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Reliable Communication in Post Disaster Environment Using Delay Tolerant Network (DTN)

Chandrima Chakrabarti [1], Bingshati Mondal[2], Arindam Das[3], Nabanita Das[4], Krishnendu Roy[5], Disha Basu[6], Swapnendu Kolay[7], Rakesh Ghosh[8]

[1] Computer Science and Engineering Data Science Department/Associate Professor, Narula Institute of Technology, Kolkata, India , chandrima.narula@gmail.com
[2]Computer Science and Engineering Department/Assistant Professor, Narula Institute of Technology, Kolkata, India,
[3]Computer Science and Engineering Data Science Department/Assistant Professor, Narula Institute of Technology, Kolkata, India
[4]Computer Science and Engineering Data Science Department/Associate Professor, Narula Institute of Technology, Kolkata, India
[5]Computer Science and Engineering Department/B.TECH Student, Narula Institute of Technology, Kolkata, India, roykrishnenduroy01@gmail.com
[6]Computer Science and Engineering Department/B.TECH Student, Narula Institute of Technology, Kolkata, India, dishabasu07@gmail.com
[7]Computer Science and Engineering Department/B.TECH Student, Narula Institute of Technology, Kolkata, India, swapnendukolay@gmail.com
[8]Computer Science and Engineering Department/B.TECH Student, Narula Institute of Technology, Kolkata, India, rakeshghosh200224@gmail.com

Abstract— Natural disasters like earthquakes, landslides, floods, and cyclonic storms cause severe damage to local communication facilities resulting in delays in rescue operations. In those situations, reliable communication establishment is very crucial to cooperating with rescue operations. Disaster responders require a high volume of accurate data with less disruption time. These needs can only be fulfilled through Delay Tolerant Network (DTN), as this paper proposes the use of reliable communication in a post-disaster environment. Implementing a Delay Tolerance Network (DTN) communication system and evaluating the efficiency of the rate of data transmission, network coverage, and network security in terms of data encryption-decryption, amount of energy to be consumed, considerable disruption and noise in the data during transmission. This paperwork proposes the DTN system which gives a high rate of data transmission, low energy consumption, wide network coverage, node base encryption-decryption security and low delay or disruption during data transmission. To check the efficiency of the designed DTN-system model Opportunistic Network Environment (ONE) is used.

Keywords: Delay or Disruption Tolerant Network (DTN), energy consumption, data transmission rate, network coverage, node encryption-decryption security, post-disaster management.

I. INTRODUCTION

In a post-disaster environment, establishing reliable communication to communicate and data sharing is not an easy task due to damage to traditional network connection infrastructure. The Delay Tolerance Network is known for its resilient nature relying on a structure and adaptable protocols to ensure uninterrupted communication and message delivery with limited infrastructure. The network operates on the

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principle of having delay tolerance for disruptions by utilizing redundancy self-repair mechanisms and mesh networking to create an infrastructure for communication. Key aspects of DTN include responsive communication, scalability, and adaptability to changing conditions. The system incorporates technologies like radio and opportunistic network forwarding, message bundle is forwarded to the first opportunity available in the random walk [1] to maximize resource utilization. This makes it particularly suitable for disasters where conventional infrastructure may be severely damaged. Our research involves implementing DTN through simulations and practical testing to validate its effectiveness in disaster scenarios. Through testing, we demonstrate how the network can successfully establish and maintain communication links, between emergency responders, relief organizations, and affected communications. This research contributes to the advancement of communication solutions, enhancement of the data transmission rate, node-to- node encryption-decryption, and power efficiency, for situations after a disaster, making sure that high volume accurate data can be shared efficiently and dependably during times of emergency. End-to- end encryption is employed to secure the content of messages, ensuring confidentiality even if messages are intercepted during their journey through the DTN and the encryption node can only be accessed by the sender, decryption node accessed by the receiver. Adaptive encryption algorithms allow nodes to choose appropriate encryption methods based on available resources to protect from malicious and unauthorized access nodes in the DTN routing protocol. The Delay Tolerance Network emerges as an approach to strengthen communication resilience ultimately assisting inefficient response and recovery efforts, in a post- disaster environment. Pre-planned alternatives like secure Delay Tolerant Networks (DTNs), Mobile Ad-Hoc Networks (MANETs), Wireless mesh networks (WMNs), and Vehicular Ad-Hoc Networks (VANETs) can be used and they are crucial for saving lives in disaster-hit areas where traditional network system fails to save lives. We propose the power efficient, high rate of data transmission, node-encrypted, low network latency Delay Tolerant Network (DTN) system model to establish reliable communication in disaster- disrupted areas.

II. Related Work

Disaster causes severe damage to the traditional network infrastructure leading to poor communication in that area. Taking rapid rescue and relief action, the traditional network system falls completely due to its physical complexities whereas the wireless routing system is fast and reliable in establishing communication in post- disaster environments to protect lives. The Delay Tolerant Network (DTN) was launched as an Inter- Planetary Network (IPN) to connect arbitrary nodes located on various alien planets. Traditional routing protocols fail to serve delay-tolerant systems due to high latency rates, high rates of error, and high noise frequency. IPNs are named in special case scenarios as Intermittently Connected Networks (ICNs), which can be added to terrestrial networks to act as store-and-forward mechanisms [2]. Bundle forwarding takes place only when the next appropriate hop comes. Big buffer space is required because the next hop is unknown. To increase the bundle delivery probability, a technique called flooding is used. In flooding, message copies are used to send more than one node multiple times as a result buffer space overflows, buffer space is vital for this type of network [2]. DTN uses the ICN protocol stack [3] and also provides high storage capacity, parallel message forwarding, node encryption and many more communication schemes to handle long-term disruption where traditional TCP fails to do so. The problem of sending bundle packets from one place to another with the help of gateways and adopting according to variable delays, bandwidth mismatch a new protocol is required. The IRTF DTNRG developed the most popular bundle protocol which is inspired by the SMTP protocol [4]. The bundle protocol combines data and control signals to form a single entity and transmit it over DTN is known as bundle. There are many research works done regarding the establishment of new message forwarding protocols over existing protocols being evaluated based on bundle packet delivery rate, and energy efficiency to improve the overall performances of the system network architectures in disaster- stricken areas. The previously contributed research works are discussed in given section below. The performance of forwarding protocols (PRoPHET, MaxProp, TTR and Epidemic) is analysed by

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authors in [5] and showed that MaxProp has the best message delivery rate whereas TTR has the best in cost and overhead. The performance of message delivery depends upon the situation where the DTN is deployed. In [6] authors differentiate between the forwarding protocols (Direct delivery, wait and PROPHET, Binary spray, Epidemic, First contact and Spray and wait) and none of the protocols justified the message delivery fairness between nodes and simulation results. The message forwarding protocol needs to be performance efficient as well as energy efficient. As in the disaster network system, energy efficiency is a vital element to sending and receiving crucial data in time, in such cases replacing the battery or charging the assigned nodes is not possible. Authors in [7] proposed two new energy-efficient forwarding protocols (PropTTR and PropNTTR). The reduction in the number of retransmissions and discarding the bundle after it reaches its final destination can reduce energy consumption and help to decrease the forwarding overhead of the nodes for efficient working. Besides power and energy efficiency, forwarding messages need to be delivered in priority order to convey the critical message first followed by other messages based on their priority order. In [8] the authors showed a DTN forwarding protocol which assigns an order of priority to the messages and forwards them based on their priorities. Priority- based message forwarding is very advantageous in opportunistic networks where it does not follow the maintained route, continuously finding the best route to forward critical messages over low-priority ones. The opportunistic network is efficient for the retransmission of the bundle to the nearest node. The authors of [9] proposed DistressNet, an Ad- Hoc wireless opportunistic network architecture designed for disaster response through distributed sensing which minimizes the energy consumption of the nodes. It leverages bodynets and teammates to provide localization, monetarization, and communication capabilities to first responders and support staff within a disaster area. DistressNet utilizes a combination of routing protocols to ensure connectivity and energy frequency, addressing challenges such as high connectivity and node mobility. It also incorporates cross-layer optimization of MAC and routing protocols to manage network congestion effectively. In [10] authors proposed a DTN MapEx which is a distributed computing system that generates a situational map of the disaster-hit area according to the system architecture. The rescue team act as nodes and follows the map to reach the assigned areas for retrieving the triage data [11]. Nodes send the data over DTN to the pre-selected computing node, and after receiving the data generate a disaster map through distributed computing and is routed back to the node. The generated map is used to point out the critical areas and take the necessary rescue services for efficient relief work in the disaster area. The authors in [12] proposed the simulation map to evaluate the performance of social-based routing protocols for sending emergency messages within the Rajshahi University (RU) campus when traditional communication is disrupted. They analyze the performance of DTN based on delivery ratio, average latency, cost of transmission, and average hop count in a particular situation when message size and node density are increased. The simulation result showed that dLife performs better in terms of delivery ratio, whereas the Spray-and- Focus outperforms all the performance test cases. The paper provides valuable insights into the practical implementation of DTN in demanding settings, highlighting its potential advantages in real-life situations using more power-efficient algorithms. The aim is to enhance situational awareness, automate updates, and improve communication in disaster scenarios. However, challenges such as the unpredictable nature of disasters and complex communication requirements exist. The paper emphasizes the establishment of reliable communication networks in disaster areas to bridge connections between rescue operations and fast responders. Various models and protocols are proposed to enhance communication efficiency, including the deployment of mobile and ad hoc networks, relay nodes, and a novel movement model based on tactical analysis.

III. SYSTEM MODEL

In disaster response operations, the ability to communicate effectively and coordinate efforts is crucial for saving lives and providing timely assistance to victims. The diagram outlines a structured framework that includes essential components such as the Control Room, Control Server, Wi-Fi Tower, and various rescue teams. These elements work collaboratively to ensure real-time data sharing, resource allocation, and strategic decision-making in the face of emergencies.

To enhance the security of communications within this framework, the RSA (Rivest-Shamir- Adleman) Cryptography Algorithm is implemented for encryption and decryption of sensitive information. RSA is a widely used public-key cryptographic system that ensures secure data transmission by encrypting messages with a public key, which can only be decrypted by the corresponding private key. This robust encryption method protects the integrity and confidentiality of communications between the control room, rescue teams, and medical personnel, thereby mitigating the risks of unauthorized access and ensuring that critical information remains secure throughout the disaster response process.

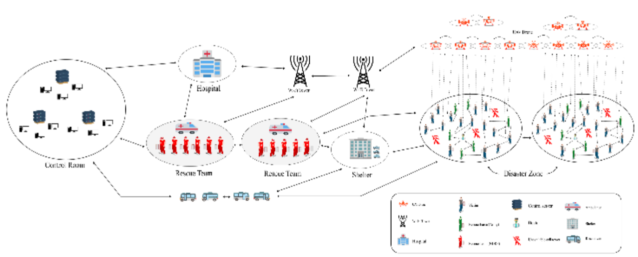

Figure 1. Disaster Management using DTN

Disaster Zone:

The Disaster Zone is the area affected by the emergency, where rescue operations are conducted. It is often chaotic and may present numerous challenges, including damaged infrastructure and hazardous conditions. Rescue teams operate in this zone to locate and assist victims, assess damage, and provide immediate care. The disaster zone is where the effectiveness of communication and coordination is put to the test, making the roles of the control room and other nodes critical. The data transfers as a encrypted bundle to the victims, and rescue nodes present in the disaster zone.

Victim:

Victims of the disaster may have mobile phones that can be used to communicate their location and needs. This direct line of communication can be vital for rescue teams to locate and assist individuals in distress. Victims can provide real-time updates on their condition and surroundings, helping to prioritize rescue efforts and ensure that help reaches those who need it most.

Control Room:

The Control Room serves as the central hub for managing disaster response operations. It is staffed by trained personnel, separate control servers, who monitor real-time data, coordinate rescue efforts, and facilitate communication among various teams. Equipped with advanced technology, the control room analyzes incoming information, tracks resources, and makes strategic decisions to optimize response efforts. It plays a critical role in ensuring that all teams are informed and that resources are allocated efficiently.

Hospital:

Hospitals are vital nodes in the disaster response framework, providing medical care for victims. They receive information about incoming patients from the control room and prepare to receive casualties. Hospitals coordinate with rescue teams to ensure that medical personnel and resources are ready for immediate action. They also play a role in triaging patients based on the severity of their injuries, ensuring that those in critical condition receive prompt attention.

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Shelter:

Shelters provide temporary housing for victims displaced by the disaster. They are crucial for ensuring the safety and well-being of individuals who have lost their homes. Shelters are often set up in safe locations and are equipped with basic necessities such as food, water, and medical care. Coordination between shelters and the control room is essential to manage the flow of displaced individuals and provide adequate support.

UAV- Drone:

UAV-drones, are increasingly used in disaster response for aerial surveillance and data collection. They can quickly assess damage, locate victims, and provide real-time imagery of the disaster zone. Drones equipped with cameras and sensors can relay critical information back to the control room, enhancing situational awareness and aiding in decision-making. Their ability to access hard-to-reach areas makes them invaluable in search and rescue operations. The data sent and received in encrypted form, decrypt and process accordingly.

Rescue Team (NDRF):

The National Disaster Response Force (NDRF) is a specialized team trained to respond to various disasters. Equipped with mobile phones, team members can communicate directly with the control room and other rescue personnel. They gather information on victim locations, assess the situation on the ground, and relay critical updates back to the control room. Their mobile devices enable them to access real-time data and coordinate their actions effectively, ensuring a swift and organized response.

Rescue Force (Army):

The Army's rescue force is often deployed in large-scale disasters to provide additional manpower and resources. Equipped with mobile phones, they can communicate with the control room and coordinate their efforts with other rescue teams. The Army's presence enhances the overall response capability, providing logistical support, security, and specialized skills in challenging environments.

Rescue Van:

Rescue vans are equipped vehicles that transport rescue personnel, essential materials, and medical supplies from control station, hospital to the disaster zone. They are essential for moving resources quickly and efficiently, allowing teams to reach victims in need of assistance. Rescue vans may also serve as mobile command centres, equipped with communication tools to stay connected with the control room and coordinate efforts on the ground.

Doctor:

Doctors play a crucial role in the medical response to disasters. They may be stationed at hospitals or deployed to the disaster zone to provide immediate medical care to victims. Doctors assess injuries, administer treatment, and make decisions regarding patient transport to hospitals. Their expertise is vital in triaging patients and ensuring that those with life-threatening conditions receive urgent care.

Ambulance:

Ambulances are critical for transporting injured victims from the disaster zone to hospitals. They are equipped with medical supplies and staffed by trained personnel who can provide health support. Coordination between ambulances and the control room is essential to ensure that they are dispatched efficiently and that hospitals are prepared to receive patients.

Wi-Fi Tower:

The Wi-Fi Tower is essential for maintaining communication in areas where traditional cellular networks may be compromised. It provides a stable internet connection that enables rescue teams, the control room, and hospitals to communicate seamlessly. The Wi-Fi tower supports secure data transmission from UAV drones and allows for real-time updates, ensuring that all parties involved in the response are connected and informed.

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Figure 2: Flowchart of the system

Algorithm: Post-Disaster Communication and Rescue Framework
Input:

- global:NETWORK_STATUS, THRESHOLD_ENERGY, THRESHOLD_QUALITY

1. Define DeviceData class
deviceID
deviceType (rescue, victim, control room)
batteryLevel
location (x, y)
2. Define RescueData class
teamID
teamType (NDRF, Army)
rescueStatus
location (x, y)
3. Define CommunicationData class
signalStrength
routeQuality
networkDelay

Output:
- Efficient rescue nodes coordination and optimized communication routes finding

Post-Disaster Communication & Rescue
1. If NETWORK_STATUS == DOWN and batteryLevel < THRESHOLD_ENERGY
2. exit() (network failure and low energy)
3. If detectSignal(deviceID):
4. if routeQuality > THRESHOLD_QUALITY:
5. networkOptimization(devicedata, routeQuality) (Form optimized communication network using "devicedata" object and "routeQuality")

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6. else:
7. routeQualityChecker(routeQuality,devicedata) proceed next
8. If deviceType == victim:
9. call rescueResponseTeam(devicedata,routeQuality)
10. if victim_Condition == “minorly_injured” :
11. call localDoctorsTeam()
12. else if victim == “moderately_injured”:
13. provide immediate treatment and shift them to shelter()
14. else
15. call ambulance() for “critical_situation”
16. log successful rescue to the controlStation using LiveSaviour(“successful”)

This algorithm is designed to find out the victim nodes stuck in disaster prone areas with help of rescue nodes. The communication is built in such a way to establish delay tolerant network using Wi-Fi towers, UAVs (drones, vehicles) to ensures faster rescue operations. The checking starts with victim node’s system’s battery level, if network status is down and batteryLevel is less than threshold energy then it will exit if not then proceed with the next processes. The function detectSignal is called if having valid deviceID, if it’s true then it goes for nested checking Where routeQuality is checked first based on that network optimization or best route finding with the help of with the help of drone’s imagery data. In the next stage of algorithm it’s checking for the deviceType is victim or not. If the devieType is detected as victim then we call response team to initialize rescue operations. Based on the victim conditions we call for required functions to facilitate treatment. At the end of the algorithm we log successful message to the control station after completing the rescue operations.

IV. CONCLUSION

Disasters can be natural or man-made and are unavoidable events with greater impact. Through efficient proactive disaster management, post disaster relief work can be effective. This paper proposes the utilization of Delay Tolerant Networks (DTN) in disaster-hit areas efficiently and effectively. It presents a sturdy DTN system model crafted to ensure dependable communication in the aftermath of disasters. Furthermore, this system model works on store-and-forward mechanisms and prioritizing energy efficiency, and data transmission rates to enable efficient coordination among disaster responders and affected communities. Through simulations, the DTN system model’s effectiveness is showcased in Figure I in providing high-volume, accurate data transmission through energy-efficient message forwarding protocol while minimizing energy consumption and disruption. t, the system integrates node-based encryption-decryption security measures to protect sensitive information during transmission. In situations where traditional network infrastructure is compromised, the DTN system emerges as a crucial tool for bolstering communication resilience and facilitating efficient response and recovery efforts. This research contributes to the advancement of communication solutions tailored for post-disaster environments, ultimately aiding in the preservation of lives and mitigation of damage.

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Authors Profile

Author 1: Dr. Chandrima Chakrabarti is an Associate Professor and Head of the Department of the Department of Computer Science and Engineering (Data Science), Narula Institute of Technology, Kolkata, India. She is an accomplished author. Dr. Chakrabarti received her Ph.D (Technology) degree in Computer

Science and Engineering from Maulana Abul Kalam Azad University of Technology, West Bengal, India in 2022. Earlier she received M. Tech. in Computer Science & Engineering and B. Tech. in Information Technology, degrees from Maulana Abul Kalam Azad University of Technology (formerly West Bengal University of Technology), India. She has around 16 years of experience in academics and research. Dr. Chakrabarti has published more than 25 research articles in international journals, conferences, book chapters including 1 Indian Patent. Her research interests include database management systems, data science and its applications, reliable communication in Delay Tolerant Networks, Opportunistic Networks, Applications of Mobile Computing in Disaster Management, Mobile Ad hoc Networks. Dr. Chakrabarti is an active member of professional organizations like IEEE.

ıti Mondal Assistant professor of Computer ring department at Narula Institute of lone B.Tech in 2017 from MAKAUT and MAKAUT, W.B. Ms. Mondal has published rticles in international journals, conferences, arch interests include database management systems, Computer Networks, Applications of Mobile Computing in Disaster Management, Mobile Ad hoc Networks etc.

Author-3: Mr. Arindam Das earned his B.Tech. and M.Tech. degrees in 2021and 2023, respectively, and is currently pursuing a Ph.D. He is working as an Assistant Professor in the Department of Computer Science and Engineering (Data Science)at Narula Institute of Technology,

Agarpara, since 2024. Previously, he was an Assistant Professor at Supreme Knowledge Foundation in 2024 and also served as an Assistant Professor in the Department of Computer Science and Engineering at Swami Vivekananda University. He has published several conference papers, patents, and copyrights, including a book on Natural Language Processing.

Author 4: Dr. Nabanita Das is an Associate Professor in the

Department of Computer Science and Engineering Data Science, Narula Institute of Technology, Kolkata, India. Her research interests include Machine Learning, Deep Learning, IoT, Image Processing, Pattern Recognition Computer-Aided Diagnosis, etc. She received the P. hD. degree from GIET University, Orissa, India, and completed M.Tech. and B.Tech. under MAKAUT University. She has more than fifteen years of teaching experience.

shnendu Roy is a B.Tech student in Computer hnology (CGPA 8.54) with a strong research focus mmunication in Post-Disaster Management using Network (DTN), demonstrating a 55% reduction efforts through effective node implementation. He has presented his research at an international conference. In addition to his research work, he has developed projects including a real-time messaging system, tweet management platform, to-do app, and URL shortener. He is proficient in full-stack web development using ReactJS, NodeJS, ExpressJS, Django, MongoDB, PostgreSQL, and SQLite3, with expertise in data structures, algorithms, and artificial intelligence.

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Author 6: Disha Basu is currently pursuing her B.Tech in Computer Science and Technology at Narula Institute of Technology, with a strong academic record (GPA: 8.60). Her research interests include Artificial Intelligence, Database Management Systems, and Network Communication. She secured a top 5% rank in an NPTEL exam on AI and has contributed to the field by presenting a paper on "Reliable Communication in Post-Disaster Management using Delay Tolerance Network (DTN)" at an international conference. She is dedicated to exploring innovative solutions for efficient and resilient communication systems in disaster scenarios.

onendu Kolay is a B.Tech student in Computer echnology at Narula Institute of Technology, third year. Since his first year, he has been t research paper-related work, focusing on areas such as data structures, algorithms, and artificial intelligence. He is actively involved and contributing in UI/UX designs and frontend development. He is passionate about creating real-world solutions. He is a part of international conference where "Reliable Communication in Post-Disaster Management using Delay Tolerance Network (DTN)" is presented.

esh Ghosh is a B.Tech student in Computer echnology at Narula Institute of Technology, currently in his third year. Since his first year, he has been passionate about research paper-related work, focusing on areas such as data structures, algorithms, and artificial intelligence. He is also actively involved in competitive programming on platforms like LeetCode and Codeforces. He is a part of international conference where "Reliable Communication in Post-Disaster Management using Delay Tolerance Network (DTN)" is presented.