

Investigating Research Trends on Survivability of Wireless Network Failures

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Abstract

Failures resulting from various kinds of wireless connectivity problems have always made transmitting packets over a wireless network difficult. In order to find newly undiscovered regions such as swarm-based, evolutionary algorithm, adaptive, and reactive optimization routing, this study offers an overview of wireless network optimization routing issues. In wireless network research, there is a clear tendency towards route optimization between 2012 and 2023. However, the uptakes in the ADPV and the TORA areas have not been thoroughly investigated in solving multiple node-links and multiple link failures, with only a few articles available. As a development of a newly proposed wireless network survivability model for restoration and knowledge generation as an instruction guide to comprehend wireless network survivability, this research is relevant to wireless network restoration and telecom network restoration guide.

Keywords: Survivability, Failures, Optimization, Wireless network, Open research, Rerouting, Routing, Restoration,

1. Introduction

Wireless technology and its services are becoming more and more important to the world, but it's not certain if wireless network infrastructures can keep up with the growing demand. Failed systems not only restrict current data and voice usage, but they can also impede the development of new wireless applications such as e-commerce and high-bandwidth Internet access. The increased role of wireless and related systems in emergency response makes network disruptions more significant. The increasing use of wireless networks has led to a greater visibility of network infrastructure vulnerabilities. Providers now need to consider both preventing network outages and handling them when they do occur (Pundalik Chavan1 et al., 2023). An investigation of wireless network optimization routing subjects was conducted to resolve most of these failures and achieve optimal utilization of network services. The goal was to identify understudied and previously unexplored areas such as swarm-based, evolutionary algorithm, adaptive, and reactive optimization routing to use for wireless networks to survive wireless network failures. The sustainability of wireless networks is a growing problem for network operators and service providers. Examples of infrastructure-based and non-infrastructure wireless networks include the Internet of Things (IoT), mobile ad-hoc networks (MANET), wireless asynchronous transfer mode (WATM) networks, sensors networks, satellite communication networks, cell phone networks, and terrestrial microwave networks. These wireless networks should always have access to critical services, even in the face of adverse circumstances like attacks, natural disasters, or frequent failures. Due to constant failures brought on by all kinds of wireless network connectivity issues, packet transfer over wireless networks has never been easy. The aforementioned malfunctions have resulted in significant disturbances, and the tardiness in identifying and diagnosing them has intensified their consequences concerning financial loss,

operational efficiency, and human elements such as technology assurance (Jacek Rak et al., 2021). Failure of a single link, a single node, multiple links, multiple nodes, failure of single node-links, and failure of multiple node-links are the various types of failures. Many strategies have been put out in the literature for wireless network survival in order to prevent a protracted network failure; some of these strategies include swarm intelligence, evolutionary algorithms, reactive, proactive, and adaptive routing optimization techniques. Swarm Intelligence (SI) is a rapidly developing field of study that offers a more effective approach to solving problems than the conventional way in almost every engineering discipline. SI is a result of mimicking some insects' and animals' social behaviours. Systems like ACO, Artificial Honeybee (ABC), Fireflies (FF), and Honey Bot have all been created using it (Rashmi Sonkar & Shish Ahmad (2022)). Within the field of "Ant Algorithm," models that are observed and learnt from real ant colony behavior are studied. Specifically, the ACO within the field of "Ant Algorithm" explores models that are observed and learned from real ant colony behaviour. Because of its many benefits, SI is currently thought to be one of the most promising AI strategies, with a constant growth in scientific attention. This is supported by the increasing number of publications and conferences on Swarm Intelligence, as well as the increasing number of successful SI research outputs. Another optimization method for wireless networks is the evolutionary algorithm. Complex optimization problems are solved using metaheuristic algorithms, like evolutionary algorithms. Even though they were introduced decades ago, applying them to actual optimization problems requires significant computational resources that were not available at the time. (Essam H. Houssein et al., 2024). With their multi-core designs, modern laptops and computers are capable of millions of processes per second, which opens up new applications for evolutionary algorithms in many scientific domains. They rely on the crossover and mutation of the genetic operator to develop a population of workable solutions. Evolutionary algorithms have proven to be a viable solution for a wide range of mobile multi-hop optimization issues, including topology management, broadcasting techniques, routing protocols, and mobility models. The Ad-hoc On-Demand Distance Vector is another optimization technique used (AODV). One well-known optimal reactive technique for figuring out the route while the topology changes is AODV. The hardest difficulty is rerouting packets between wireless networks. The node upstream of the break can choose to fix the broken link locally when it occurs in an active route. Depending on the state of its downstream node, the upstream node, also known as the mending node, classifies and applies distinct processes for various types of link breakage when they occur. (Dipika Sarkar et al., 2024). Another routing optimization strategy to look into is the Adaptive Disjoint Path Vector (ADPV) method. It is an adaptable approach that takes into account energy levels and node failures. By dynamically adjusting the transmission intensities of sensor nodes, ADPV achieves its goal of preserving super-node connectivity in the event of node failures. By using the Adaptive Disjoint Path Vector (ADPV) algorithm, the ADPV technique guarantees a dependable super link between nodes. There are two steps to the ADPV: restoration and single startup. (Fatih Deniz et al., 2021). They are able to double the super connection between nodes as compared to the conventional DPV approach.

For extremely dynamic mobile multi-hop networks, the source-initiated, link-reversal-based Temporally Ordered Routing Algorithm (TORA) is an adaptive routing technique. This protocol responds to topological changes with localization, enabling it to swiftly design routes and minimize communication overhead. TORA uses the "direction of the next destination" to transmit data, as opposed to the idea of the quickest way, when choosing routes (R. Jeevitha et al., 2024). There will be less processing and bandwidth usage as a result. The source node takes one or two paths that pass through a number of neighbouring

intermediary nodes route to the destination. Route generation, route maintenance, and route erasure are the three fundamental procedures of the TORA protocol.

1.1 Research questions and contributions

Based on the above motivations, this research poses the questions:

- (i) How can swarm-based and evolutionary algorithms be leveraged to enhance wireless network survivability, addressing challenges posed by multiple node-links and link failures?
- (ii) What implications do these strategies have for operational service and technological confidence in future?

The proposed framework addresses the research questions leading to the following contributions:

- (i) **Survey and synthesis of route optimization trends:** By conducting a comprehensive survey, this research consolidates knowledge in the field of wireless network optimization routing, which provides a synthesized overview of existing research trends between 2012 and 2023. It identifies a clear trend by providing insights into the volume and direction of publications on this subject.
- (ii) **Framework creation identifying understudied areas:** This research establishes a framework encompassing numerous sub-themes within wireless network optimization and routing, which offers a structured approach to understand the diverse aspects of the field. It sheds light on previously unexplored areas within swarm-based, evolutionary algorithms, adaptive, and reactive optimization routing.
- (iii) **Research topic exploration:** The study generates open research topics and questions, which encourage further exploration and development of intelligent systems for optimizing wireless network solutions to meet the evolving needs of network operators and subscribers. This is relevant to the development of restoration models, acting as a reference guide and contributing to the broader field of telecom network restoration.

2. Related Works

2.1 Wireless networks

Human labour in gathering data at many locations has decreased thanks to wireless network technology, which has replaced wired infrastructure with wireless infrastructure and enabled mobile devices. One of the biggest barriers to quality of service (QoS) in wireless networks is network failure, since these networks need to be accessible and effective. Among these failures are single node failures, multiple node failures, single link failures, and multiple node-links failures. There is discussion of various wireless networks and how these problems are handled on various wireless networks.

2.1.1 Asynchronous Transfer Mode (ATM) Networks

The Asynchronous Transfer Mode (ATM) Network has been designed as the standard for future networking that is anticipated to transfer speech, real-time video, and images, in addition to the growing amount of computer data. The digital network's broadband integrated service is now a

reality thanks to the ATM. This technique allows for the overall flexibility and efficiency needed for high-speed multi-service and multi-media networks by providing bandwidth on demand (Owoade & Osunmakinde, 2016). Wireless ATM is a further benefit of ATM networks: they can be expanded to a wireless environment. With guaranteed Quality of Service (QoS), WATM can be viewed as a wireless extension of ISDN networks, offering integrated data transmission. The versatility of wireless ATM technology will allow it to support several protocols, such as Internet and ISDN (Integrated Services Digital Network) protocols.

2.1.2 Mobile Ad-hoc Networks (MANET)

An ad-hoc network is a wireless mobile communication system composed of a number of mobile nodes outfitted with wireless transceivers. It is not dependent on already-built infrastructure and is transient. Using their own wireless transceivers, the network's mobile nodes exchange information; if the information is outside of their communication range, other intermediary nodes can relay it (Abdulleh et al., 2015). These are frequently utilized in situations like military applications, sensor networks, disaster relief, and emergency response where wired networks are unavailable or where communication is only temporarily needed. Every node in a MANET functions as a host and a router, and the network's wireless channels link the nodes.

2.1.3 Networks for the Internet of Things (IoT)

The next significant development in the Internet's growth from a computer-to-computer communication medium to a platform that includes everyday objects (things) is the Internet of Things (IoT). This might have a significant impact on a number of areas of the economy and society at large, including the development of intelligent energy supply management, smart cities, and smart transportation systems—all of which are made possible by sensor data (Al-Absi et al., 2021). IoT-based systems can be unreliable and prone to mistakes, which can lead to network problems and, occasionally, inappropriate behavior. Many types of flaws in Internet of Things networks are caused by issues with nodes, links, protocol conversion, and communication. Device malfunctions resulting from defective hardware and software are possible. The most severe network failures are those resulting from node or connection failures. Consequently, an Internet of Things network consists of interconnected layers, including computing layers, device, controller, internet, gateway, and restful services. (JKR, 2020). This study (Kamel Tari et al., 2019) employs forensics analysis to find faulty IoT nodes. It deals with the issue of identifying nodes that produce inaccurate data. Temperature sensors are used to begin collecting data for the study in a cloud computing server, and the host identity protocol (HIP) is used for node communication. Data mining classification techniques are used for the detection to be able to classify the linked items based on the dimensions that have been gathered. Very positive findings from the study's conclusion provide the foundation for future research. In order to create Medical Internet of Things (MIoT), (Ye et al., 2016) suggested combining traditional health care IoT practices. MIoT wants to make sure that patients can respond to their treatment more quickly and effectively. However, protecting user privacy is vital while collecting and handling extremely sensitive personal health data. MIoTs, however, only have a little amount of computing capacity, therefore they can only use basic security measures. Because of this, patient data is susceptible to data leakage when health data is transferred over

MIoT. The authors of this paper emphasize the significance of implementing adequate security measures to increase the MIoT's resilience to intrusions. Additionally, according to the authors, this work examines the main issues with IoMT security and privacy and provides an overview of current approaches. The concept of the Internet of Things (IoT), which is emerging as a fresh path for technological advancement, introduces new issues like the administration of such devices, correct and prompt detection of these devices, and security flaws that might be used for nefarious purposes. IoT device connection generates traffic with unique characteristics and variations from that of traditional devices. This study examines the viability of using these attributes to categorize gadgets, irrespective of their function or intention (Cvitić et al., 2021). This form of classification is necessary in a dynamic and diversified environment such as a smart home, where the number and diversity of gadgets grow every day. In all, 41 IoT devices were employed in this investigation. To create a classification model, the notion of supervised machine learning was added to the logistic regression technique. 13 network traffic parameters produced by IoT devices were used to create a multiclass classification model. According to research, based on the attributes of these devices that affect traffic flow, it is feasible to categorize devices into four previously specified classes with high performance and accuracy (99.79%). Precision, F-measure, True Positive Ratio, False Positive Ratio, and Kappa coefficient are all high (0.997-0.999, 0.997-0.999, 0-0.001, and 0.9973, respectively) are model performance metrics. Such a built model can be used as a foundation for administering and monitoring large-scale IoT settings like industrial IoT, smart homes, and similar environments.

2.1.4 Sensor Networks

Wireless sensor networks (WSNs) are made up of numerous sensor nodes that are used for tracking targets, environmental monitoring, health surveillance, and detecting fires. Sensor nodes are made up of wireless interfaces, radio transceivers, and transducers that gather environmental data. Together, these inexpensive, small sensors form a network that carries out tasks based on their needs. Numerous sensor nodes, including biosensors and mechanical, optical, magnetic, thermal, and chemical sensors, can be connected to one another in order to identify changes in the environment or specific properties. Radio transmissions are used to communicate between the source and the base station since sensor nodes are situated in remote areas and have limited battery life, memory, and processing capacity (Cvitić et al., 2021). Sensor networks can be categorized into two types: organized and unstructured. Generally speaking, WSNs have minimal or no infrastructure. Undersea wireless sensor network (UWSN) is one of the possibilities that can help us learn about certain areas, such as natural assets and undersea resource exploitation, while addressing the benefits of sensor networks. However, given the absence of radio waves, which encounter a variety of difficulties in this environment, the acoustic signal is the only practical alternative for underwater communication (Wahid et al., 2014). Numerous routing techniques have been developed by academics to address these problems, yet energy consumption in underwater communication remains an issue. A trustworthy and energy-efficient routing approach is developed to deal with the issue of rapidly depleting energy. By avoiding redundant data forwarding, it achieves energy savings and ultimately increases network lifetime. The assertion that the suggested approach achieves energy efficiency coupled with a greater delivery ratio by lowering the data transmission error rate during the routing decisions is supported by simulation results.

2.1.5 Satellite Communication Networks

The satellite communication network is among the most dependable wireless communication methods. Satellite communication networks have several advantages over typical wireless communications, including long-distance communication, a large coverage area, and configurable communication settings (Do et al., 2020). Their significance in emergency applications is growing yearly as a result. This is particularly true in the case that widespread catastrophes harm the infrastructure used for communication. In the event of a crisis, even if there are only a few reachable connection links, more demand could lead to network overload and congestion. Therefore, if satellite communication is used, disaster relief activities will be more feasible and essential.

2.1.6 Cell Phone Networks

A collection of terminals, entities, and nodes connected by links to enable communication between terminal users make up cellular phone networks, a type of telecoms network. The entities are people who are using portable mobile devices to communicate with each other through text messages or voice call signals. Many technologies, such as the Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), and Enhanced Data Rates for GSM Evolution (EDGE), support and offer cell phone networks (CDMA), Long-Term Evolution (LTE) is a combination of the Universal Mobile Telecommunications System (UMTS), High-Speed Downlink Packet Access (HSDPA), and Universal Mobile Telecommunications System (UMTS) (Cvitić et al., 2021). Due to its ability to be used everywhere and at any time, cell networks have become the most popular means for individuals to connect with one another. It began with two-way radio systems and progressed to mobile networks using 4G technology to carry high-quality data. The issue that needs to be solved in this paper in order to get the greatest network performance and the highest data rate for all users is how to link the user need (UE) to the best BS/tier. In this paper, two types of association are proposed: the best BS in each of the three tiers is found, and the UE is then associated with one of them using an association algorithm; the best tier for the UE is chosen, and the UE is then associated with one of the BS in this tier using an association algorithm. The Nash bargaining solution (NBS) is used to handle the opportunistic user association problem as an optimization problem (Al-Dabbagh et al., 2017). The first and second proposed methods in this work both reach optimality and boost total system data rate (SDR) by 7% and 2%, respectively. Additionally, they increased the total Jain's Fairness Index (JFI) by 6% and 2%, respectively, for the first and second proposed methods.

2.1.7 Terrestrial Microwave Networks

Microwave is a type of spectrum that includes frequencies ranging from 1 GHz to 300 GHz. Microwave transmissions is the process of transmitting and receiving information using microwave networks, and it might include voice, data, television, telephony, and/or radio signals. Microwaves are emitted by both natural and man-made things, as well as from outer space. Microwaves can be employed in a wide range of applications since they span such a large portion of the electromagnetic spectrum (CommScope, 2017). Within the larger field of radio frequency communications, point-to-point communications are often conducted using microwave frequencies between 1 GHz and 100 GHz along line-of-sight paths known as links.

Large amounts of data can be transmitted wirelessly between distant communication nodes thanks to these frequencies' propagation properties.

2.2 Wireless Networks Failures

Because wireless lines are brittle and error-prone, they can cause network-wide flaws and, in certain situations, misbehaviour. Failures in a wireless network can be node, connection, protocol conversion, or communication related. Device malfunctions resulting from software and hardware issues are possible. The most severe network failures are those brought on by node or link failures. Wireless networks can experience failures of the gadgets, the regional network, the control unit, the interface, the internet, and problems with faraway data management and storage (S. JKR, 2020). Anywhere there is a problem, the wireless network will become unusable and unusable.

2.2.1 Single Link Failure

In a wireless network, outage of one link element is called one link failure. One link outage issue could be resolved by creating an updated connection that are still operational and have the capacity to handle the extra traffic from the failed link (Awoyemi et al., 2018).

2.2.2 Single Node Failure

A single node failure occurs when one node in a cluster of computational nodes malfunctions (B. Varghese et al., 2010). Numerous factors, such as a device turning off for servicing or breaking owing to hardware outage, might cause these events. For example, supposing a terminal fails and it is a main node controlling other terminals in the network, it could lead to the failure of other nodes (Xin et al., 2005).

2.2.3 Multiple Links Failure

There are two common circumstances in which more than one link fails. (i) Any random link on the network could malfunction, and before it can be fixed, another link might also malfunction, creating a sequence of multi-link failures. (ii) In actuality, a single shared conduit may be used to route two different physical links. When several connections fail, the backup capacity of a connection may be lost in the first failure, and when the second link fails, the connection may become vulnerable or unprotected (L. Wosinska, 2006). The example of many links in real life Failure happens (i) when different fiber links come together to create a Shared-Risk Link Group and share common failure structures. (ii) Additionally, each physical fiber connection can handle several light paths using wavelength division multiplexing once the light routes have been routed on the physical topology. It is possible for two or more light pathways to share a physical link. Many links in a logical topology may break as a result of the failure of a single physical connection.

2.2.4 Multiple Nodes Failure

Multiple node failure refers to the failure of more than one node in a cluster of computational nodes. Many node failure is the term used to describe the outage of many equipment or nodes in a network at the same time (Fu et al., 2019). Strategies for network recovery are intended to protect more than one network parts against multiple failures, with the understanding that, although uncommon, multiple, nearly simultaneous, failures do occur occasionally.

2.2.5 Multiple Node-Links Failure

A phenomenon known as multiple node to link outage occurs when a node in a wireless network fails, leading to the breakdown of associated links. This communication technique drastically limits the capacity of nodes and links. Node-link failures can happen when a small number of links and nodes in the connection are overloaded beyond its ability, rendering the entire network unavailable for use (Fu et al., 2019). It happens when numerous node-link failures take place simultaneously. In other words, if a node-link in a connection fails, it often results in more than one node-links failing.

3. Methodology

3.1 Suggested Wireless Network Optimization Framework

The goal of the suggested wireless network research framework, which encompasses a large number of wireless networks, is to create optimization techniques for withstanding network failures so that the network can keep working. Additionally, it gives network developers vital information on the critical steps involved in setting up a durable wireless network.

3.1.1 Wireless Network Routing Optimization Strategies

We developed a common routing optimization framework that supports several wireless networks, including ATM, MANET, IoT, sensor network, satellite communication network, mobile phone network, and terrestrial microwave network, after doing extensive research on wireless network routing optimization. Numerous types of wireless network failures, including single link, single node, multiple links, multiple nodes, and multiple node-links failures, have been documented. The suggested framework examines network routing failure difficulties. Multimedia, audio, and video messages are all sent out by these networks. The proposed framework acknowledged ACS, evolutionary algorithm (Genetic Algorithm), particle swarm optimization (PSO), Ad-hoc On-Demand Distance Vector Protocol (AODV), ADPV, and TORA as techniques for wireless network routing optimization. Based on performance statistics, the recommended technique determines which optimization options are optimal. The suggested wireless network optimization framework is shown in Figure 1.

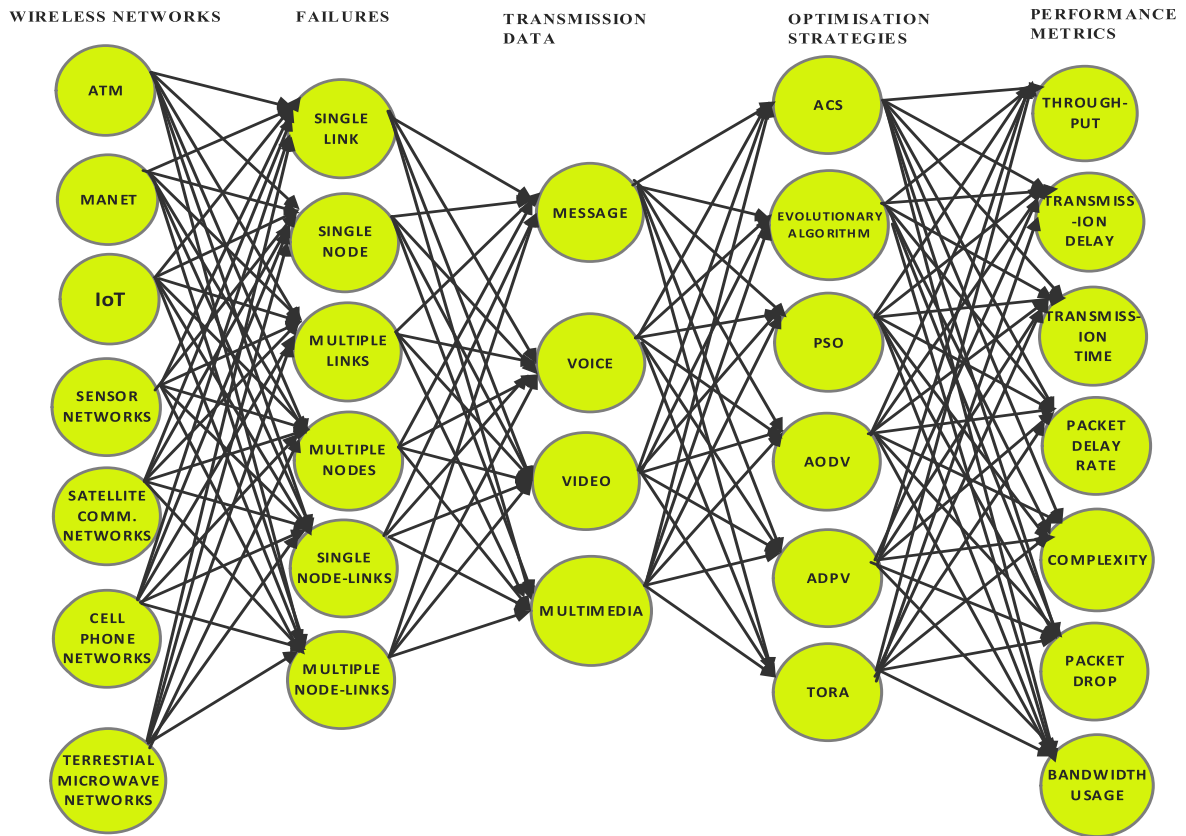


Figure 1. Proposed Wireless Network Optimization Framework

3.2 Optimization Strategies Emerging from Literature

Following our review of the literature, we discovered several optimization approaches. This section goes over optimization techniques and the different types of failures that they can handle.

3.2.1 Ant Colony System

Since the initial ACO method was released in the early 1990s, ACO has attracted the interest of an increasing number of academics, and several effective applications are now available (Chandra Mohan & Baskaran, 2012). Additionally, a sizable body of theoretical research is becoming accessible, offering practitioners and scholars crucial guidance for upcoming ACO implementations. Inspired by ant foraging behaviour, ACO is a Swarm Intelligent procedure which may be used to discrete optimization issues (Chandra Mohan & Baskaran, 2012), (Shunmugapriya & Kanmani, 2017). The ability of ant colonies to solve emergent problems, including obtaining food, has influenced the creation of effective connectivity procedures, particularly for Ad-Hoc Wireless Networks. There are certain issues with ACO that need to be resolved when modifying it. Because of a state called "Stagnation," distributing the load is among the important issues. When congestion causes packets to be lost and all packets start traveling on the optimal path, the situation is known as stagnation. ACO tackles this problem in a number of ways (Hsin et al., 2010). This study looks at several strategies for handling different kinds of wireless network failures.

3.2.2 Single Link Failure

Link failure is a common problem in wireless connections. To minimize the impact of an outage, a lost connection needs to be quickly restored. In the event that only one link fails, (Mohan, et al., 2016) offered a fix for the survivability problem in all wireless networks. The recovery time from a single link loss is shortened by using this technique. The nearby shortest cycle and the Ant Colony Optimization (ACO) method are used to determine other routes for data retransmission. In this study, the link failure issue is addressed by (Mohan et al., 2016), and in a distributed situation, the shortest path is found using the ACO method in the event of a link failure. After using the ACO to solve the link failure problem, an assessment of outcomes in Prim's algorithm and the ACO demonstrates that the ACO method aids in selecting the quickest route in the least duration of time (Vargas et al., 2009).

3.2.3 Single Node Failure

Ahmed (2021) presented a crank back strategy, ACO-based route and spectrum assignment (RSA) algorithm to address single node outages. The procedure can be used to establish light-paths during regular network operation as well as recover light-routes impacted by one link or one node outages.

3.2.4 Multiple Links Failure

ARA is an example of an ACO-based wireless network routing protocol, was proposed by in order to resolve multiple connections failure (Zhang et al., 2017). Based on on-demand routing, ARA is a fundamental meta-heuristic for ant colony optimization. The routing algorithm consists of three steps: route maintenance, route discovery, and managing connection failures. The path finding stage of the ACO-based Routing Algorithm is built in a manner akin to AntNet. Forward ants (FANTs) and backward ants (BANTs) are deployed during the route discovery phase. The FANTs are broadcast by the sender. By using their sequence numbers, intermediate nodes are able to distinguish and eliminate duplicate FANTs. Once FANTs arrive at their destination nodes, BANTs are created and returned to the source nodes. In order to minimize the overhead associated with using periodic ants, ARA uses data packets to keep the route up to date. A node deactivates a link by setting the pheromone value to zero when it detects a link failure. It then searches for an alternative connection. If this does not work, it alerts its neighbours. Until a different route is discovered or the source node receives a route error alert, these steps are repeated.

3.2.5 Multiple Nodes Failure

Many factors, including as natural disasters or malevolent human behavior, can lead to multiple node failure (Zhang et al., 2021), and a number of remedies are being investigated to increase wireless network readiness for such circumstances. An ant colony system (ACS) paradigm was proposed by (Owoade & Osunmakinde, 2019) as a solution to the failure of multiple nodes. In this architecture, certain performance guarantees were provided to a rerouting channel in the event of a failure between peering nodes, including

adequate low-latency bandwidth and general efficient use of network resources. In the case of a capacity loss, the design includes enough variation and additional capacity to allow systems to be restored at the targeted quality of service.

3.2.6 Multiple Node-Links Failure

Hu et al. (2016) overcame several nodes connected by a connection failure in wireless connectivity by creating a novel multi-fault localization strategy based on ant colony optimization. The ant colony optimization-based multi-faults localization mechanism has a high success rate and reduced flooding time and warning packets when compared to current localization strategies. The recommended method consists of two steps: (1) applying the ACO algorithm for fault localization, and (2) restoring the network to reduce its loss rate. For every option, the ant applies the transition rule. To find out if the ant would try to identify a new potential fault or exploit previous pheromone deposits, the first stage in this technique is to generate a random number. The forward ant follows the global updating rule, which is applied by the feedback ants on the opposite path. Once the feedback ant reaches the source alarm, the algorithm has finished running. The suggested method assumes a bidirectional link between nodes, with two unidirectional fibres extending in opposing directions. Every update interval, a search packet containing messages is sent to every network node to check the connection state during regular operations. This paper reports on the low convergence rate of the conventional method for Mesh network connectivity optimization. An improved multi-path routing protocol based on the ant colony algorithm was presented by Li and Peng (2020). In order to expedite route optimization, the protocol initially incorporates an ant colony algorithm-based sorting procedure and presents the concept of elite ants. Secondly, self-organizing connections is examined in this study. Based on the simulation findings, the methodology can find numerous best quality pathways with minimal overhead and quick integration than ADOV, DSR, and AOC routing approaches.

3.3 Evolutionary Algorithm

Researchers are developing nature-inspired algorithms to solve complicated problems; network design is one area in which they have been applied extensively. Evolutionary algorithms (EAs) are iterative metaheuristics that can be applied to NP-complete situations (Reina et al., 2016). Typically, they work with a population of initial solutions to the issue that are concurrently evolving into more effective ones. Stochastic operators are applied to the solutions in order to carry out this evolution process, which aims to simulate the natural evolution process. People are evaluated to ascertain the worth of the solution they stand for (those who are fittest will endure for future generations). Until the termination condition is met, EAs iterate over the collection of viable solutions (typically after finding the best solution or after doing numerous iterations). With each iteration, solutions are evolved through the use of evolutionary operators such parent selection, recombination (or crossover), and mutation. The evolutionary operators that have been employed to evolve different EA families typically vary.

3.3.1 Single Link Failure

In order to prevent failure of a single link inside a connection, Biswas & Podder (2021) provide a method of recovery with continuous exchange of messages which connects those links for data transfer and uses BER evaluation of alternative links. Should a malfunction occur on any functional network connection, every cycle that lies between the end nodes of the failing link are identified using this recommended method, which uses BER evaluation to ascertain the least BER value of an adjacent channel between two nodes in a given network. Next, the Genetic Algorithm (GA) is used to find the path that fits the best. The fundamental criterion for selecting the optimal path is the link's BER performance. The failed link can be avoided and kept linked at all times by designating adjoining cycles of the failed connection with the lowest BER value. Those adjacent cycles comprise the failed link's source and destination nodes.

3.3.2 Single Node Failure

Genetic Algorithm (GA) (DSN) is used by (Bhajantri & Nalini, 2014) to identify and fix node malfunctions in distributed sensor networks when a portion of the sensor nodes are broken. The primary goal of this research is to use GA to identify faulty terminals in the connection based regarding energy deficiency and node--node connection outage, resulting in an error resilience system that can adapt to the network and energy efficient. The proposed fault detection paradigm is used to identify faults at the node and network level (link failure and packet error).

3.3.3 Multiple Links Failure

In 2021, Owoade & Osunmakinde (Owoade et al., 2023) looked on cascading video traffic link failures on wireless networks that were under attack. In order to promptly address link-link failures, the aim of this work was to develop an enhanced genetic algorithm (EGA) that prioritizes capacity efficiency and swift restoration. On a complex node network, this fault-tolerant paradigm was assessed for such failures. The suggested method offered the best detours and the bandwidth required for quick video stream rerouting.

3.3.4 Multiple Nodes Failure

A collection of limited-capability sensor nodes makes up wireless sensor networks (WSNs) (Khosrowshahi & Shakeri, 2018). In hostile situations, such war zones or disaster areas, WSNs might have frequent node failures and lose connectivity because they get divided into irregular segments. Relay nodes (RNs) represent a novel approach to connectivity. Since they require less of them to be used due to their greater mobility, power, and transmission range, they are more expensive than sensors. Creating an evolutionary method for positioning RNs in multiple separated networks (GA) is the aim of this project. We restate the problem as the NP-hard Steiner tree problem, where the objective is to discover the minimum number of Steiner points at which RNs need be placed in order to re-establish connection. To determine the initial chromosomal length, an upper bound on the number of RNs is first estimated. The GA method then reduces the

amount of RNs while iteratively determining their position. Comparing the suggested GA against the best current work, experimental outcomes display that with a suitable number of RNs, it can provide a network connection. Owoade & Osunmakinde, 2021 assess the adaptability of an evolutionary computing paradigm that relies on on-demand recovery and capacity utilization to quickly address node-link failures because the Internet of Things (IoT) is susceptible to random failures. The concept was put to the test at several places using node-link failures in big networks. The suggested design might offer reliable detours in addition to the bandwidth needed for quick rerouting of multimedia traffic.

3.4 Particle Swarm Optimisation (PSO)

Inspired by the social behavior of organisms like fish schools or flocks of birds, Eberhart and Kennedy developed Particle Swarm Optimization (PSO) in 1995 to solve the meta-heuristic optimization problem (Sarasvathi et al., 2015). Particle Swarm Optimization (PSO) influenced by nature. Its foundation is swarm intelligence, which was developed as a result of studying a flock of birds' behavior, particularly their ability to utilize and explore their environment in quest of food. PSO, or particle swarm optimization, is a simple algorithm. After several rounds, the variables self-adjust to the member whose value is closest to the answer. PSO, or particle number swarm, uses a pre-specified particle number, let's say NP. Every particle has the capacity to provide a solution. In the d th dimension of the search space, a particle P_i , $1 \leq i \leq N_p$ has a position $X_{i,d}$ and a velocity $V_{i,d}$, $1 \leq d \leq D$ (Anand & Pandey, 2017). The dimension D is the same for every particle. Each particle is evaluated by a fitness function to make sure the solution is the best. Every particle records the dimensions in the problem space associated with the solution, which represents its current maximum fitness value.

3.4.1 Single Link Failure

In 2015, Robinson and Rajaram presented an energy-aware multipath routing method based on particle swarm optimization (EMPSO). This approach uses a continuous time recurrent neural network (CTRNN) to handle optimization problems. CTRNN determines the optimal loop-free approach to link disparate routes in a machine learning network. A set of the best pathways between the source and destination are produced using the CTRNN path selection method. The CTRNN employs the particle swarm optimization (PSO) technique for training its RNN. The proposed method makes advantage of dependability metrics such energy factor, transmission cost, and optimal traffic ratio between source and destination to enhance routing performance. In the route discovery phase, PSO can be used to find optimal loop-free pathways by searching for nodes with higher connection quality.

3.4.2 Single Node Failure

Researchers have also worked on a node and link lifetime prediction technique for MANET route recovery that is based on PSO (Particle Swarm Optimization) (Manickavelu & Vaidyanathan, 2014). They noted that route failure happens in all route-finding techniques in conventional mobile ad hoc network (MANET) systems, leading to data loss and communication overheads. Routing must therefore take into account the mobility of the network. This work proposes a particle swarm optimization (PSO)-based

lifetime prediction method for MANET route recovery. This technique predicts the lifetime of a link and node in the available bandwidth, taking into account factors like relative node mobility and energy drain rate. Fuzzy rules have been constructed to ascertain the node state, and predictions have been used to fuzzify the parameters. All nodes are intended to share this info. As such, each node's state is verified prior to data transfer. A route recovery mechanism's performance is designed so that, even for a weak node, connected routes are diverted to the strong nodes.

3.4.3 Multiple Links Failure

The optimal cluster head selection was achieved by creating energy-aware clusters using Particle Swarm Optimization (PSO). Ultimately, the PSO reduces the expense of choosing the optimal location for cluster head nodes. The PSO is a semi-distributed technique because it is applied within the group as opposed to the base stations. The smallest typical separation between component vertices, the likelihood of head node head count, and residual energy are the selection criteria for the objective function (Singh & Lobiyal, 2012). Furthermore, the influence of the anticipated number of packet retransmissions is displayed in the proposed energy model. This work uses the swarm optimization method to find the best cluster head (CH) position to minimize overall energy consumption while sending packets to the sinks. The authors also compute the anticipated number of retransmissions along a sensor network path and investigate the effect of link failure probability on packet transmission.

3.4.4 Multiple Nodes Failure

Most popular node localization method is the range-free localization algorithm, which has shown impressive outcomes. Only a small number of approaches, though, are appropriate in convex areas, the ones which have drawbacks including errors in hop length and increased temporal difficulty. It is recommended that two stages of the PSO procedure be presented for wireless sensor node localization in "concave regions" in order to address these problems (Meng et al., 2020). Next, in the first stage, offers a similar overlap ratio and route finding approach for measuring distance, and in the second stage, it uses maximum probability estimate to finish the first localization of unknown nodes. In order to enhance the initial localization results from the first stage, updated PSO approach is used in subsequent phase. The experimental findings demonstrate that the algorithm's localization error remains below ten percent while its running time remains around twenty seconds, even when the communication radius and beacon node ratio vary. Thus, with low processing resources and energy consumption, the method could accomplish great localization precise measurements in wireless sensor networks using concave-area. Consequently, the sensor nodes' life span can be significantly increased.

3.4.5 Multiple Node-Links Failure

The proposed method (Abdel-Kader, 2011) incorporates an effective changing element that is capable of manage changing situations arising from node-link failure or changes in multicast group membership without requiring multicast tree reconstruction. Simulation results suggest that the hybrid approach may be able to overcome the

limitations of genetic algorithms and particle swarm optimization, leading to better QoS performance. In this paper (Sheikhan & Hemmati, 2012), a Hopfield neural network (HNN) with particle swarm optimization (PSO) algorithm-tuned parameters is used to create a multipath routing system. The link expiration time (LET) between any two nodes serves as the connection dependability estimation metric. This approach can find either node-disjoint or link-disjoint paths in single-phase route discovery.

3.5 Ad hoc On-Demand Distance Vector (AODV) Routing Algorithm

3.5.1 Single Link Failure

In order to address one connection outage, (Kumar et al., 2011) proposed a Backward AODV (B-AODV) that attempts various route replies. In contrast to previous on-demand routing protocols for Ad-hoc Networks, Backward AODV (B-AODV) achieves higher performance and does away with path fail correction messages. Backward, AODV performs superbly with regard to transmission delay, electrical usage, and proportion of packets delivered. In mobile ad hoc networks, mobile devices wander freely to utilize wireless connectivity and dynamically alter network topology. One of the on-demand ad hoc routing technologies that has been studied the most is AODV (Ad-hoc on-demand Distance vector routing). The majority of ad hoc on-demand routing protocols, such as AODV, employ a single route reply along the reverse path.

3.5.2 Single Node Failure

In order to lower node energy consumption in wireless sensor networks, (Azzuhri et al., 2018) proposed an improved Ad-hoc On-Demand Distance Vector (AODV) routing protocol based on node-grade. Young Grade-AODV (G-AODV) is an upgraded AODV that assigns a grade to each node based on the hop distance between the node and the sink node. A node's grade decreases as it gets closer to the sink. Only signals from nodes containing routes demand (RREQ) that are increased graded than it is accepted by each node. Because route paths with lower hop distances are formed, there are two ways that the suggested G-AODV can lower node usage of electricity.: (1) by avoiding needless RREQ broadcast, and (2) by requiring fewer network resources for each packet.

3.5.3 Multiple Links Failure

A network simulator 2 is used in this study (Jassim, et al., 2011) to describe a parameterized method of the Adhoc On-Demand Distance Vector (AODV) transmission procedure (ns2). Instead than implementing a fixed choice inside the usual AODV procedure, a adaptable technique is examined regarding both of these essential responsibilities by exploiting two AODV protocol characteristics, namely HELLO and local route maintenance. The HELLO is utilized to identify broken links in the event of a route failure, and the local route repair feature in AODV is applied to repair and find other routes. In this work, two functions have been applied to enhance AODV's effectiveness. The connectivity outage location configuration for AODV's localized route maintenance is the second, the first is how long it needs to use the HELLO message to identify a connection loss.

3.5.4 Multiple Nodes Failure

a wireless peering network where hubs communicate without the need for infrastructure is called a mobile ad-hoc network, or MANET. Nodes also have total flexibility to move arbitrarily and join and exit the network whenever desired, and arrange themselves anyway it fits. Due to the nature of MANET, hostile and self-serving nodes may try to undermine the operation of the routing protocol, leaving MANET open to security breaches and producing inaccurate routing. The ad-hoc on-demand distance vector routing (R-AODV) described by the authors (Gupta et al., 2010) is based on the most direct and reliable routes. It is compared to the previously utilized AODV trusted framework to tackle the issue. Performance disparities are examined using a variety of metrics, including packet delivery percentage, balanced route load and mean end-to-end latency.

3.5.5 Multiple Node-Links Failure

By looking through the twelve-journal database, it was also found that the AODV optimization technique has not yet seen a lot of study on multiple node-link failure.

3.6 The Temporally Ordered Routing Algorithm (TORA)

Extremely flexible, effective, and scalable, the Temporally Ordered Routing Method (TORA) is a distributed routing system built on the idea of link reversal. A wireless protocol called TORA is designed for extremely dynamic multi-hop mobile networks. It's an on-demand routing system that the source started. It finds many routes from a source node to a destination node. One of the main features of TORA is that the control messages are directed towards a relatively small group of nodes close to the occurrence of a topological change. The nodes use the routing information of nearby nodes to accomplish this. The three crucial protocol operations are route formation, route maintenance, and route erasure. TORA is unique in that it keeps several paths to the objective, enabling topological changes to happen without any input. The protocol doesn't respond until all paths to the target are lost. Should a network split happen, the protocol has the ability to detect it and eliminate any erroneous paths.

3.6.1 Single Link Failure

Ad-hoc networks' dynamically changing network architecture is acknowledged to cause regular pauses in the path which require network re-establishment across new paths, hence compromising their quality of service. Therefore, ad-hoc networks are inappropriate for interactive sessions that take place in real time, such voice or video calls. For multi-hop networks, TORA is a distributed, loop-free multipath routing protocol that supports source- and destination-initiated routing. (Broustis & Jakllari, 2004) created a token-based queue for TORA to handle link failure in wireless networks and provide higher QoS guarantees for real-time interactive applications known as RT-TORA. In terms of average packet latency and delivery ratio, the RT-TORA routing algorithm performs better than the original TORA method—particularly for networks with a high number of connections.

3.6.2 Single Node Failure

According to Liu et al. (2020), the authors provide an adaptive repair method for the flood control strategy-based TORA routing protocol called AR-TORA-FCS. Firstly, the formula is built based on the properties of the uniform deployment of the nodes in the network, and the self-repair process of the self-repair nodes in the directed acyclic graph (DAG) of TORA is transformed into the optimal search issue for the optimal nodes. It has been demonstrated that the search result represents the best possible outcome for the Ray-Algorithm used to find the optimal node. Next, a conditional technique for determining the self-repair process is determined, and the conditional threshold for starting the process is calculated. Before the path fails, it is repaired, and a mapping relationship is created between the nodes' distance from one another and their self-repair process.

3.6.3 Multiple Links Failure

The temporally ordered routing algorithm (TORA) and the ideal link state (ILS) routing algorithm are compared in terms of relative performance by Deniz et al. (2016). Performance metrics evaluated include throughput, latency, and end-to-end message packet efficiency in addition to control and data bandwidth efficiency. The routing methods are compared in the context of a dynamic, multichip wireless network that uses broadcast transmissions. Among the attributes that were altered were average network connection, average network size, and average rate of topological changes. The average rate of topological changes and the size of the network were shown to be important determinants in determining how well TORA and ILS performed in comparison, although average network connectedness was not found to have a significant impact. The findings also demonstrate that TORA's performance eventually outperforms ILS for a given available bandwidth when network size or the pace of topological change increases.

3.6.4 Multiple Nodes Failure

It has been noted that there are no TORA papers available for fixing multiple node failures. The majority of articles in the article database did not address the issue of numerous links failing.

3.6.5 Multiple Node-Links Failure

It was discovered that no pertinent papers on multiple node-links failure could be located after scanning the journal's database.

3.7 ADPV Optimisation

3.7.1 Single Link Failure

No pertinent publications on multiple node-links failure were found after a search of the journal's database.

3.7.2 Single Node Failure

Shah & Bansode (2016) proposed an adaptive connectivity restoration after node failure(s) in wireless sensor networks. The harsh deployment conditions and insufficient energy supply may cause nodes to fail, which would impair network connectivity. Most current research focuses on this problem since a single node failure (cut-vertex) eliminates connectivity and splits a network into different sections. On the other hand, multiple node failure would be catastrophic for the network as a whole and would need immediate repair. As a subset of multiple node failures, only a few number of research studies have been proposed to address multiple cut-vertex failures. Consequently, a thorough solution to the single and multiple node failure problems is presented in this paper. The single node failure problem is addressed by the Collaborative Single Node Failure Restoration algorithm (CSFR), which focuses solely on cooperative communication. Nevertheless, CSFR-M, an extension of CSFR, incorporates node motion to address the single node failure problem more effectively.

3.7.3 Multiple Links Failure

Regarding ADPV's ability to optimize or fix multiple link failure in wireless networks, no published information exists.

3.7.4 Multiple Nodes Failure

Wang et al. (2016) introduced the adaptive, energy-aware, distributed fault-resistant Adaptive Disjoint Path Vector (ADPV) approach for heterogeneous wireless sensor networks. In this heterogeneous architecture, it is envisioned that the super-nodes will be connected to both traditional sensor nodes and resource-rich super-nodes. ADPV, in contrast to the static Disjoint Path Vector (DPV) method, aims to enable super-node connectivity in the event of node failures by dynamically adjusting the transmission intensities of the sensor nodes. The two steps of the ADPV technique are a single initialization phase at the beginning and restoration phases that are triggered in the event that the super-node connectivity of the network is disrupted. Alternative routes are computed in the initialization phase using a special optimization based on the well-known set packing problem, and are utilized in the restoration phase.

3.7.5 Multiple Node-Links Failure

ADPV papers that addressed the failure of multiple node-links were non-existent

4. Results and discussion

4.1 Wireless Networks Optimization routing comparative analysis

Table 1 summarizes the comparative analysis of the related work with respect to different network parameter.

Table 1: Comparative Analyses of the Related Work with Respect to Different Network Parameters.

Networks/ Parameters	Sensor Networks	WATM	MANET	IoT	Terrestrial Microwave Network	Satellite Communicati on Networks	Cell Phone Networks
Bandwidth Usage	Minimal (They are designed to transmit small amounts of data)	High (They are designed to transmit larger amount of data)	High (They are designed to transmit larger amount of data)	Minimal (They are designed to transmit small amounts of data)	High (They are designed to transmit larger amount of data over a short distances)	It has lesser bandwidth compare to fiber optics	High bandwidth consumption compare to satellite network
Transmissio n Delay	Increased transmission delay compare to WAN	Lower transmiss ion delay compare d to sensor networks	It has higher transmissi on delay compared to wired networks.	IoT networks have higher transmission delays compared to wired networks.	It has lower transmission delay compared with satellite communicatio n networks	It has higher transmission delay compare to fiber optics.	It has lower transmission delay compare to satellite communicati on networks
Throughput	Its throughput depends on the type of network used. For example, in low duty cycle wireless sensor networks the life time of energy limited nodes is improved but the network's throughput is decreased.	WATM networks throughp ut is higher than that of MANET due to higher number of nodes, routing protocols and mobility models in MANET.	It has lower throughput compared to that of WATM networks	The throughput of IoT network is lower than that of terrestrial microwave network. It is difficult to compare the two networks because they have different characteristi cs.	The throughput of terrestrial microwave network is higher than that of satellite communicatio n networks	Satellite communicatio n network has lower throughput compared to terrestrial communicatio n network.	Cellular telephone networks have higher through than satellite communicati on network because cellular networks use fibre optic cables to transmit data which can handle higher bandwidths than satellite communicati on networks.

Power Utilization	Sensor networks	WATM networks	MANET networks	IoT networks	Terrestrial microwave networks	Satellite communication networks	Cell phone networks
are designed to operate with low power consumption. They are typically powered by batteries and have limited energy resources whereas WATM are designed to monitor large areas for temperature changes therefore they consume more power than sensors networks.	consume d more power than sensor networks .	consume more power than IoT because they require more energy to maintain network connectivity	consume more power than IoT because they require more energy to maintain network connectivity	consume lower energy compared to MANET.	consume less energy than satellite communication networks because terrestrial microwave networks use less energy to transmit data over short distances compared to satellite communication networks which require more power to transmit data over long distances.	use more power than terrestrial microwave networks due to long distance coverage.	consume more energy that satellite communication network because cell phone networks require more energy to transmit data over short distances compared to satellite communication networks which require less power to transmit data over long distances.

A wireless network optimization routing approach was used to classify 320 journal papers in total. The only criteria used to evaluate the articles were their year of publication, the optimal routing strategy used to publish them, and how frequently they appeared in particular journals.

4.2 The Publications Year's Trend

The bulk of this review was centred on journal publications rather than conference proceedings papers. Conference papers made up just approximately 5% of the overall material used. Journals were chosen for their excellent content since researchers and academics frequently utilize them to disseminate new information and discoveries on strategies for wireless network optimization to the research community. A survey of journal articles released in the years 2010–2020 was conducted. The selection of journal articles was based on how well they applied to wireless network optimization. The literature study found publications in 12 internationally renowned journals, despite the method's subjectivity in that studies published in non-English language research channels were disregarded owing to language limitations. The construction of wireless network optimization routing frameworks will result from an understanding of wireless network optimization routing strategies, which was made possible by the literature review. Since there were not many optimization-related publications published before 2010, 2010 was chosen as the launch year for the publishing survey. There have been a lot more studies published since 2010 covering

every facet of optimization routing techniques (See Figure 2). The significance of the journals listed below for wireless network routing and optimization:

- IEEE/ACM Transactions on Networking
- IEEE Transactions on Evolutionary Computing
- International Journal of Mobile Networks Design Innovation
- Computer Networks
- Sensors
- International Journal of Distributed Sensor Networks
- Ad Hoc Networks
- Journal of Computer Networks and Communications
- Procedia Computer Science
- International Journal of Computational Intelligence Systems
- Swarm and Evolutionary Computation
- Journal on Wireless Communications and Networking

Figure 2 shows the annual distribution of articles on wireless network optimization routing approaches from 2010 to 2023, showing an annual growth. From 2010 to 2014, there was an increase in the number of articles published on optimization routing technique; however, by 2015, there was a decline in the amount of work done in this area. Between 2015 and 2019, the number of articles published on optimizing routing techniques increased exponentially. The decline in publications from 2019 up till 2020 can be ascribed to certain journals not having completed their publication of articles on optimization techniques at the time of review. The number of publications also start improve 2020 until 2023 (Sebastián Laborde et al, 2022 & Ayoade A. Owoade et el, 2023).

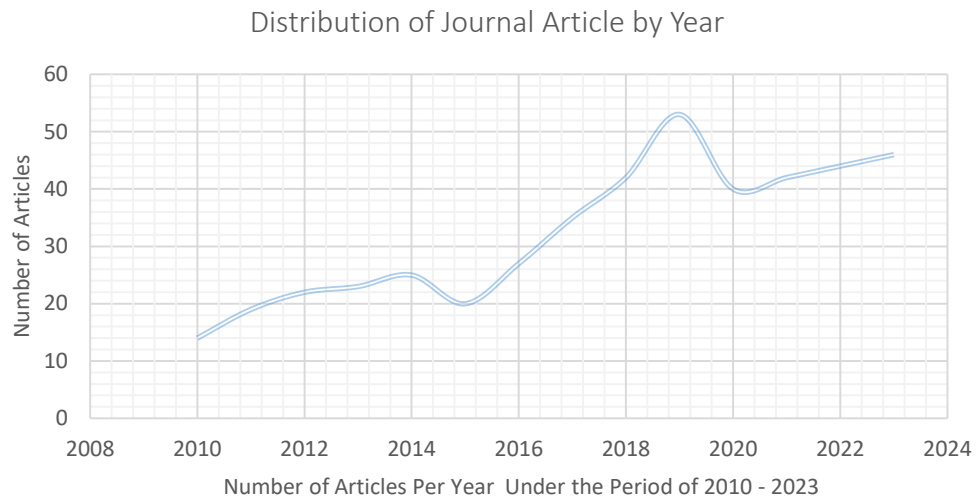


Figure 2 Distribution of Papers per Year

4.3 The Trend of Total Papers in Particular Journals

Figure 9 displays the total number of wireless network papers published by journal. The IEEE/ACM Transactions on Networking publishes 11.2 percent of papers, with optimization routing schemes being the most prevalent. The majority of its publications center on Ah-hoc and sensor network-related network problems. The second most commonly cited field in the optimization routing technique is computer networks. International Journal of Procedia and Distributed Sensor Networks with 93% of articles, computer science has the third greatest number. Ah-hoc networks rank fourth, and the majority of failed restoration papers employ a wide range of techniques. The fields of optimization routing technique is also covered by the IEEE Transactions on Evolutionary Computing, Sensors, Journal of Wireless Communications and Networking, and Journal of Computer Networks and Communications. Some others published as well, though less frequently. With 5.6% of publications, International Journal of Mobile Networks Design Innovation has the fewest.

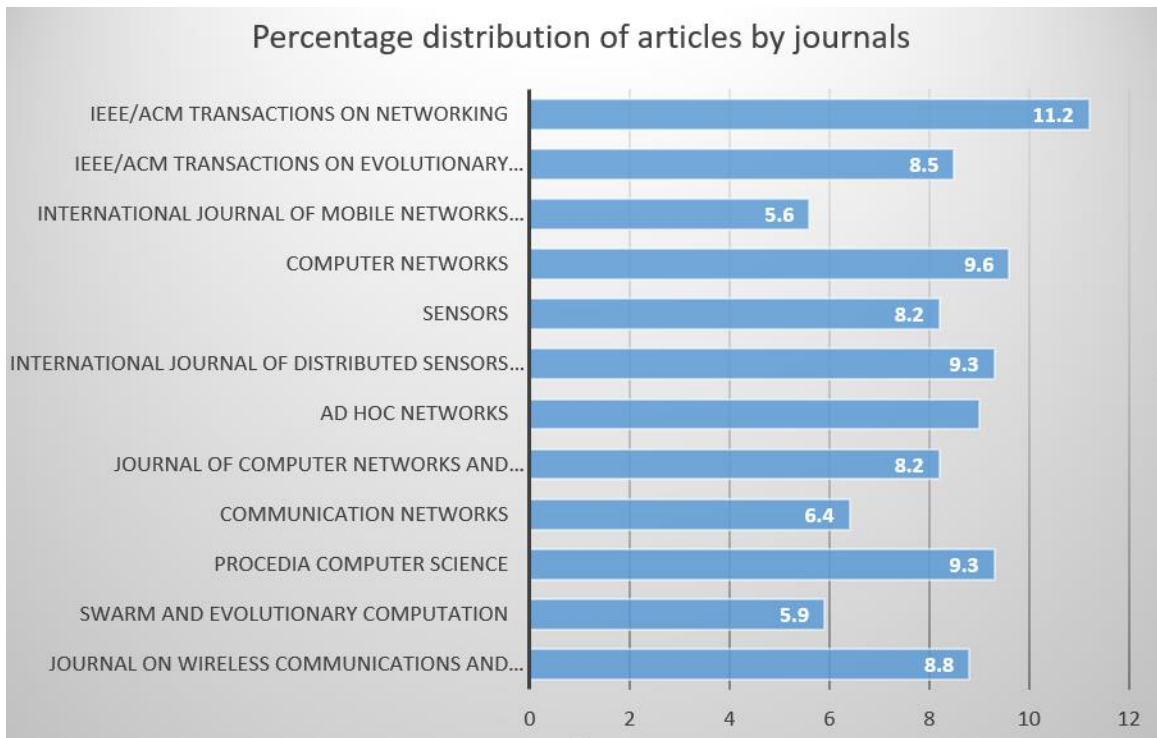


Figure 3: Journal Trends in Optimization Routing Articles

4.4 Trend of Optimization Routing Methods by Topics

The frequency of articles on optimal routing techniques from 2010 to 2023 is shown in Figure 4. With 98 articles (24.9%), ant colony optimization was the most popular topic. Particle swarm optimization came in second with 96 papers (24.4%), and ADPV optimization received the fewest papers (19 papers).

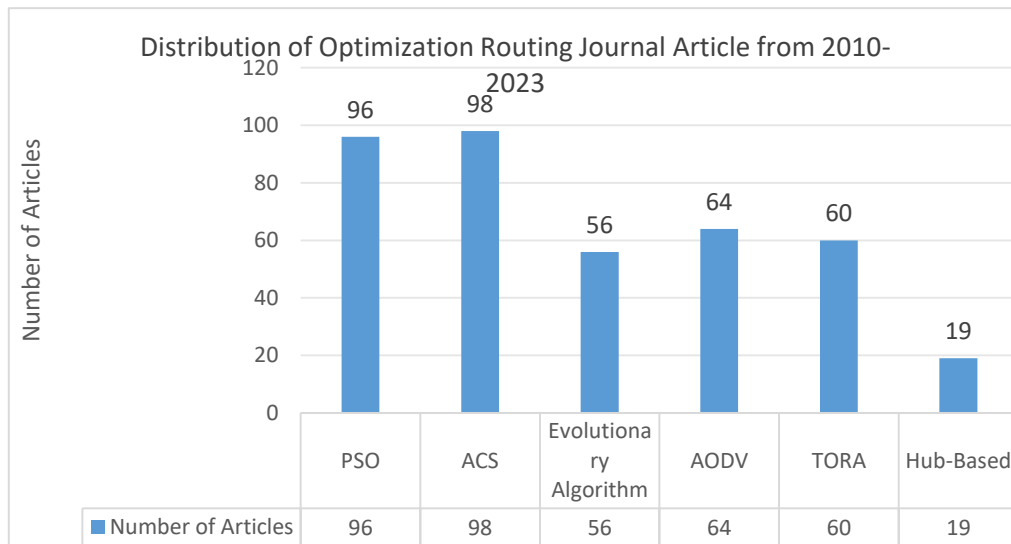


Figure 4. Optimization Routing Technique Articles' Trend by Subject

4.5 Trend of Optimization Routing Techniques by Sub-Topics

The percentage of publications in each of the six categories of ACS optimization routing technique subjects is shown in Figure 5. In the ACS optimization area, single node failure accounted for 27% of publications, followed by multiple node failure (22%), and single link failure (20%). Failure of many node-links was the least discussed topic, making just 13% of the total.

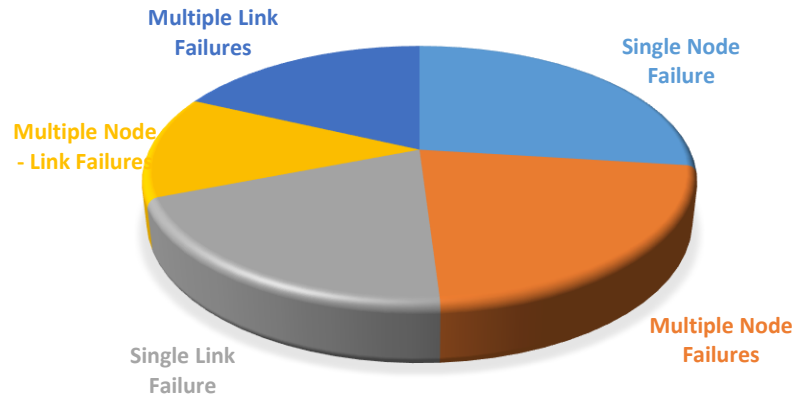


Figure 5 Percentage of Publications Using the ACS Optimization Routing Technique

The percentage of articles in each of the six categories of evolutionary algorithm optimization technique is shown in Figure 6. Of all articles, single node failure accounted for 25% of studies in the evolutionary algorithm optimization area, while multiple node failure made up 23% of the papers. With 11% of all strategies, multiple node-link failure was the least popular topic.

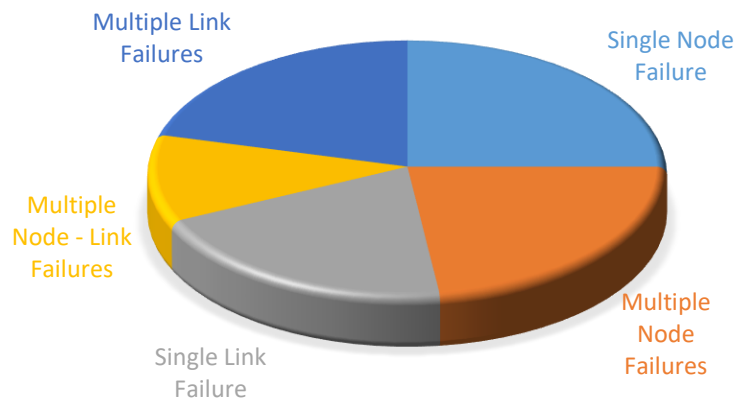


Figure 6 The Proportion of Papers utilizing Evolutionary Algorithm Optimization Routing Technique

The percentage of articles that fall into each of the six PSO optimization technique groups is shown in Figure 7. PSO's total publishing was 38% accounted for by single node failure and 21% by single link failure. Failure of many node-links was the least discussed topic, making just 7% of the total.

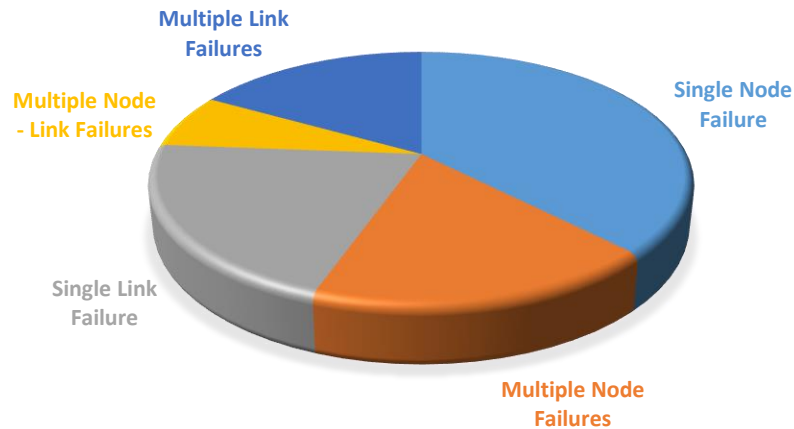


Figure 7 PSO routing Technique Paper Percentage

The percentage of articles in each of the six categories of subjects using the AODV optimization technique is shown in Figure 8. Thirty percent of AODV's publications were caused by multiple link failures, compared to thirty percent by single link failures. The optimization method takes into account both single- and multiple-node failures. Only fourteen percent of the publications discussed multiple node failure. Articles about the failure of numerous node-links were absent.

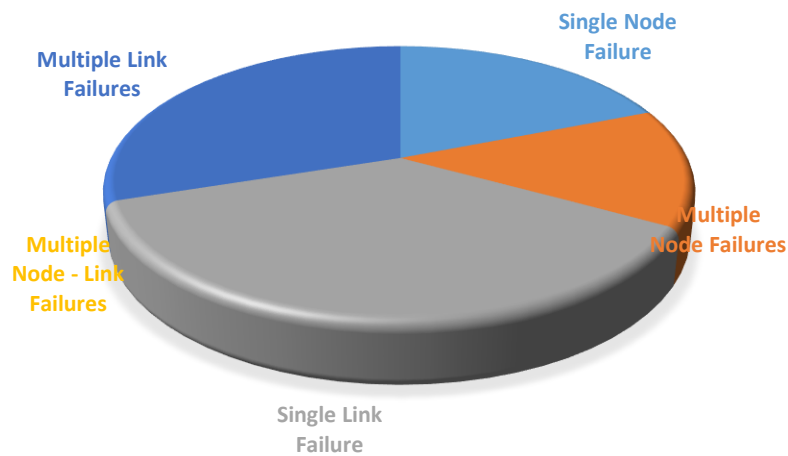


Figure 8 Percentage of Articles Using the AODV Routing Technology

The percentage of publications in the six categories of TORA optimization technique themes is shown in Figure 9. With single link failure accounting for 40% of the total and multiple link failure accounting for 30%, TORA focused on these two types of failures. The failure of many nodes and multiple node-links was not covered in any articles. Additional clarifications are provided in Figure 9.

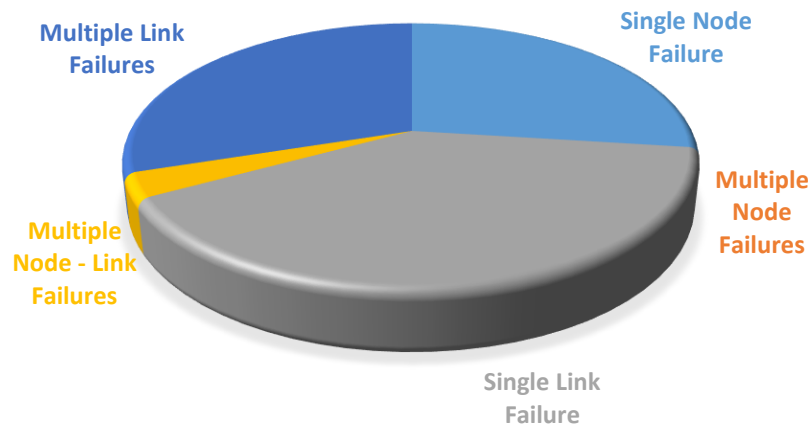


Figure 9 Percentage of Articles Using the TORA Routing Technique

The percentage of articles in each of the six categories that made up the ADPV optimization method themes is shown in Figure 10. ADPV focused on the failure of a single node, which was responsible for 60% of articles, and multiple nodes, which was responsible for 40% of them. There were no articles about any form of link failure—single, multiple, or multiple node-links.

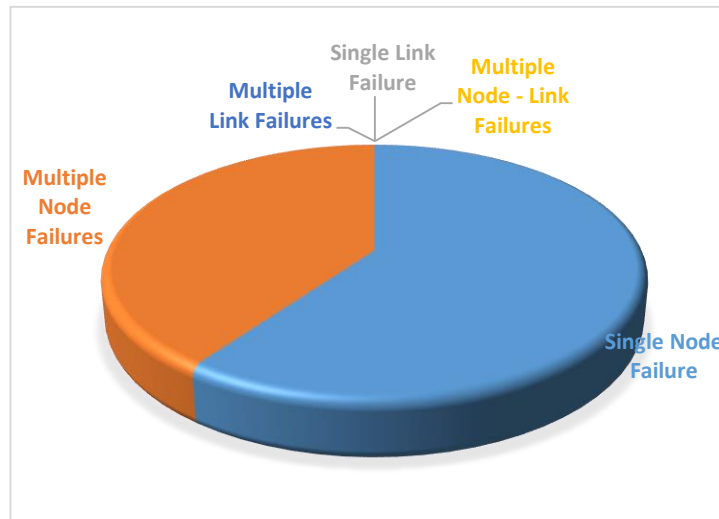


Figure 10 Percentage of Articles Using the ADPV Routing Technology

4.6 Performance evaluation metrics

Measures such as throughput, packet loss rate, complexity, transmission time, packet delay rate, and capacity are used to assess a wireless network's performance. The effectiveness and efficiency of the network are influenced by these elements. The following should be considered while evaluating performance metrics:

- i. **Throughput:** Is the quantity of digital data units that a system can process in a specific length of time. It is suitable for many other kinds of systems, such as network systems.

- ii. Transmission delay is the amount of time that the physical layer at the source needs to move packets over the channel. The number of active sessions, the transmission capacity of the link, the MAC access delay, and the OS's context transition are some of the factors that contribute to this delay.
- iii. Transmission Time: Transmission time is the amount of time a packet takes to go from the sender to the recipient.
- iv. Packet Delay Rate: The delay brought on by the data rate of the network.
- v. Complexity: is the length of the input divided by the amount of time it would take an algorithm to run. It determines how long it takes for each algorithmic code expression to execute.
- vi. Packet Drop: Routers must lose some packets because of congestion. Before, this was done at random, which led to the performance of multimedia traffic being inefficient.
- vii. Bandwidth Usage: The capacity of a network to transfer data over the internet or between devices in a specific length of time is referred to as bandwidth. More bandwidth allows for the faster transmission of data.

Using the journals database, we examined the most used performance metrics for assessing a wireless network's performance between 2010 and 2020. A few of the measures used to evaluate the performance of wireless networks are shown in Figure 11. Among the indicators are throughput, packet drop, time complexity, bandwidth utilization, packet delay rate, transmission time, and transmission delay. The most often used metrics in the assessment of wireless networks are throughput and bandwidth utilization, with packet delay rate coming in second. Transmission delay is also used in most cases. Complexity is the factor that contributes the least to wireless network performance assessments.

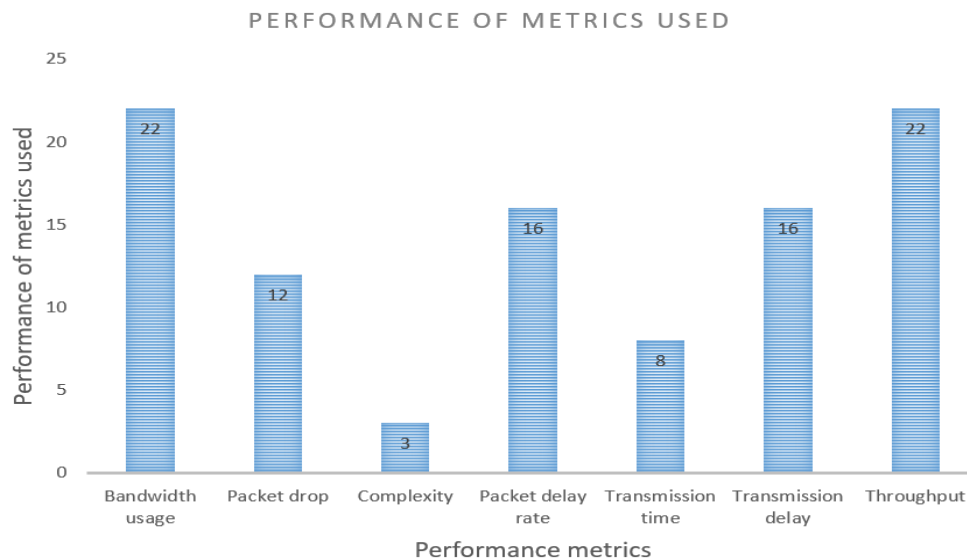


Figure 11 Metrics for Evaluating the Performance of Wireless Networks

4.7 Future Research Areas in Swarm Optimization

4.7.1 Wireless Network Routing

Future researchers should expect significant implications from the results of 11 years of study on optimization routing algorithms. At least 20 articles in wireless network research will be published

between 2012 and 2020 (see Figure 2), with a distinct trend toward route optimization. Unfortunately, the uptake in the ADPV and TORA areas has not been well investigated because there are so few papers available (see Figure 4). The seven wireless network themes that wireless network routing protocol writers need to take into account when assessing new routing protocols are shown in Figure 1, along with the optimal routing strategies that work for wireless networks. According to the results shown in Figures 5–10, wireless network optimization routing approaches are needed to respond to the following:

- (i) ACS routing techniques' subtopic, in particular the failure of multiple node-links.
- (ii) Subtopic of routing techniques using evolutionary algorithms, with a focus on multiple node-link failure.
- (iii) PSO routing methods' related subjects, in particular (a) multiple link failure and (b) multiple node-link failure.
- (iv) Subtopics related to AODV routing techniques, specifically (a) multiple nodes and (b) failure of multiple node-links.
- (v) Subtopics related to TORA routing techniques, specifically (a) multiple nodes and (b) failure of multiple node-links.
- (vi) ADPV routing techniques' subtopics, in particular (a) single link, (b) multiple links, and (c) failure of multiple node-links.

Time complexity is rarely utilized when testing the effectiveness of optimization routing schemes, as Figure 11 illustrates. The percentage of throughput and bandwidth use is higher. Future researchers should look at the following intriguing research problems in the less-explored optimization routing subtopics, where there are less published articles:

- (i) How can ACS techniques be created to endure the failure of many node-links in wireless networks?
- (ii) How can solutions based on evolutionary algorithms be created to ensure the survival of wireless networks in the event of multiple node-link failures?
- (iii) How far can PSO techniques be established to withstand the transmission of messages in IoT wireless networks when there is a failure of multiple links (a) and (b) multiple node-links?
- (iv) How much can AODV techniques be created to survive cell phone wireless networks when sending video data amid (a) multiple nodes and (b) multiple node-link failures?
- (v) How much can be done to build TORA solutions to withstand sensor wireless networks that are vulnerable to (a) many nodes and (b) multiple node-link failures that transmit speech data?
- (vi) How can ADPV methods be created to ensure that multimedia data transmitted via MANET wireless networks is resilient to failures in (a) single links, (b) multiple links, and (c) multiple node-links?

5. Conclusion

The aim of this study was to investigate different optimization routing methods in wireless networks to find gaps that could be used as a basis for further research by future wireless researchers. Sub-themes were identified and created from the failures of a single link, a single node, multiple links, multiple nodes, and multiple node-links. Utilizing the sub-themes, a wireless network routing system was built. The literature has not given much attention to ADPV and TORA optimization strategies in wireless networks. Less focus has been placed on multiple node failures as well as multiple node-link failures. It is important to

investigate multiple node-link failure, particularly in light of possible ADPV approaches, as it has not gotten much attention. Future research could focus on creating routing protocols that are accessible, effective, and robust while taking into account all quality-of-service requirements. This research is anticipated to motivate designers of wireless network protocols to explore alternative optimized routing strategies that take quality of service attributes into account while developing new routing protocols.

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