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Reliability Modeling of a Cluster Based Distributed Mobile Ad-hoc Network

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Abstract: Modelling of a mobile ad-hoc network is a simplest way to represent real life networks for reliability and performance analysis. In this paper, an effort is made to develop a model of ad-hoc network cluster for evaluation of reliability. This model is based on Continuous-Time Markov Chain (CTMC). A mobile ad-hoc network model is especially useful to understand the practical implications and limitations of real world problems. A Cluster based approach is desirable for a large-scale multi-hop Mobile Ad-hoc Networks (MANET) in many future applications. The network models, mobility models and simulators for MANETs are reviewed by identifying their current limitations and future trends. Markov model is being used to solve dynamic system such as MANET. It is a mathematical system consisting of finite number of possible states that undergoes transition from one state to another state. In this paper, we also discuss how Markov's model is used for estimating the reliability of a distributed ad-hoc network cluster using available tools. This paper also uses simulation scenarios and discusses simulation model design for reliability and performance evaluation of Ad-Hoc network.

Keywords: Mobile Ad-hoc Networks (MANET); Continuous-time Markov Chain (CTMC); Reliability Modeling

1. INTRODUCTION

The main function of Mobile Ad-hoc Networks equipments mostly depends on software. Therefore, for wide applications of such equipments reliable software systems are essential and evaluation of reliability of these systems is an important concern now-a-days. The Markov model is an important tool to represent the architecture of the software and provides a means for evaluation of the reliability of software. A Markov Model is a mathematical model and a widely used technique in reliability evaluation that undergoes transitions from one state to another between a finite number of possible states.

The Markov Model is suitable for performance and reliability evaluation of MANET due to its simplistic modeling approach, Redundancy management techniques in case of any type of failure, consideration of mutually exclusive events and its ability to model complex systems.

The major drawback of Markov model is the explosion of number of states as the size of system increases. The resulting models are large and complicated [1].

MANET is highly dynamic system in nature. Markov model [2] is powerful tool to solve such stochastic system or processes. Its stochastic process is a sequence of outcomes X_t, where t takes value from a parameter space T. Its study involves the analysis of collection of random variables.

If the parameter space T is discrete and countably finite, the sequence is called a discrete time process and if the parameter space is continuous or uncountable, it is called a continuous time process. There are four types of Markov processes classified according to their state space and time space as shown in Table I [2].

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TABLE I. FOUR TYPES OF MARKOV PROCESSES

Type	State Space	Time Space
1 (DTMC)	Discrete (Markov Chain)	Discrete (countably finite)
2 (CTMC)	Discrete	Continuous (uncountable), T= (0,∞)
3	Continuous (multi-parameter modeling)	Discrete
4	Continuous (degraded state)	Continuous

State space: Set of all possible and distinct results in a stochastic process. Its elements are called states. If its state space is discrete, then the process is called a discrete state process, otherwise it is called continuous state space.

- Discrete-Time Markov chain (DTMC): The discrete process is referred to as a chain, therefore discrete state and discrete time Markov process is called Discrete Time Markov Chain (DTMC). The analysis of this type of chain can be unmanageable for long term evaluation.
- Continuous-Time Markov chain (CTMC): The discrete state and continuous time Markov process is called the Continuous Time Markov Chain (CTMC). The tools are available to solve such process.

The solution and analysis of the other two types of Markov process is more complex.

Evaluating the performance and reliability of Ad-hoc networks with mathematic modeling needs many considerations and assumptions. These assumptions are unable to address many of the stochastic factors and dynamic behavior of MANET. The mathematical solution may be intractable. Simulation technology is one of the popular approaches for performance and reliability evaluation of such networks. Ad-hoc network reliability simulation covers many models: the network traffic model, the node mobility model, and the node failure model.

Through simulation, one can compute the throughput and mean delay of the MANET and other related parameters in case of node failure. Reliability analysis has been felt essential at the design level as well as at the operation and maintenance level of wireless mobile network systems. Considerable research efforts are going on in the ad-hoc network reliability evaluation and analysis.

2. LITERATURE SURVEY

There is several related work in literature. Divya Bindal et al. [1] discussed regarding Markov modeling of software, its application and how it is used for estimating the reliability of software. An efficient Binary Decision Diagram (BDD) truncation algorithm to reduce time and space consumption of truncated BDD generation by taking two approximate reliability evaluation methods and the corresponding truncation error estimators and evaluation procedures for different requirements are proposed in by Yuchang Mo, et al. [3]. S. Sivavakeesar et al. [4] presented a framework for dynamically organizing mobile nodes in large-scale mobile MANETs in order to support Quality of Service (QoS) routing. In this scheme, each MN is expected to predict its own mobility pattern and this information is disseminated to its neighbors using a scalable clustering algorithm. This model presents a scalable way to predict mobility and availability of MNs which is achieved with the introduction of geographically-oriented virtual clusters. A. H. Azni et al. [5] described stochastic correlated node behavior models which enable the efficient simulation of realistic scenario of correlated node behavior for dynamic network topology in ad hoc networks. They developed correlated degree based on even sequence in epidemic-like models to capture the spread of correlated behavior. Accordingly, a necessary condition for correlated behavior to spread in ad hoc networks is derived. Nicholas Cooper et al. [6] considered the Random Waypoint, Random Direction, Gauss-Markov, City Section and Manhattan mobility models and simulated for various network density and node mobility levels. Their studies include the lifetime per multi-path set, the multi-path set size and the average hop count per multi-path. Ben Lee et al. [7] discussed the various issues in scalable clustered network architectures for MANETs. A model for reliable packet delivery in Wireless Sensor Networks based on Discrete Parameter Markov Chain with absorbing state is presented in [8]. This model demonstrated the comparison between cooperative and non cooperative automatic repeat request (ARQ) techniques with the suitable example. Tracy Camp, Jeff Boleng, and Vanessa Davies et al. [9] described several mobility models that represent mobile nodes whose movements are independent of each other and several mobility models that represent mobile nodes whose movements are dependent on each other. Tarek H. Ahmed et al. [10] presents a new adaptive and dynamic routing algorithm for MANETs inspired by the Ant Colony Optimization (ACO) algorithms in combination with network delay analysis. Kayhan Erciyes et al. [11] described network models, topology control models and mobility models and simulated these models for MANETs by investigating their current limitations and future trends.

Jason L. Cook et al. [12] described a Reliability analysis method for Mobile Ad-hoc Networks. Tao Wang et al. [13] used probabilistic analysis to guide clustering algorithm towards more reliable clusters. Their work

considers scatter search to perform clustering while considering various performance metrics and experimental results show that clustering approach produces more reliable clusters than prior approaches. Nianjun Zhou et al. [14] used information in theoretic techniques to derive analytic expression for the minimum expected length of control messages exchanged by proactive routing in a two-level hierarchical ad-hoc network. Practical design issues are studied by them providing the optimal numbers of clusters that asymptotically minimize (i) the memory requirement for each cluster head; (ii) the total control message routing overhead. Xiaoyan Hong et al. [15] presented a survey of various mobility models in both cellular networks and multi-hop networks. Wang Ji-Lu et al. [16] applied the Markov process in Ad-hoc network system modeling. The model analyzes the connection availability of stead-state links when there are system exceptions. When the exception is thrown, it can analyze the phenomenon of instantaneous packet losses and delay at a network node by means of queuing theory. With a combination of steady-state availability analysis and instantaneous non-response nodes, authors have drawn a conclusion that evaluation indicators like connecting probabilities, packet losses and delay can be used in survivability evaluation of Ad-hoc network.

Work undertaken in [17] proposes several approaches for failure detection, including the heartbeat and probe comparison strategies. Authors found that the presence of faulty node affects the efficiency and throughput of the network, which makes the network inconsistent. Also the above approaches lack of scalability and are not applicable to the large scale MANETs. Many researchers used clustering concept in their proposed algorithms. The drawbacks of those approaches are poor clustering algorithm and large failure detection time.

S. Sivavakeesar et al. [18] presented a framework for dynamically organizing mobile nodes (MNs) in large-scale mobile ad-hoc networks, with the eventual aim to support Quality of Service. Distributed clustering approach described here is based on intelligent mobility prediction that enables each MN to anticipate the availability of its neighbors. Authors presented a scalable way to predict the mobility, and thus availability, of MNs, achieved with the introduction of geographically-oriented virtual clusters.

3. Model for Reliability Evaluation of Future Large Scale Distributed Ad-hoc Networks

The performance of ad-hoc networks is determined by software or hardware reliability and the reliability of networks for communication. This paper presents a model on the reliability of ad-hoc systems by considering the cluster based system.

Clustered based MANETs can provide high levels of reliability if appropriate levels of fault detection and recovery software are implemented in an application layer. The applications can be made as reliable as the user requires. There is no general recognized classification of ad-hoc networks. However, a classification on the basis of the network types treated in the literature can be presented. Ad-hoc networks are classified according to communication, topology, node configuration, and coverage area. The cluster based ad-hoc network model for reliability estimation is proposed. This system consists of many clusters. Each cluster having master nodes, administer the cluster is responsible for data transfer on to the other cluster. Normal Nodes communicate within the cluster directly together and with nodes in other clusters with the help of the master node. Normal nodes are considered are as slave nodes.

In Fig. 1, a cluster based distributed ad-hoc network is shown, which can be used modern disaster recovery situations, each node can be considered as member in a system and furnished with different equipment for various tasks. The information collected from each node in a cluster is sent back to a master. Then, the master node can analyze all the information and sent out commands to respective nodes. The task of nodes in different clusters may be diversified in a disaster recovery system.

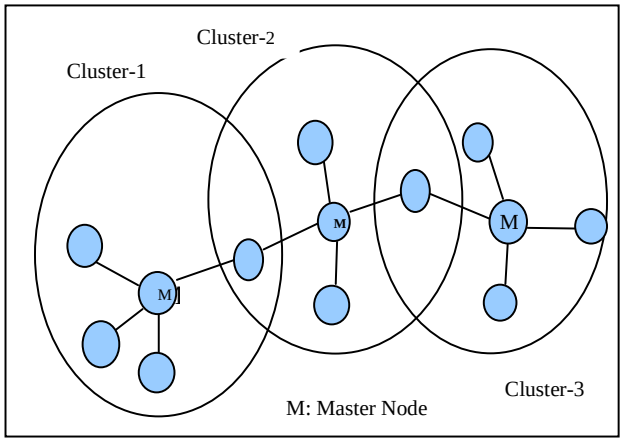

Figure 1. Cluster based Ad-hoc network model.

In large-scale ad-hoc networks, the hierarchical architecture is effective in addressing the scalability problems [19]. However, node mobility still poses a big challenge. In a hierarchical network, clusters are constructed from the nodes in vicinity and communications are supported by the connected clusters. When a node moves, it may be attached to different clusters at different times; resulting in frequent path rediscovery each time it changes the point of attachment. The cluster connectivity affects the path stability and when an inter-cluster link fails, all the communication paths traversing the broken link have to be replaced.

A. Reliability Model

Based on the general distributed computing systems, Cluster based hierarchical distributed ad-hoc network system reliability is the probability that all the distributed programs are executed successfully under the distributed computing environment, which consists of hardware, software, and network links [2].

Consider the distributed ad-hoc network cluster in Fig. 2 consists of four nodes N1, N2, N3, and N4. The N2 is the master node, which is responsible for inter cluster communication.

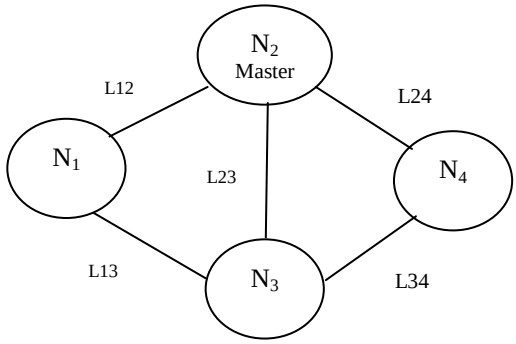

Figure 2. A distributed ad-hoc network cluster.

The cluster reliability depends on the reliability of all nodes and communication links of the cluster.

To estimate the Cluster based hierarchical distributed ad-hoc network systems reliability some assumptions are given below:

- Each node or link in the cluster has two states: operational or faulty.
- If a link is faulty, information cannot be transferred through it.
- If a node is faulty, the program contained in the node cannot be successfully executed and the information is not possible to be transferred through it.
- If master node is faulty, the cluster connectivity to the other cluster is not possible i.e. inter cluster link fails.
- The probability for processing nodes/master nodes Ni to be operational is constant, which is denoted by pi and qi = 1 - pi
- The probability for communication link Lij to be operational is constant, which is denoted by pij and qij = 1 - pij
- Failure of all the nodes and links are statistically independent from each other.

Kumar's analytical tool et al. (1986), which is based on Minimal File Spanning Tree (MFST), can be used to evaluate the reliability of cluster based hierarchical distributed ad-hoc network system. The distributed system reliability can be written as the probability of the intersection of the set of MFSTs of each program, which is:

$$DSR = Pr\left(\bigcap_{m=1}^{M} MFST(P_m)\right)$$

Where MFST (P_m) denotes the set of all the MFSTs associated with the program P_m.

B. Markov Modeling

Cluster based hierarchical distributed ad-hoc network, is a collection of clusters in which any member of cluster is identical, and autonomous. This model is based on the Markov model presented in [2]. Consider following assumptions for this system:

- A system has n+k clusters. Where n clusters are necessary and k clusters are in spare state, serving as backup.
- Consider every cluster is overlapped and having number of normal nodes and a master node.
- For each node, there are three types of failures: software and hardware and link failure. Suppose the failure rate for software is λ_s, for hardware λ_h and for link λ_l. .
- Those failed nodes may or may not be repaired.
- Consider all the links are perfect.
- If all the clusters failed, the system fails. Otherwise whenever one cluster can work, the system is working.

To evaluate the reliability of cluster based ad-hoc network CTMC [2] can be used as described in model given below. In Non-repairable systems the nodes are not repairable if they are failed. Thus, for n + k number of cluster without repair, the Markov model can be depicted by the CTMC in Fig. 3.

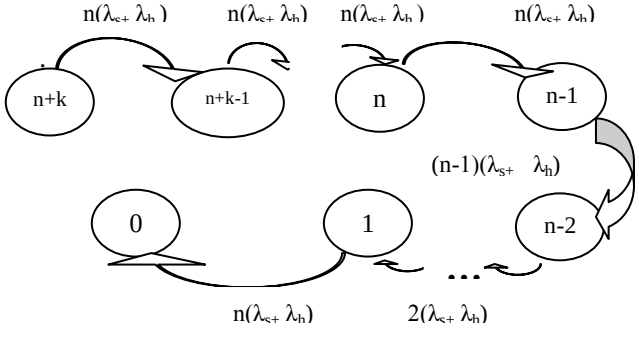

Figure 3. Continuous Time Markov Chain of cluster based ad-hoc network.

The state i in Fig. 3 represents the number of good clusters includes both active and standby. If i≥n, the system must keep n clusters active, so the failure rate should be $n(\lambda_s+ \lambda_h)$. if 0<i<n, it means that no spare cluster is available and the no. of active cluster is i. hence the failure occurrence rate is $(\lambda_s + \lambda_h)$.

Denote Pi (t) (i=0, 1, 2...,n+k) the probably for the system to stay at state i at time instant t, the Chapman-Kolmogorov equation can be written as

$$Pn+k\ (t) = -n(\lambda_s + \lambda_h)\ Pn+k\ (t)$$

$$Pi'(t) = n(\lambda_s + \lambda_h)\ Pi+1\ (t) - n(\lambda_s + \lambda_h)\ Pi\ (t),\ i = n, n+1,...,n+k-1$$

$$Pi'(t) = (i+1)\ (\lambda_s + \lambda_h)\ Pi+1(t) - i(\lambda_s + \lambda_h)\ Pi(t),\ i = 1,2,3,\ldots,n-1$$

$$P0'(t) = (\lambda_s + \lambda_h)\ P1\ (t)$$

We assume that the system begins from the state n+k that all the clusters are good initially, hence, the initial conditions are

$$Pn+k\ (0)=1 \text{ , and } Pn+k-1(0) = Pn+k-2(0) = P0(0) = 0$$

With numerical program, solution of the above differential equations with initial conditions can be obtained. The probability of the system failure state P0(t) determines the unreliability function. Therefore, the reliability function as the probability that at least one cluster works well is R(t) = 1 - P0 (t).

In section 4, we have evaluated performance of MANET using simulation method.

4. PERFORMANCE EVELUATION USING NETSIM SIMULATOR

SYSTEM MODELLING

In the view of realistic scenarios, a node failure model is designed, which is based on constant hazard model described in reliability engineering literature.

A. Node Failure Model

A node failure model is designed and incorporated in Network Simulator (NetSim) that accounts for uncertainty and the failures of nodes. The node failure model is based on constant hazard model which is designed to study the effect of node failure on reliability and performance of MANET. The Reliable node model is also designed to improve the performance of the MANET.

B. Reliable Model Design

To reduce the effect of node failure and improve the performance and reliability of MANET, a Reliable node model is designed, which is based on the following considerations:

- Initially nodes stay paused for a certain time.
- Start to move with average speed for given time within area, after the nodes reach their destination, they stay stall in their position for some time (pause time).
- After that each node again chooses another random destination in the simulation area and move towards their destination.
- It is important to provide redundancy in terms of providing multiple node-disjoint paths between source to destination nodes.
- For providing multiple node-disjoint paths reliable nodes R (nodes) can be placed for efficient operation of DSR.
- The same simulation scenario has been used as in Node failure model.

MANET Simulation Scenarios

Simulation scenarios have been set up using NetSim Standard Version 7. Since, routing is one of the important aspects of ad-hoc networks towards reliability evaluation; modified DSR protocol is considered for routing.

The NetSim is customized for node failure model and Reliable node model with following common properties:

Traffic Properties:

- Transmission Type: Point to Point
- Traffic Type: Custom
- Application Data size: 512 Bytes, Constant distribution
- Inter-arrival time: 200,000 micro seconds, constant distribution
- Number of nodes: 18, 39

Mobility model properties:

- Same for all the nodes
- Mobility Model: Random Way point
- Pause Time: 1 second
- Velocity: 5m/sec.

Wireless Environment Properties:

- Fading_figure = 0
- Frequency = 2412
- Path_loss_exponent = 3
- Standard_deviation = 0
- Simulation Time - 100 Sec

The numbers of nodes are varied from 18 to 39 nodes and the other parameters are kept same for simulating node failure model and reliable node model and to observe the effect of changing the size of the MANET.

TABLE II. SIMULATION RESULTS: THROUGHPUT OF VARIOUS MODELS WITH NUMBER OF FAILED NODES

Number of Failed nodes	Throughput			
	Node Failure Model (18 Nodes)	Reliable Model (18 Nodes)	Node Failure Model (39 Nodes)	Reliable Model (39 Nodes)
0	0.002887	0.002887	0.006487	0.006487
0	0.002887	0.002887	0.002346	0.002346
3	0.000285	0.002887	0.004682	0.00116
11	0.000215	0.000338	0.001326	0.004013
11	0.000213	0.000338	0.000408	0.000408
15	0	0.000185	0.000812	0.001621
16	0	0.000139	0.000946	0.000446
16	0	0.000138	0.000408	0.000408
16	0	0.001142	0.000408	0.000832

C. Result and Analysis

The numerical results and data obtained after simulation of Node Failure Model and Reliable Model with 18 and 39 nodes are shown in the Table II - Table V. On the basis of simulation results various performance parameters have been evaluated. Graphs have been plotted among various parameters to analyze the effects of both the model.

The failed nodes Vs throughput characteristic as shown in Fig. 4 is plotted on the basis of throughput values obtained in Table II by simulating only node failure model.

It can be clearly observed that the throughput is much higher if we have more number of nodes (39) in the network in case of node failure. It means we can deploy more number of nodes to enhance the reliability of services in mission critical applications. Deploying more number of nodes is feasible now-a-days due to availability of hardware devices at lower rates.

The failed nodes Vs throughput characteristic as shown in Fig. 5 is plotted on the basis of throughput values obtained in Table II by simulating only reliable node model.

It can be clearly observed that the throughput is much higher if we have more number of nodes (39) in the network in case of reliable node model. Initially till 5 failed nodes throughput is less even with 39 nodes network, but afterwards with increase in no. of failed nodes throughput is always at higher side in comparison to 18 nodes network. Hence, we can deploy more number of nodes to enhance the reliability of services in mission critical applications. Deploying more number of nodes is feasible now-a-days due to availability of hardware devices at lower rates.

The failed nodes Vs throughput characteristic as shown in Fig. 6 is plotted on the basis of throughput values obtained in Table II by simulating node failure model and reliable node model.

It is seen from the graph for node failure model and reliable node model with 18 nodes the throughput is better for reliable node model, but when we compare the graph for node failure model and reliable node model with 39 nodes the throughput is less even with 39 nodes reliable node model till around 7 no. of failed nodes, afterwards throughput is better with increase in no. of failed nodes.

We can conclude that the more number of nodes or more number of reliable nodes in MANET can ensure the reliability of service but does not guaranty for better performance always.

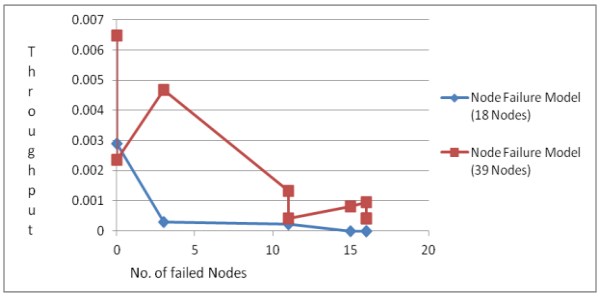

Figure 4. Number of failed nodes Vs Throughput characteristic.

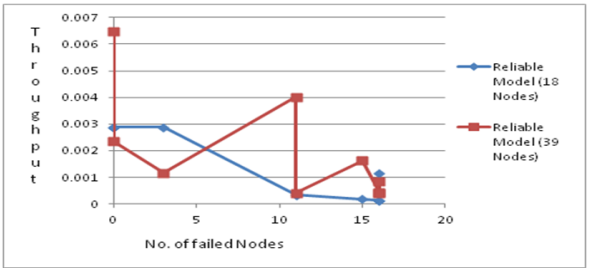

Figure 5. Number of failed nodes Vs Throughput characteristic.

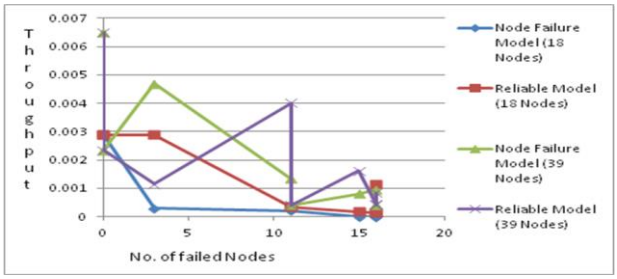

Figure 6. Number of failed nodes Vs Throughput characteristic.

The failed nodes Vs mean delay characteristic as shown in Fig. 7 is plotted on the basis of Table III by simulating node failure model. It can be observed from the graph that the mean delay is higher for MANET with more number of nodes. It means delay is more for large network. Further, it can be seen that delay is generally decreasing with increasing number of failed nodes. This also signifies that delay is less if numbers of active nodes in the network are less. The failed nodes Vs mean delay characteristic as shown in Fig. 8 is plotted on the basis of Table III by simulating reliable node model. It can be observed that the mean delay is almost less if we have more number of nodes (39) or reliable nodes in the MANET. Hence, more number of reliable nodes enhances the performance and reduces the effect of node failure.

TABLE III. SIMULATION RESULTS: MEAN DELAY OF VARIOUS MODELS WITH NUMBER OF FAILED NODES

Failed nodes	Mean Delay			
	Node Failure Model (18 Nodes)	Reliable Model (18 Nodes)	Node Failure Model (39 Nodes)	Reliable Model (39 Nodes)
0	85490394	85490394	47941866.38	47941866
0	85490394	85490394	26443876.22	26443876
3	16826835	85490394	49086046.3	5822195
11	20963077	26759057.38	7245112.182	95778668
11	22775857	26759057.38	921378.49	921378.5
15	0	36444071.5	4966811.742	22290177
16	0	76215292.15	12040835.74	1539808
16	0	66083070.18	921378.49	921378.5
16	0	69278442.06	921378.49	5950103

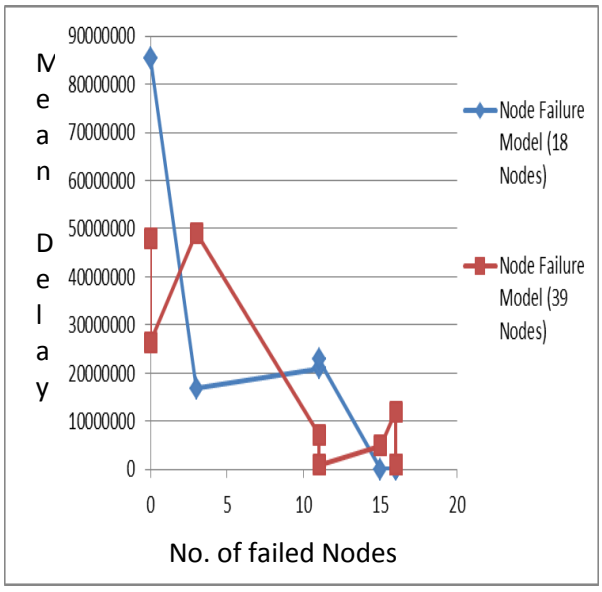

Figure 7. No. of failed nodes Vs Mean delay.

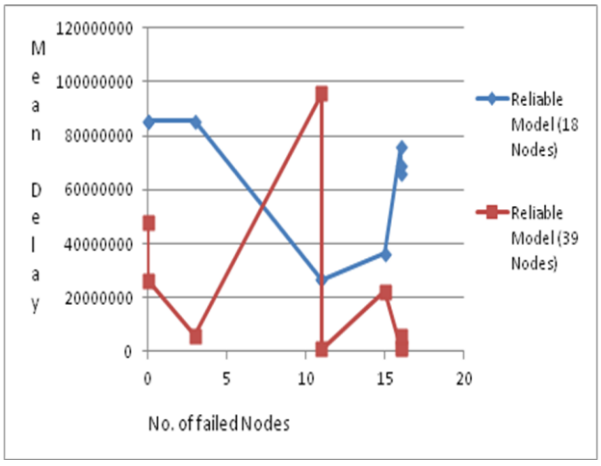

Figure 8. No. of failed nodes Vs Mean delay.

The MTTF Vs throughput characteristic as shown in Fig. 9 is plotted on the basis of Table IV by simulating only node failure model. It can be observed from the graph that throughput is almost higher if we have more number of nodes (39) in the network in case of node failure. Further, throughput is increasing with increase in MTTF.

The MTTF Vs throughput characteristic as shown in Fig. 10 is plotted on the basis of Table IV by simulating reliable node model. It is observed that the throughput is increasing with increase in MTTF for reliable node model with 39 nodes. Throughput is constant with increase in MTTF for reliable node model with less number of nodes (18). It means more reliable nodes and large network improves the performance of MANET.

The MTTF Vs throughput characteristic as shown in Fig. 11 is plotted on the basis of Table IV by simulating node failure model and reliable node model. It is seen from the graph for node failure model and reliable node model with 18 nodes that the throughput is better for reliable node model and is almost constant. When we compare the graph for node failure model and reliable node model with 39 nodes the throughput is increasing with increase in MTTF.

In conclusion, the more number of nodes or more number of reliable nodes in MANET can ensure the reliability of service and throughput is increasing with increase in MTTF.

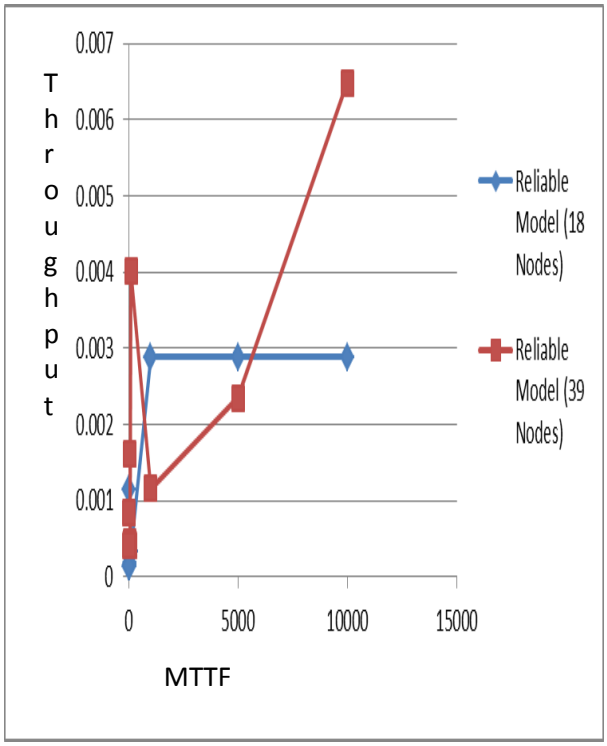

Figure 9. MTTF Vs Throughput characteristic.

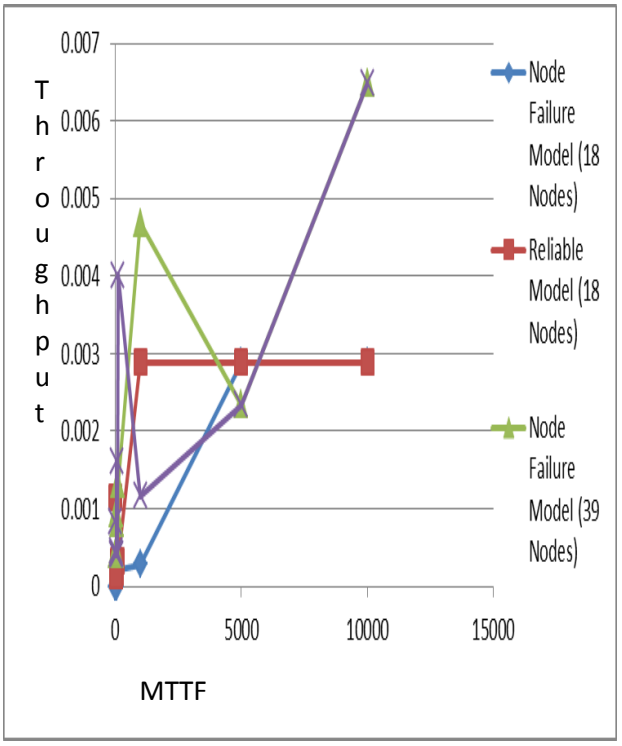

Figure 11. MTTF Vs Throughput characteristic.

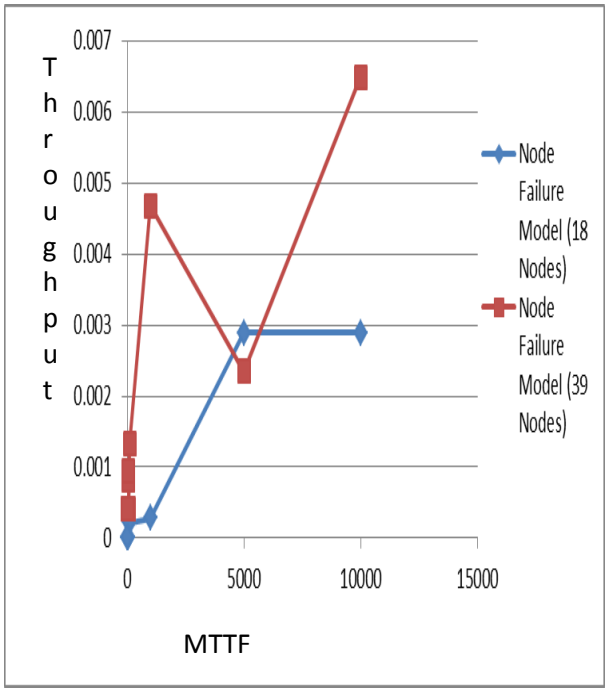

Figure 10. MTTF Vs Throughput characteristic.

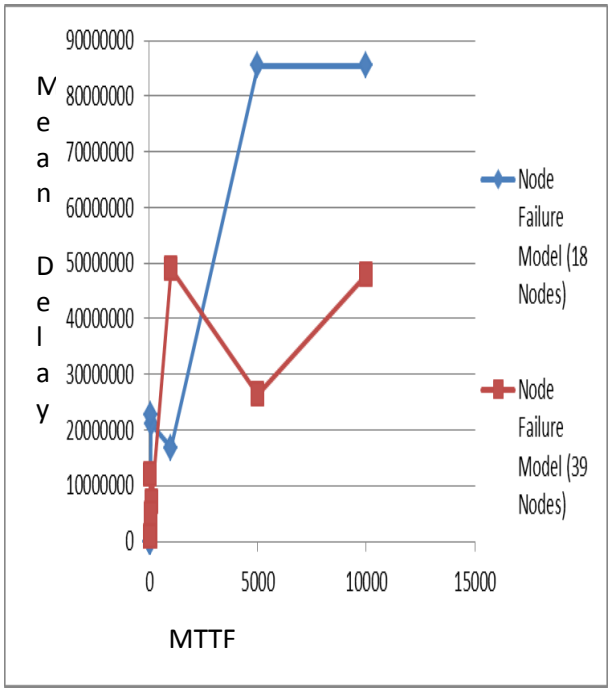

Figure 12. MTTF Vs Mean delay.

TABLE IV. SIMULATION RESULTS: THROUGHPUT OF VARIOUS MODELS WITH MTTF

MTTF	Throughput			
	Node Failure Model (18 Nodes)	Reliable Model (18 Nodes)	Node Failure Model (39 Nodes)	Reliable Model (39 Nodes)
10000	0.002887	0.002887	0.006487	0.006487
5000	0.002887	0.002887	0.002346	0.002346
1000	0.000285	0.002887	0.004682	0.00116
100	0.000215	0.000338	0.001326	0.004013
75	0.000213	0.000338	0.000408	0.000408
50	0	0.000185	0.000812	0.001621
30	0	0.000139	0.000946	0.000446
20	0	0.000138	0.000408	0.000408
10	0	0.001142	0.000408	0.000832

TABLE V. SIMULATION RESULTS: MEAN DELAY OF VARIOUS MODELS WITH MTTF

MTTF	Mean Delay			
	Node Failure Model (18 Nodes)	Reliable Model (18 Nodes)	Node Failure Model (39 Nodes)	Reliable Model (39 Nodes)
10000	85490394	85490394	47941866.38	47941866
5000	85490394	85490394	26443876.22	26443876
1000	16826835	85490394	49086046.3	5822195
100	20963077	26759057.38	7245112.182	95778668
75	22775857	26759057.38	921378.49	921378.5
50	0	36444071.5	4966811.742	22290177
30	0	76215292.15	12040835.74	1539808
20	0	66083070.18	921378.49	921378.5
10	0	69278442.06	921378.49	5950103

The MTTF Vs mean delay characteristic as shown in Fig. 12 is plotted on the basis of Table V by simulating node failure model. It can be clearly observed that the mean delay is much higher and increasing with increase in MTTF for node failure model with 18 numbers of nodes in comparison to MANET with large number of nodes.

The MTTF Vs mean delay characteristic as shown in Fig. 13 is plotted on the basis of Table V by simulating reliable node model. It can be observed that the mean delay is higher and almost constant with increase in MTTF for reliable node model with 18 numbers of nodes in MANET.

The MTTF Vs mean delay characteristic as shown in Fig. 14 is plotted on the basis of throughput values obtained in Table V by simulating node failure model and reliable node model. It is seen from the graph for node failure model and reliable node model with 18 nodes that the mean delay is higher and almost constant for reliable node model, but its increasing linearly with increase in MTTF for node failure model. When we compare the graph for node failure model and reliable node model with 39 nodes, the mean delay is less with 39 nodes reliable node model and its increasing gradually with increase in MTTF.

In short, the more number of nodes or more number of reliable nodes in MANET can reduce the mean delay.

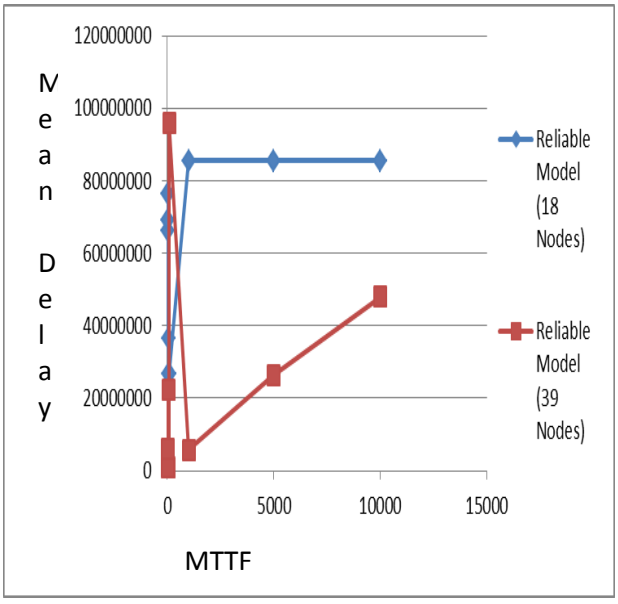

Figure 13. MTTF Vs Mean delay.

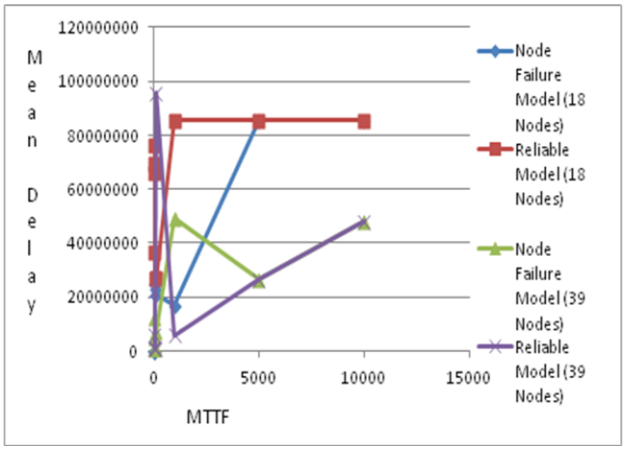

Figure 14. MTTF Vs Mean delay.

5. CONCLUSION

It is planned to develop a model to evaluate the reliability of MANET using simulation along with mathematic modeling based on Markov model. In this paper, a model of ad-hoc network cluster for evaluation of reliability is presented. Markov's model is depicted by CTMC for estimating the reliability of a ad-hoc network cluster with the help of available tools.

Node failure model and reliable node models have been simulated using NetSim. Through simulation results it is found that when number of nodes are varied in the network from 18 to 39, the throughput is much higher in case of node failure model. Therefore, more number of nodes can be deployed to enhance the reliability of services in mission critical applications. Deploying more number of nodes is feasible now-a-days due to availability of hardware devices at lower rates. It is also found that more number of reliable nodes enhances the performance and reduces the effect of node failure.

The mean delay is higher for MANET with more number of nodes in the network. This shows that delay is more for larger network in case of node failure. It is also found that the throughput is increasing with increase in MTTF. In conclusion, the more number of nodes or more number of reliable nodes in MANET can ensure the reliability of service.

REFERENCES

[1] Divya Bindal, A review of Markov Model for estimating software reliability, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 6, June 2013..

[2] Min Xie, Yuan-Shun Dai, and Kim-Leng Poh, a book on " Computing System Reliability Models and Analysis" , ISBN 0-306-48496-X, 2004.

[3] Yuchang Mo, Jianmin Han , Zhizheng Zhang , Zhusheng Pan and Farong Zhong, Approximate reliability evaluation of large-scale distributed systems, Zhejiang Normal University and Southeast University, China.

[4] S. Sivavakeesar & G.Pavlou, A Scalable QoS Routing Scheme using a mobility prediction-based clustering approach for Large-Scale Ad-Hoc networks, Center for Communication Systems Research, University of Surrey Guildford GU2 7XH, United Kingdom.

[5] A.H Azni, Rabiah Ahmad, and Zul Azri Mohamad Noh, Epidemic modeling for correlated node behavior in Ad-Hoc networks, International Journal of Chaotic Computing (IJCC), Volume 1, Issues 1-4, Mar-Dec 2013.

[6] Nicholas Cooper1 and Natarajan Meghanathan2, Impact of mobility models on multipath routing in mobile ad-hoc networks, International Journal Of Computer Networks & Communications (IJCNC), Vol. 2, No.1, January 2010.

[7] Ben Lee, Chansu Yu and Sangman Moh, Issues in scalable clustered network architecture for Mobile Ad Hoc Networks, Oregon State University, Corvallis, Cleveland State University, Cleveland, Chosun University, Gwangju, 501-759, Korea.

[8] Vijay Kumar, R. B. Patel , Manpreet Singh and Rohit Vaid, Markov model for reliable packet delivery in Wireless Sensor Networks, International Journal of Computer Science Issues, Vol. 8, Issue 3, No. 1, May 2011,ISSN (Online): 1694-0814.

[9] Tracy Camp, Jeff Boleng, and Vanessa Davies, A survey of mobility models for Ad-Hoc network research, Wireless Communication & Mobile Computing (WCMC): Special issue on Mobile Ad-Hoc Networking:Research, Trends and Applications, vol. 2, no. 5, pp. 483-502, 2002.

[10] Tarek H. Ahmed, Modeling and simulation of a routing protocol for Ad-Hoc networks combining queuing network analysis and ant colony algorithms, Thesis, 2005.

[11] Kayhan Erciyes, Orhan Dagdeviren, Deniz Cokuslu, Onur Yılmaz, Hasan Gumus, Modeling and simulation of Mobile Ad- hoc Networks, CRC Press, Taylor and Francis, 2011.

[12] Jason L. Cook and Picatinny Arsenal Jose Emmanuel Ramirez-Marquez, Recent research on the reliability analysis methods for Mobile Ad-hoc Networks, Systems Research Forum, Vol. 2, pp. 35-41, 2007.

[13] Tao Wang and William N. N. Hung, Reliable node clustering for Mobile Ad Hoc Networks, Journal of Applied Mathematics Volume 2013 , Article ID 285967, 8 pages, 2013.

[14] Nianjun Zhou and Alhussein A. Abouzeid, Routing in Ad-Hoc Networks: A theoretical framework with practical implications, ISIT'2003.

[15] Xiaoyan Hong, Mario Gerla, Guangyu Pei and Ching-Chuan Chiang, A group mobility model for Ad-Hoc wireless networks, Published in proceeding of the 2nd ACM international workshop on Modeling, analysis and simulation of wireless and mobile systems MSWiM '99, Pages 53-60, ACM, New York, NY, USA, 1999

[16] Wang Ji-Lu, Research on survivability evaluation of Ad-Hoc network connectivity, Proceedings of the 2nd International Conference on Systems Engineering and Modeling (ICSEM-13), 2013.

[17] Shabnam Parveen Avni Jindal, Survey of cluster based adaptive distributed fault diagnosis in MANET, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 4, April 2013.

[18] S. Sivavakeesar, G. Pavlou, and A. Liotta, Stable clustering through mobility prediction for large-scale multi-hop intelligent ad-hoc networks, WCNC 2004 / IEEE communications Society. 2004.

[19] Diane Barlow Close, Arnold D. Robbins, Paul H. Rubin, Richard Stallman, and Piet van Oostrum, The AWK Manual, Edition 1.0., December 1995.

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