Reliability Modeling of Working-Table Production Oriented MANET

Zhao Zhifeng
Computer Department
Zhenjiang Watercraft College
Zhenjiang, China
zhaozhif@126.com

Zhong cheng
Computer Department
Zhenjiang Watercraft College
Zhenjiang, China
hngoe@163.com

Zhao Xibin
Software Department
Tsinghua University
Beijing, China
zxb@tsinghua.edu.cn

Tian Lixin
Nonlinear Science Research Center
Jiangsu University
Zhenjiang, China
tianlx@ujs.edu.cn

***Abstract*—With the serious environment of most of shops in manufacturing, MANET(Mobile ad hoc network) is introduced into our scheme that the communication network is basic of Manufacturing Execution System (MES). MANET is a kind of dynamic wireless communication network that does not rely on a fixed infrastructure and is lack of any centralized control. Based on a deep analysis of the application and real work environment, this paper proposes a reliability model for a working-table production model oriented MANET. And the analysis of this reliability model is presented.**

Keywords-reliability; MANET; production

I. INTRODUCTION

Since the market competition of manufacturing becomes intense, improving the productive efficiency is of quite importance. In order to improve the productive efficiency, a new enterprise business model, order-driven production and flexible manufacturing, turn into the main business model of business model of manufacturing, especially for large discrete manufacturing. At the same time, how to link the management and production becomes the key problem of the manufacturing. Manufacturing Execution System(MES) is considered to be good solution to the problem. MES is information technology system that manages production in factories. MES is prominent to improve the whole manufacturing and management layer. As a base infrastructure, network is necessary for the application of MES in manufacturing. But, due to the serious environment of most of shops in manufacturing, the deployment of the communication network meets a new requirement.

Traditional communication program in working-shop is to deploy a wired network, this program there is a big problem. The major factor is the space constraints. Most of the wireless application is Access Point (AP). However, this method still has many problems in this environment. There are still many blind spots, in the real deployment. Besides, too many APs also cause excessive spending.

For the complex shop environment of large manufacturing, we consider that the Mobile Ad Hoc Network (MANET)[1] is a more reasonable solution. MANET is composed of a set of mobile wireless devices. The communications rely on the forwarding of every mobile device by multi-hop. And these mobile devices organize the network by themselves. So MANET is particularly suitable for building wireless applications in the environment without infrastructure. Deploying the MANET in shop neither meet the binding of the cable network nor require reform of the shop. Besides, without many added equipments, MANET will be the most economic plan. However, because of the lack of infrastructure, dynamic topology characteristics, MANET is weak in the reliability of the communication. [2][3] So there are many researchers focus on reliability modeling and the protocol improvement in MANET. [2-5] Reliability modeling is the basis of the reliability research. But most of the present reliability models are aimed at the general MANET's environment.

Without application background, these models can't supply much guidance for the real environment. Since the reliability is the most important for the continuity of communication, it is necessary to model the reliability of MANET in the shop environment. Then, the analysis result of reliability model can guide the deployment of MANET and the design of protocol.

II. RELATED WORK

In the field of traditional wired networks, network reliability has been done for a long period of research. There is a lot of mature research results. However, unlike the wired network, MANET has its own characteristics and factors affecting their reliability and the reliability of the evaluation differing from the traditional wired networks. Recently, as the MANET is considered to be more useful in real environment and it is weak in reliability, the reliability analysis of MANET become one of the hotspots in reliability research.

Trajanov makes reliability model based on the statistical basis for MANET network link. [2] However, this method only taking current network state reliability calculation, he does not consider MANET topology evolution.

Jose proposes a method based on hybrid evolutionary optimization to address the problems of all terminal network reliability under minimal overhead. [3] And only considering the mobility of nodes, the assumption is the same for all nodes.

Integrated current findings regarding the reliability of MANET, most of the work can be found concentrated on only some features of MANET. In fact, reliability studies are needed to further consider more MANET characteristics, because the real MANET environment is a complex and multidimensional network. [2][3][4] Especially due to the autonomous mobile node, network topology is dynamic. For the dynamic topology with a great impact on the reliability of the entire network, therefore, in order to study the reliability of the network, we must consider the node movement patterns. Therefore, the reliability of a model really suitable MANET should not only be taken full account of both the multi-dimensional characteristics and reliability of global stability, but also be able to support the network topology evolution with time and consist of the actual application environment.

From the two areas, You Zhiyang makes network reliability analysis based on MANET. [5]First, model and reliability analysis based on assembly-line in the field of mobile manufacturing. On the other hand, he analyzes MANET node connectivity, the lifetime of the link and so on based on the mobility model.

Based on the paper, [5] this paper proposes another model for MANET reliability analysis on working–table production model in order to improve network reliability and shorten the adjustment and deployment time, better access to the actual situation of production.

III. RELIABILITY MODELLING

The mobility model, which is related to the application and environment, is the most important for the reliability model in MANET. So, in this section, we first analyze the application and environment. Then we present the mobility model, and the reliability model will be proposed on the basis of the mobility model.

3.1 Application Analysis

In order to analyze the application and environment clearly, we investigate many shops, which belong to the representative manufacturing enterprises, such as CNR Datong Electric Locomotive Co. Ltd, CSR Qishuyan Locomotive Co.Ltd and Jiangsu Rongsheng Heavy Industries Co. Ltd. Then we highlight three key parts, which is related to the reliability.

First, it is the environmental condition. As said before, the communication environment is quite terrible in most shops. The noise from machines influences the direct communication between users. Besides, the interference of wireless signal is more serious than we thought. The communication range of Wifi, which is 150m in normal area, will reduce to 30-50m. And the value will be less than 15m in some places.

Second, it is the classification of uses. There are two kinds of users which require communication in the shop. They are worker and patrol inspector. And both of them communicate with the dispatching center.

Third, it is the production mode, which is the most important for mobility model. Current mainstream discrete manufacturing system can be summarized into two types: assembly-line production model and working-table production model. And their staff mobility model also has a corresponding difference.

（1） assembley-line production model

In assembly-line production, there is a fixed production line, along which components and semi-products are continuously provided and products are continuously produced. The main feature of assembly-line production is that the steps of production manipulation is fixed, in other words, each step of the process is fixed. The transportation capacity of assembly-line is large, and the distance of transportation is long.

During the process, according to the different duties, employees can be divided into two kinds: normal workers and patrol inspectors. Their movement's styles are different. As demonstrated in Fig 1, normal workers move randomly along their stations, while patrol inspectors move randomly along the assembly-line.

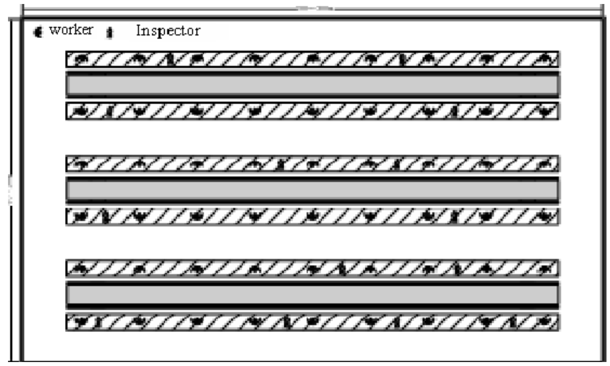


figure1 View of assembly-line production model

Hence, it is reasonable to assume that the movements of nodes are restricted in a line.

（2） working - table production model

The main features of working - table production model is not assembly-line. However, the workers's work platform are working - tables, which is shown in figure 2.

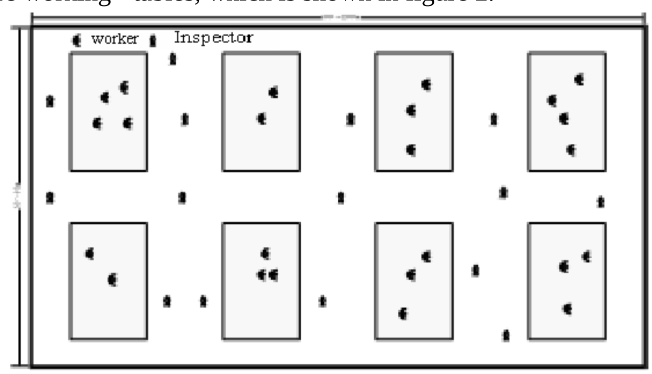


figure 2 View of working- table production model

Normal workers perform production around their own working–tables. They walk random within their working–tables, which are described by each square.

Patrol inspectors also move randomly along the working–table line which is consisted of working–tables. In fact, patrol inspectors movement model can be considered as assembly-line.

Reliability based on the assembly-line has described in paper. [5] The main purpose is to describe the reliability based on the working–table in this paper. So, the rest part of paper concerns the working–table production model.

3.2 Mobility Model

Though working–tables in most of shops are different, the mobility patterns of worker in working-table are similar. Hence, we take a specific working-table to model the mobility of the workers.

There are 2 to 4 workers in each working – table station. Workers within the station make the random motion based on personnel demand, personnel inspection or work demand.

The entire production area is generally square or rectangular. According to the characteristics of production location and working-tables, we can put the entire production area into a grid group consisting of $m \times n$ small rectangular. Each working-table is only in a partition rectangular grid. Partition rectangular grid boundary line pipe is patrol inspectors and material delivery routes. Patrol inspectors in shop move randomly alone rectangle border, and obey urban mobility model law.

In order to predict the reliability of the network, each rectangular grid is divided into smaller rectangular grid so that each employee's position within the grid is only one. So each worker's location is measured clearly. All of workers choose their direction of motion independently and obey random walk model probability matrix moves.

In order to simplify the modeling, we make following assumpetions:

1) According to the position of the working-tables, they can be put the entire production area into an $m \times n$ small rectangular grids. Where m is number of production lines, n is number of production platforms, etc working-table. Thus, all of small rectangular grid consists of rectangular grid group, which is denoted by

$$U = \{u_0, u_1, u_2, ..u_{k-1}\}, \quad k = m \times n$$

u_i is the i th small rectangular grid. Following the same law on the division of working-tables, each u_i is divided into more small rectangular grid, $\{u_{i0}, u_{i1}, ..., u_{i\,k-1}\}$, setting $u_i = \{u_{i0}, u_{i1}, ..., u_{i\,k-1}\}$ .Each worker is located in a grid, which is denoted by u_{ij}.

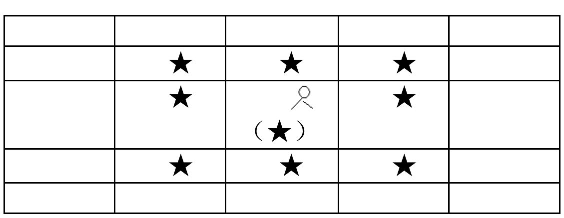
2) Let $W = \{w_0, w_1, .., w_{p-1}\}$ is the set of all workers, $G = \{g_0, g_2, ..., g_{q-1}\}$ was all the patrol inspectors.

3) Each normal worker's range area of movement of is $l_{ij} \times r_{ij}$ m^2, which is the area of grid u_{ij}.

Establish mobility model(EMM) by the following steps:

Step1： u_i and u_{ij} are determined by the mobile model assumpetions 1)

Step2： in $l_{ij} \times r_{ij}$, each worker w_s moves by Random Work Model. However, in practical work, the worker's location of the next movement obeys a certain distribution, and each worker faces nine choice of direction. See below chart.



To address the issue of convenience, the position of the node(worker) $(x_{ij}(t), y_{ij}(t))$ is divided into x and y coordinates. So each worker movement location, at each coordinates, can only be considered: left, right and freeze, respectively, with 0, 1 and 2 represented. The number 0 represents worker are freeze in its original position, 1 to the left, and 2 to the right. So, each node needs to mark two state matrixes.

$$p_{ij}^{x} = \begin{vmatrix} p_{ij}^{x}(0,0) & p_{ij}^{x}(0,1) & p_{ij}^{x}(0,2) \\ p_{ij}^{x}(1,0) & p_{ij}^{x}(1,1) & p_{ij}^{x}(1,2) \\ p_{ij}^{x}(2,0) & p_{ij}^{x}(2,1) & p_{ij}^{x}(2,2) \end{vmatrix} \quad (1)$$

$$p_{ij}^{y} = \begin{vmatrix} p_{ij}^{y}(0,0) & p_{ij}^{y}(0,1) & p_{ij}^{y}(0,2) \\ p_{ij}^{y}(1,0) & p_{ij}^{y}(1,1) & p_{ij}^{y}(1,2) \\ p_{ij}^{y}(2,0) & p_{ij}^{y}(2,1) & p_{ij}^{y}(2,2) \end{vmatrix} \quad (2)$$

Step3：According to the above assumptions 2), in the actual production, the worker w_i moves within rectangular grid and patrol inspector g_i moves by boundary of the rectangle grid. And basically they obey a random movement and location of inspection and distribution obeys certain regularity. w_s within their work area moves back and forth at each operating point or there may be a short freeze. According to the actual needs of work and the actual situation, we can determine the probability p_{ij}^{x}、 p_{ij}^{y} of w_i.

Step4 By the mobility model assumptions 3) and step2, we can get the transition probability matrix P.

Step5 By the ergodicity, we can get limit distribution π_{ij}^{x} and π_{ij}^{y}.

Step6： Let a worker w_s 's state location $(x_{ij}(t), y_{ij}(t))$, then the next location is

$$\begin{cases} x_{ij}(t+\tau) = x_{ij}(t) + \alpha v \tau \\ y_{ij}(t+\tau) = y_{ij}(t) + \beta v \tau \end{cases} \quad (3)$$

where $(x_{ij}(t), y_{ij}(t))$ is the displacement of a node at previous time, α and about the limit distribution β are the parameters which indicate the direction. v is the average speed, τ represents a time interval.

α 、 β and v are defined as follows:

$$\alpha = \begin{cases} -1 & p_{ij} < \alpha_s \\ 1 & p_{ij} \geq \alpha_s \end{cases} \quad (4)$$

$$\beta = \begin{cases} -1 & p_{ij} < \beta_s \\ 1 & p_{ij} \geq \beta_s \end{cases} \quad (5)$$

Where α_s , β_s represents the transition probability threshold.

$$v = \begin{cases} 0 \\ v_0 \end{cases} \quad (6)$$

Where 0 is the velocity is zero, which means that worker is staying, v_0 is the average speed.

Patrol inspectors walk along rectangular grid border, which is considered as on dimensional random movement model with reflecting barriers. This establishes the mobility model based manufacturing shop.

IV. SERVICE ACCESS RELIABILITY BASED ON THE MANUFACTURING ORITEDED MENET

Since the main communication in the shop between the dispatching center and worker or between the dispatching center and patrol inspector, we give the definition of reliability as the traditional two-terminal reliability. [4] (Because node is a normal name in MANET, we let nodes denote workers and patrol inspectors in the following.)

Definition 1: Reliability in the shop is the probability that there exits at least one path between dispatching center and node.

$$SAR = P_{request}(t_0 \to t') \times P_{response}(t' \to t_0 + t) \quad (7)$$

Where $t_0 < t' < t_0 + \Delta t$ .Assuming the number of servers is 1, that is, considering the case of k = 1. By definition 1, we get the following formula for calculating the reliability of the calculation:

$$SAR = P_{request}(t_0 \to t') \times P_{response}(t' \to t_0 + t) \quad (8)$$

t is defined timeout, $P_{request}(t_0 \to t')$ is the probability of successful transmission service request from t_0 to the t'. $P_{response}(t' \to t_0 + t)$ is the probability of successful transmission service request from t' to the $t + t_0$. SAR may be calculated by the following algorithm(FSAR).

step1 According to EMM algorithm it can be get the position of each node.

step2 Calculate the distance d_{ij} between two adjacent nodes.

step3 By d_{ij} and wireless communication radius(WCR) of node, it can be get $P_{request}(t_0 \to t')$.

step4 Attain $P_{response}(t' \to t_0 + t)$ in the same method.

step5 Calculate SAR .

V. RELIBILITY MODEL ANSLYSIS

After above reliability modeling of working-table production oriented MANET, we get the mobility model and the calculation of the reliability in the shop environment. Then it is still necessary to do the experiment to show the situation of the reliability and analyze the result.

The assignment of variables in mobility model is set in the following table. And these values are assigned in terms of a real shop approximative. The dispatching center is set at the left border and the certain node is in the nearest scope of the right border.

TABLE I. MOBILITY MODEL REFERENCE

m	n	l	k	τ	$\lvert S \rvert$
20	*2*	*10m*	*190m*	*1s*	*100000*

This model analysis is mainly aimed at the network connection reliability as testing the communication distance of nodes increases. Here, we mainly focus on the influence of the WCR. It can be found that the reliability will increase with the WCR from figure 3. When the WCR is more than 30m, the reliability reaches to 100%. And the experiment analysis is presented that this reliability model will guide the deployment and protocol design of MANET.

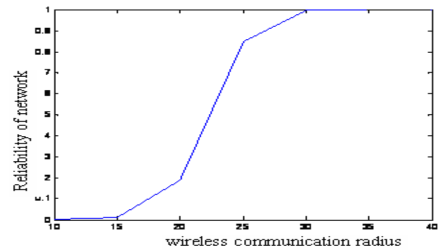


figure 3 Simulation result of the reliability

VI. CONCLUSION AND FUTURE WORK

This paper analyzes the requirement of the communication in the shop. Then, on the basis of the mobility model, a reliability model of working-table production oriented MANET for this environment is proposed. Besides, further experiment analysis is presented. We believe that this reliability model will guide the deployment and protocol design of MANET. Future work will focus on the application of this model. We plan to deploy MANET in the shops of some enterprises. And the deployment will accord the result of this model.

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