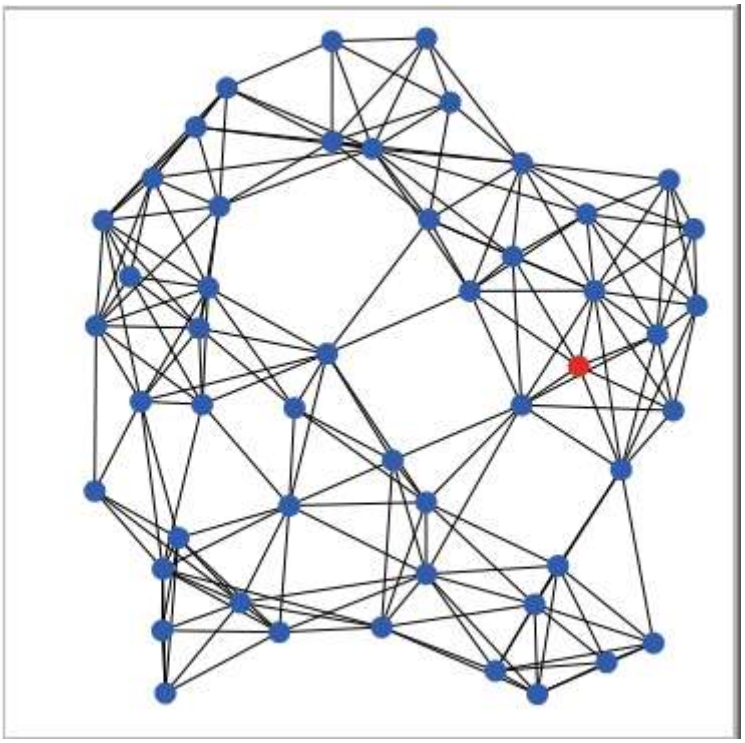

Figure 2.4: Small-World Network Model [12]

Clustering coefficient is computed as the degree of a node in network tends to cluster together. It is computed as the following formula (2.2):

$$C = \frac{Number\ of\ Links}{Maximum\ Number\ of\ Links} \quad (2.2)$$

Where:

C is clustering coefficient for each node.

Clustering coefficient of the complete network is measured by the formula (2.3):

$$C = \frac{1}{N} (\sum \mathrm{C}) \quad (2.3)$$

Where:

N is the number of nodes.

C is clustering coefficient for each node.

Mean-shortest path length is another characteristic of the small-world network is that should have at least one short path among the majority of nodes in the networks [12].

2.4.3 Scale-Free Networks

Figure 2.5 shows that there are roughly 33 nodes with a degree 1, 9 nodes with a degree of 2, and only 1 node with a degree of 20. Other types of complex networks are a scale-free network which the connectivity of node with the other nodes is really rough. Therefore, it can be designed like the majority of the nodes will have a smaller amount of connections, while some of the nodes in the network act as highly connected nodes

named by hubs. The hubs are inclined to hold the network together even in disastrous conditions [12].

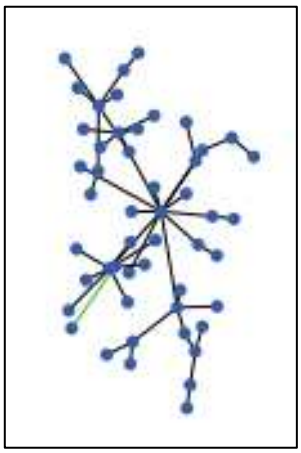

Figure 2.5: Scale-Free Network Model [12]

All the three examples of networks which are the random network, small-world network, and scale-free network only used not more than 50 nodes. This paper is not to test yet for more than hundreds or thousands of nodes to become the complex network. Therefore, this project tried to test more than a hundred nodes for user know whether this software is capable to simulate the complex network.

2.5 Mobile Ad-Hoc Network (MANET)

The authors in the paper [1] proposed a recommender system that is based on zone routing protocol (ZRP) to target a relatively new problem in the MANET. There are three types of the mobile social networks (MSN) by the mobility of users which are web-based, ad-hoc, and hybrid networks. This paper focuses on ad-hoc networks which are networks with no centralized server. This type of network is also named as Mobile Ad-Hoc Networks (MANET). The meaning of social network by this paper is a set of organizations connected by a set of social relationships. This paper proposes to use

another systematic method to enhance the accuracy of the team formation technique. That is why in this project had been added the clustering algorithm in MANET.

The authors in the paper [3] have proposed a self-organized key management technology combined with trusted certificate exchange technique for the mobile ad-hoc network. The proposed design consists of one coordinator node, servers, and common mobile nodes. The coordinator performs as a mediator for transmitting the message among the servers and mobile nodes. The self-organized MANET is illustrated as a main communication technology enabler for application such as network-centric warfare, emergency situations, disaster relief operations, and intelligent transportation systems. This paper has a minimal computation and communication overhead of nodes in the network. That is why this project takes the challenge to use a self-organization algorithm combined with clustering algorithm for the mobile ad-hoc sensor network to get the suitable number of nodes for a certain area.

2.6 Self-Organization

Self-organization is a famous method for building scalable systems containing a great number of subsystems. The author in the paper [13] proposed the networking community for better performance of self-organization mechanisms focusing mainly on the applicability in mobile ad-hoc sensor networks. This project applied the self-organized method in MANET to further support this statement by using a great tool of Netlogo software. This paper contributed a broad introduction and classification to the concepts and ideas of self-organization to provide the networking community. Table 2.1 summarizes the central properties of self-organizing systems. Self-organization is focused on a large number of algorithms and methods that organize the overall performance of a system based on inter-system communication.

Table 2.1: Properties of self-organizing systems [13]

Property	Description
No central control	There is no global control system or global information available. Each subsystem must perform completely autonomously.
Emerging structures	The global behavior or functioning of the system emerges in form of observable pattern or structures.
Resulting complexity	Even if the individual subsystems can be simple and perform basic rules, the resulting overall system becomes complex and often unpredictable.
High scalability	There is no performance degradation if more subsystems are added to the system. The system should perform as requested regardless of the number of subsystems.

Self-organization can be cleared as the spontaneous creation of a globally logical pattern out of local interactions among initially independent components. Examples of self-organizing systems are flocks of birds, shoals of fish, and swarms of bees which are they move together in a gracefully matched behavior without a leader which coordinates them and decides movement. Some characteristics of self-organizing systems are global order from local interactions, distributed control, robustness and resilience, organization, and emergent properties [14].

2.7 Clustering

The authors in the paper [15] proposed a balanced clustering algorithm with distributed self-organization for wireless sensor networks of non-uniform distribution which can deal with stochastic distribution of sensor nodes. Some advantages of clustering algorism that compared with traditional algorism are algorism now can form more stable and reasonable cluster structure and also improve the network lifecycle considerably. The simulation result in this paper proved that the algorithms are feasible and have better performance. Next, the sensor network may changes rapidly because of some reason such as sensor node failure as battery runs out, location change of sensor nodes, and destruction of environmental issues. Another issue that stated in this paper when using a large number of nodes and then these nodes can only gets part of the

network topology information. This project tried to add self-organization combined with clustering to get more stable and reasonable model of structure.

The authors in the paper [16] demonstrated the use of Netlogo for clustering in peer-to-peer (P2P) systems. Nodes begin messaging between nodes to generate the self-organization behavior. Figure 2.6(a) and 2.6(b) show the initial unclustered nodes and clustered nodes after applying self-organization.

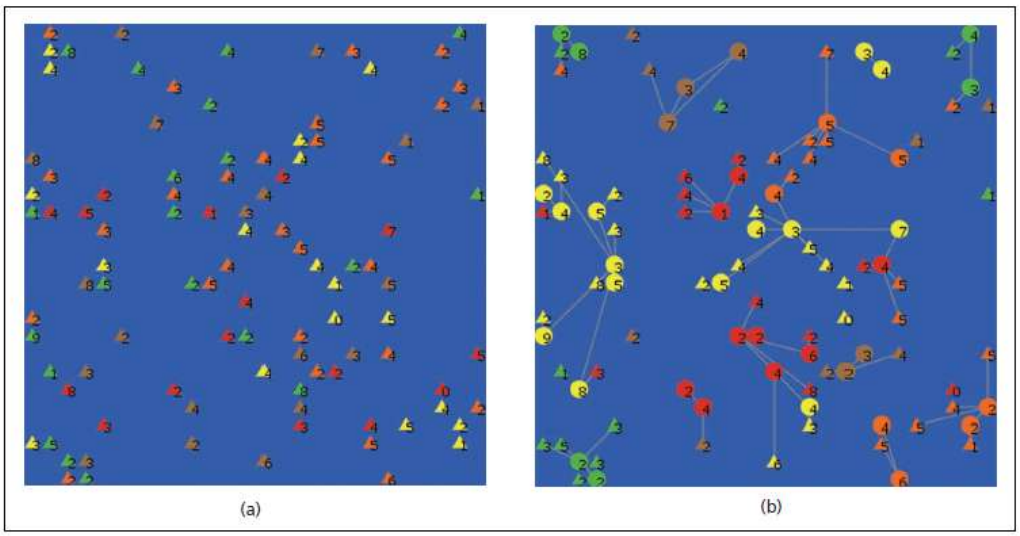

Figure 2.6: a) Initial unclustered nodes b) Clustered nodes after applying self-organization [16]

Clustering sensor nodes is an actual topology control approach. Clustering is mainly used for applications that need scalability to hundreds or thousands of nodes. Scalability means involved the need for load balancing, efficient resource utilization, and data aggregation. Clustering can also be used by routing protocol. Clustering can be valuable in one-to-many, many-to-one, one-to-any, and one-to-all that means broadcast communication. The problem such as unbounded delay and routing loops can occur if dynamic routing in which data is forwarded to nodes with the highest residual energy is used. This project tried to use the hundreds of nodes in clustering algorithms to justify this statement where the clustering can used for application to hundred of nodes by using a new approach model that is agent-based modeling and simulation.

Supposed node i have k_i neighbor nodes. Among these k_i nodes, it is easily calculated that the number of edges is at most k_i (k_i - 1) / 2. The clustering coefficient of node i, denoted by C_i, is defined as the ratio of actual and possible numbers of edges among these k_i nodes:

$$C_i = \frac{2e_i}{k_i\,(k_i - 1)} \tag{2.4}$$

Where:

e_i is the actual number of edges.

C_i is the clustering coefficient of the whole network [17]

2.8 Chapter Summary

By reviewing the existing types of networks, the mobile ad-hoc sensor network is decided in this project. Then, organization communication network is done with the suitable pattern of the algorithms and techniques. Hence, the mobile sensor ad-hoc network can be used to perform some algorithms like self-organization algorithm and clustering algorithm. The mobile ad-hoc sensor network is typically developed by using software named NetLogo as the main part of this project. Lastly, this NetLogo is used to model and simulate the advance and complex communication network which is agent-based modeling and simulation.