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Research Article

Reliability evaluation of Two cells wireless ad-hoc network using Markov process

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***Abstract*— This paper focuses on modeling and assessing the dependability of an ad-hoc networks, which are wireless communication systems with two communicating stations and routers at their intersections. This network's reliability was assessed using the Markov approach, which gives the reliability engineer the freedom to use a range of hypotheses and behaviors in estimates for system failure probability and repair. In order to determine the reliability indices of three routers and demonstrate the availability and reliability of this wireless system, a computer program is created in this study using the programming language MATLAB. This allows for the best possible design for a wireless network. Reliability of the system will be with the system where the reliability will be (0.99999683), and for long time (100000 hours), with a steady state availability (0.82223) after (1000000 hours).**

***Index Terms*—Reliability, Communication system, ad-hoc network, Availability**

I. INTRODUCTION

The reliability of a system in general, is the probability that, when operating under stated environmental conditions, the system will perform its intended function adequately for specified interval of time. This study's wireless network research has mostly focused on evaluating the availability and dependability of ad hoc networks, which lack a fixed base station. In situations where cellular infrastructure is unavailable or unreliable, such as in military and other tactical applications like emergency rescue or exploratory missions, these networks are extremely helpful.[1]

Given that wireless networks are more likely to experience malfunctions and access loss due to factors like interference, poor transmission power, rough terrain, and other factors, research on wireless network reliability analysis is essential. Consequently, a thorough evaluation of wireless networks' dependability requirements is necessary. The likelihood that a system will function as intended for a predetermined amount of time under specified environmental conditions is known as the system's overall reliability. According to the definition of reliability given above, a system or device is considered reliable if it has successfully operated for the duration of its intended use and has not malfunctioned. Not yet taken into consideration are the possibilities of maintenance following malfunctions and repairs, and it is evident that the dependability in.

The following could be used to summarize the issue: [2]

1. It is challenging to assess the complex wireless communication system's availability and dependability. As a result, a teaching program is presented to help learners understand the concept of reliability and give them the tools they need to work with sophisticated wireless networks to determine their reliability.
2. Using one, two, three, or even N routers to transfer data between two points of communication
3. Displaying the optimal architecture that provides high reliability for an end-to-end ad hoc wireless network.
4. Creating a program to assess the availability and dependability of wireless systems and choose an appropriate approach from the reliability assessment techniques to show how the wireless systems are operating.
5. Illustrate how the dependability of the ad hoc network is affected by determining malty paths to transfer data between two nodes. [1]

Techniques for reliability analysis can range from quantitative to qualitative and incorporate a variety of specialized approaches, including: - [2]

1. Analysis of failure mode and effects.
2. Diagram of the reliability block.
3. Analysis of fault and event trees.
4. Model of the Markov process.

A. How Reliability Works
The probability that a system or component will carry out a necessary function for a predetermined amount of time, when used under predetermined operating conditions, is known as reliability. Alternatively, it's a probability that won't fail over time. The definition needs to be clarified in order to assess reliability in an operational sense: [3]
R(t) :- represents the probability of success of a unit in under taking a mission of prescribed duration .
Q(t) :- is the probability of failure , or the probability that the time – to – failure is in the region of (0 to t), so from Equation(1) .

$$F(t) = Q(t) = \int_0^t f(s)ds \quad (1)$$

There are only two possible outcomes in this scenario: reliability and unreliability.

$$Q(t) + R(t) = 1 \quad (2)$$

$$R(t) = 1 - Q(t) \quad (3)$$

$$R(t) = 1- \int f(s)\, ds \quad (4)$$

$$R(t)=\int_t^{\infty} f(s)ds \quad (5)$$

$$F(t)=\frac{dF(t)}{dt} = \frac{dQ(t)}{dt} = \frac{dR(t)}{dt} \quad (6)$$

B.Markov Method Analysis

Analysis Using the Markov Method Time-based reliability and availability analysis for repairable systems is a strong application of Markov analysis (MA), a potent modeling analysis technique.
An illustration of the system's reliability behavior is a state-transition diagram. A Markov model is a stochastic process whose actions are solely determined by the system's current state. [3]
UA Random procedure U: is a family of random variables with the time parameter (t) = x (t), t ≥0 }. The set of possible values is referred to as the states space, and the values that the process assumes are called the states.
Four types of models are possible:

a) Discrete state and discrete time.
b) Discrete state and continuous time.
c) Continuous state and discrete time.
d) Continuous state and continuous time.

The Markov chain method is the first kind, in which time and state are discrete.
Observe most helplessly that the new location at any given time only depends on its immediate prior location—it doesn't depend on other locations. Changes are detected by the system at a specific time [4].

Benefits of Wireless Technology for Reliability:
a) cheaper cost of upkeep and installation.
b) Simplicity in upgrading and replacement.
c) A decrease in connector malfunction.
d) Increased freedom and mobility in the body.
e) The application of micro electro mechanical system (MEMS) technology in real-world settings.

By incorporating built-in communications capabilities, integrated wireless sensors can prevent the failure modes that arise from connecting these tiny devices with large wires.
f) Quicker commissioning: Easy-to-use wireless sensor systems have the ability to quickly assemble and set up into a functional communications network.
2–9 Reliable System Conditions: [5]
For expected performance, dependable wireless system designs should fall within a set of parameters.
Before building any wireless system, it is important to study key specifications to ensure high reliability, such as data transmitted and frequency of transmission: This establishes the system's bound width and data rate.
A lower data rate system would be preferable if the monitored sensors have slow update rates, meaning that the data cannot physically change very quickly.

C.An ad-hoc network

A group of wireless mobile nodes that spontaneously create a temporary network without the aid of pre-existing network infrastructure or centralized management is known as ad-hoc network .All nodes are mobile, as opposed to infrastructure-based wireless networks, and connections can be made arbitrarily and dynamically. This may be done because installing the required infrastructure is not currently feasible, either financially or physically, or because the circumstances do not allow it.
In situations where cellular infrastructure is unavailable or unreliable, such as in military and other tactical applications like emergency rescue or exploration missions, these networks are extremely helpful. [5]

C.1Features that Ad Hoc Networks Have :[6]

Ad- hoc networks possess various attributes:
a) Since nodes are free to relocate at will, the network topology could include both directional and unidirectional links and fluctuate quickly and randomly at unpredictable times.
b) The capacity of wireless links will remain much lower than that of hardwired links. Furthermore, the actual throughput of wireless communications is frequently substantially lower than a radio maximum transmission rate when multiple access, fading, noise, and interference conditions are taken into consideration.
c) Batteries or other finite energy sources may be used by some or all of the nodes. Energy conservation may be the most crucial system design criterion for these nodes in terms of optimization.
d) Limited physical security: Compared to fixed cable nets, mobile wireless networks are typically more vulnerable to physical security threats.[7] [8]

D.Methodology of work

We will investigate the availability and dependability of a three-router wireless network in the area where two nodes network intersect.
The Markov method approach is determined to be the most

appropriate approach for addressing system reliability and availability due to its benefit of streamlining the process of assessing wireless network availability and reliability.
2. One of the main prerequisites for data transport is reliability. The focus of this paper will be on data transport reliability, which is the likelihood that the sink (node) will identify the relevant phenomenon within the application-specified time frame and without experiencing packet loss.
3. For the sake of presentation simplicity, the following presumptions have been made:
a) Every component failure event occurs independently of the others.
b) The repair rate for various failure types is the same (requiring a suitable repair time that accounts for expected failures).
c) The switching delay is minimal in relation to the typical time between router failures, ensuring that no more failure events take place during the switching delay.
Signals entering the network from a station are routed to the destination by being switched from node to node in end-to-end or node-to-node network communication. Generally speaking, a network is not fully connected if there isn't a direct connection between every potential pair of nodes. For every pair of stations, it is always preferable to have multiple paths through the network; this increases the network's reliability.
As illustrated in Figure(1), the network can be viewed with two cells to make its explanation simpler.

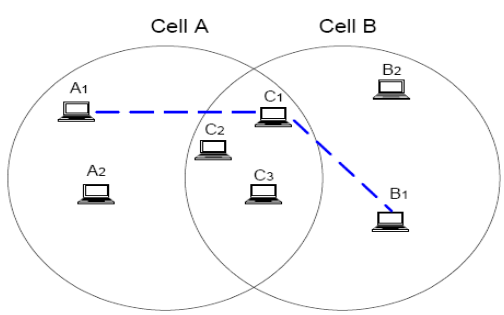

Fig. 1 Tow cells ad-hoc network

E.Reliability Model

Signals entering the network from a station are routed to the destination by being switched from node to node in end-to-end or node-to-node network communication. Generally speaking, a network is not fully connected if there isn't a direct connection between every potential pair of nodes. For every pair of stations, it is always preferable to have multiple paths through the network; this increases the network's reliability.
As illustrated in Figure, the network can be viewed with two cells to make its explanation simpler.

$$A1 \longrightarrow C1 \longrightarrow B1$$

The ad hoc, end-to-end network's availability and reliability can now be studied using a Markov diagram.

$$dR_1/dt = -(2\mu + (N-2)\lambda)\,R_1 + (N-2)\,\lambda\,R_2 + \delta_1 R_6 + \delta_2 R_7$$

$$dR_2/dt = 2\mu\,R_1 - ((N-2)\,\lambda + \lambda p_1 + \lambda p_2 + (N-1)\lambda + \mu)R_2 + (N-1)\lambda R_3 + \delta_1 R_4 + \delta_2 R_5$$

$$dR_3/dt = \mu\,R_2 - ((N-1)\,\lambda + \lambda p_1 + \lambda p_2 + 3\lambda)R_3$$

$$dR_4/dt = \lambda p_1\,R_3 - \delta_1 R_4$$

$$dR_5/dt = \lambda p_2\,R_3 - \delta_2 R_5$$

$$dR_6/dt = \lambda p_1\,R_2 - \delta_1 R_6$$

$$dR_7/dt = \lambda p_2\,R_2 - \delta_2 R_7$$

$$dR_8 / dt = (N-2)\lambda R_1 + (N-1)\lambda R_2 + 3\lambda R_3$$

Utilizing a program, the dependability is assessed for a duration of 106 hours by resolving the differential equation system derived from the Markov reliability diagram.
The program's output provides the precise state probability for both successful and failed system states.From there, system unreliability can be calculated by adding the probability of failed states, and system reliability can be calculated by adding the probabilities of success states.
When there are three routers available, the likelihood of states N-1,0 and N-2,0 is multiplied by (iρ), where (i) is the number of available routers and (ρ) is the filer rate per switching delay time. Every power/node or link failure has an impact on the system's dependability.

Reliability Study Results:

As seen in Figures below, the Markov model for case three has eight distinct states. Three states—(N,0), (N-1,0), and (N-2,0) represent the three successful states.
Figures 2,3 and 4 show how the probability of the three states changes over time.

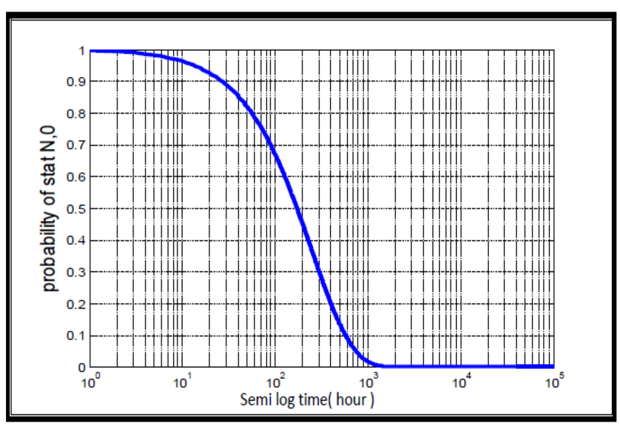

Fig.2, Probability of state N,0

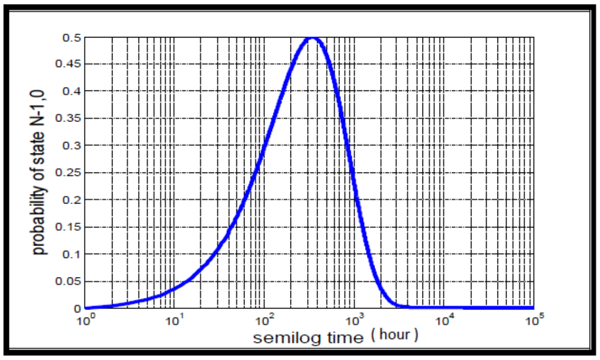

Fig.3, Probability of state N-1,0

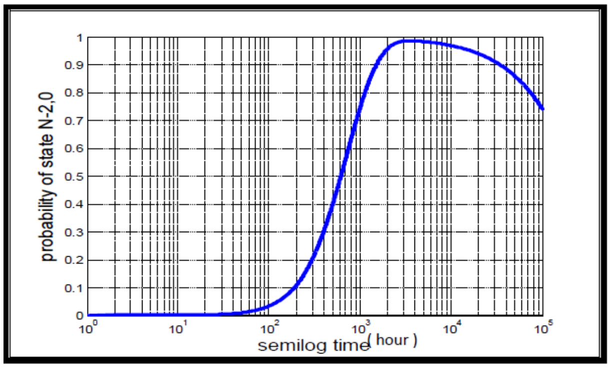

Fig.4, Probability of State N-2,0

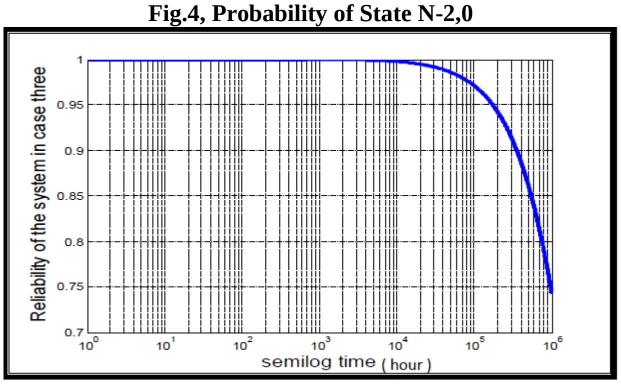

Fig.5, Reliability of the Network

The system's reliability can be assessed at any time by adding the probability of the three success states. Figure (5) illustrates how the networks' dependability changes over time.
The probability results of states (N-1,0) and (N-2,0) are multiplied by the results of Equation (3-24), where there are two available routers in state (N-1,0) at (i=2) and one available router in state (N-2,0) at (i=1). This process is necessary when a node or power fault occurs and the system needs to switch to a substitute router.
The reliability of this case is displayed in Figure (6) and the probability result of states (N-1,0) and (N-2,0) is multiplied by the result of Equations if the link fault occurs.

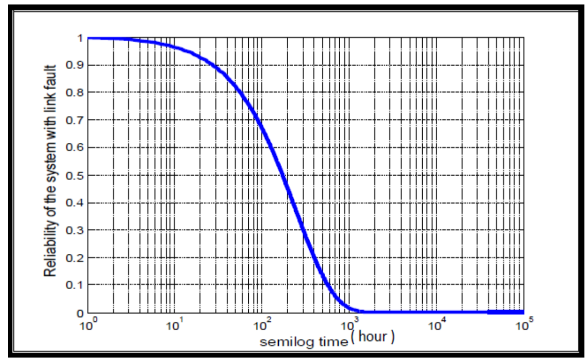

Fig.6, The Reliability of The System with Link Fault at Switching Time.

The availability program's findings for the availability study of case three show how the probability of each of the case three availability Markov model's eight states changes over time. The availability of the system can be found by adding the probability of the three successful states.
The reliability and availability results for case three are displayed in Table (4.5), along with a change over the same time period.
The availability program's results for the availability study show how the probability of each of the availability Markov model's eight states changes over time for case three.
The availability of the system can be found by adding the probability of the three successful states.
The reliability and availability results for case three are displayed in Table (4.5), along with a change over the same time period.

TABLE I. RELIABILITY AND AVAILABILITY OF THE NETWORK WITH THREE ROUTERS.

Time\hour	Systems Reliability	Systems Availability
10^0	0.999999	0.999999
10^1	0.999989	0.999997
10^2	0.999978	0.999988
10^3	0.99875	0.99900
10^4	0.9965	0.9986
10^5	0.9787	0.988
10^6	0.7576	0.8266

Unlike reliability, there is no absorbing state in the availability study, so over an extended period of operation, availability will reach a steady-state value. The availability analysis takes into consideration the repair rate from the absorbing state into any other state.A. Abbreviations and Acronyms

II. CONLUSION

This paper's work demonstrates how to assess the availability and dependability of an important contemporary wireless network called an ad-hoc network. Furthermore, it contrasts the three network designs to determine which one provides the highest level of dependability for the wireless communication network. The study demonstrated that the best way to achieve highly dependable communication is to place more routers in the intersection area between communicated nodes. From the work in the preceding steps, the following synopsis could be inferred:

1. Because the Markov method approach describes both the failure of items and their subsequent repair, it has demonstrated great flexibility in modeling various types of systems. It calculates an object's likelihood of existing in a certain state based on the order in which it has moved.
2. The consideration of wireless ad hoc communication is made, with an emphasis on router malfunctions. In this system, the system failure duration plus the packet losses during each failure are combined to create the measure of system packet losses due to failure. The outcome makes it evident that there will be more packet losses whenever the failure duration is prolonged.
3. The dependability of both ad-hoc networks and wireless networks overall will rise with a decrease in lost packets.
4. Increasing the quantity of available routers can boost the reliability of a multipath, end-to-end network. Until the used router fails, only one of these routers will be linked to the network; only then will the backup router be linked. The network has long-term high reliability thanks to its three available routers.
5. The switching delay time to the replacement router will go down as the number of available routers rises.
6. The network's reliability will decline over time. For example, at 104 hours, or 13 months, it is 0.99999; however, at 106 hours, or over an extended period of time, it drops to 0.75436.
7. The study computes the number of lost packets; it's crucial to understand that, for effective communication, the number of lost packets cannot exceed three per unit of time.

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