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Editor-in-Chief

Dr. Izzat Alsmadi

Texas A&M, San Antonio, USA

Research Interest: Cyber Intelligence, Cyber Security, Software Engineering, Social Networks

Bio: Izzat Alsmadi is an Assistant Professor in the department of computing and cyber security at the Texas A&M, San Antonio. He has his master and PhD in Software Engineering from North Dakota State University in 2006 and 2008. He has more than 100 conference and journal publications. His research interests include: Cyber intelligence, Cyber security, Software security, software engineering, software testing, social networks and software defined networking. He is lead author, editor in several books including: Springer The NICE Cyber Security Framework Cyber Security Intelligence and Analytics, 2019, Practical Information Security: A Competency-Based Education Course, 2018, Information Fusion for Cyber-Security Analytics (Studies in Computational Intelligence), 2016. The author is also a member of The National Initiative for Cybersecurity Education (NICE) group, which meets frequently to discuss enhancements on cyber security education at the national level.

In the modern day, producing new software requires utilizing the most cutting-edge tools and techniques. Due to the growing complexity of technology, effective software development increasingly depends on well-managed development processes. A software development project has its own distinctive features. There is no one software process model that can manage all the many types of software development projects because there are so many distinct sorts of them. Whatever paradigm is utilized, there will always be limitations. The goal of the healthcare system security and its application is to provide the best possible clinical treatment and to receive the best possible assistance for patient care and security. The healthcare structures need to support good health, honest economic contribution, and top-notch services. The healthcare business has quickly expanded over the past ten years, especially in developing nations. Implementing medical software programs is one of the most significant future challenging scenarios in the healthcare industry. Utilizing healthcare data structures will expand the availability of fitness services, improve patient satisfaction with care, and reduce clinical errors. We are providing a fresh approach to software engineering for healthcare programs called SDLC as a result. This approach is intended to address the software improvement issues and challenging circumstances that exist outside the healthcare area. The need to create durable, steady, and high-performing healthcare equipment is the main driver behind the development of a new software engineering methodology for the industry, including SDLC.

DOI:

Mahmud Hasan (Dept. of Computer Science, Jahangirnagar University, Dhaka, Bangladesh), Mohammed Mofizur Rahman, Arian Rahman, Md. Ahasanul Islam and Md. Mazid-Ul-Haque (Dept. of Computer Science, American International University-Bangladesh, Dhaka, Bangladesh)

Deployment of a Serverless Web Application using AWS services

[1]Harsh Anand, [2]Satyam Biradar, [3]Naveen Prajapat, [4]Prof.Shripad G Desai
Electrical Engineering, Bharati Vidyapeeth(Deemed to be University)College of Engineering Pune, India
naveen.prajapat-coep@bvucoep.edu.in

Abstract— In this digital era, the emergence of many smart applications makes the human lives in away more smart but at the same time it also increases the amount of expenses to an unprecedented rate. Today in the world of server computing it requires lot of infrastructure for an organization to work so we are employing server less computing for the organization which is cost efficiently for them and also faster than server computing in the modern era. Server less computing allows us to compute without thinking about the server management as it is done at the back-end by the cloud computing service provider.

Keywords—Amazon API Gateway, Amazon Dynamo DB, Amazon S3, AWS, AWS Lambda, Cloud Computing, Cloud Storage, S3,

I. INTRODUCTION

In today's world server computing is common seen practice for organization to work but due to server computing it costs expensively for organization to work on server where they have to buy server which costs them a lot in the sense of expenses for the organization. As in many organizations many applications are required to run for once or twice a month like salary calculation of an employee in an organization so there is requirement of his Name,bank account no. , company identity no., etc so that the salary of the person can be calculated as per the required factors for the salary calculation such as hours worked, leave taken in the month etc.So for such small application organization have to buy server which are very costly because they are physical devices either organization have to buy solely or use cloud services such as Amazon Web Services(AWS), Microsoft Azure,Google Cloud Platform(GCP) to buy servers which costs them highly but we have solution to these as we are using server less computing which is cost effective and is more reliable than server computing in the modern world of digital management of the data.[2][4]

We have understood about server less computing as the name suggests that server less means it is not based on servers. It works freely from servers in our presence and is using servers at the back-end. It is managed by the cloud platform automatically. We do not have to take a look for the servers while we are performing our task for the organization we are working in. It is done by the service provider automatically we have to just look for our code in the Lambda function and take care of Application programming interface (API) gateway we are using for our organization So server less infrastructure does not require any servers in our presence. Developers can focus on developing code that serves the customer. They can focus on core product and business logic. Server less applications doesn't require you to manage any different servers. We can focus on core product and business logic. Instead focusing on operating system access control, OS patching, scaling the servers etc.[4]

A. AWS SERVICES USED FOR SERVER LESS COMPUTING

There are four major deployment services used for server less web application namely Amazon Application programming interface (API), AWS Lambda, Amazon DynamoDB, Amazon Simple Storage Service(S3) [4].

1) Amazon Application Programming Interface(API)

API means Application programming interface. It is used to access data, business logic from backed services. Means it allows two applications to interact with each other. It is an system which allows to communicate with other system either hardware or software as it works as an bridge between the system and other devices. API Gateway is a fully managed service it helps developers to create, publish, maintain, monitor and secure API at any scale .API act as front door for application to access data, business logic or functionality from your backed services. It can handle concurrent API calls ,including traffic management ,CORS support,authorization and access control.[2][7]

2) AWS Lambda

It is server less computing mechanism which helps you to run your function code.As per the specific work you want to do for your application you want to work on. In AWS lambda we create function in language we want to write in and than AWS lambda performs or executes the task it is assigned for. It can perform any type of computing. Each lambda function runs in its space. Each function is provided with necessary RAM and CPU . Customers is charged for only the amount of function runs during the process by the cloud platform the organization is using.[3][4][8]

3) Amazon Simple Storage Service (S3)

It is an simple storage service that stores the data in the form of buckets. It is an web service provided by AWS. It is used to store and receive data from anywhere on the web. It is secure place to store the data. You can store images ,word files, PDF files, etc. as it is an object storage service. You can store data up-toa maximum of 5TB. Files are stored in form of bucket .A bucket is like a folder which we usually see in our PC,mobile etc. Advantages of amazon S3 is create buckets, store data in buckets, download data, provide permissions, provide standard interfaces, provide security. S3 object based objects consists of key,value,version id, meta data, sub resources, access control information. [8][9]

4) Amazon DynamoDB

It is a fully managed no SQL database service.It gives fast and reliable performance with scalability you don't have to worry about hardware property setup and configuration software patching or scaling.It also offers encryption which removes the burden of protecting sensitive data. With DynamoDB you can create database table which store and receive any amount of data and serve any level of traffic you can scale up and scale down your tables capacity without down time or performance degradation.You can use AWS management console to monitor resource utilization and performance matrix. It provides on demand back-ups . It helps to protect your tables from accidental write or delete operations. It has high availability and durability.[4][5]

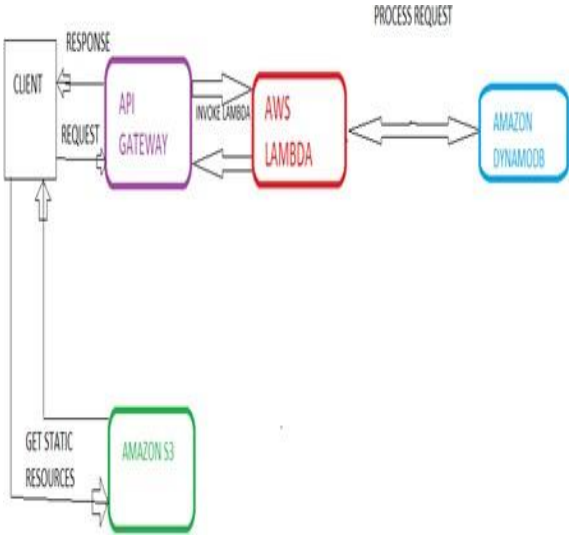

Figure1: Block diagram of server less web application

A) We created two API given as follows:
1. Get Employee Details By Email
2. PostCustomerDetails

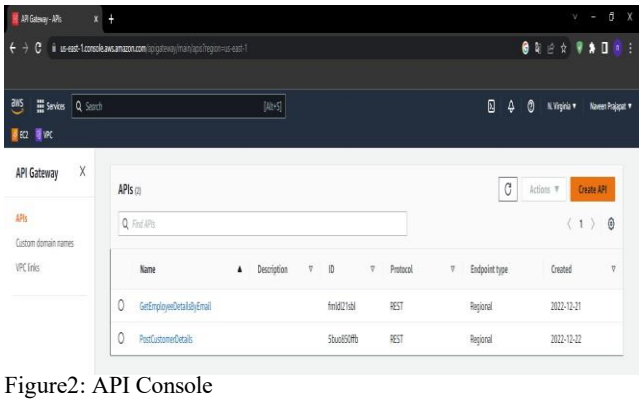

Figure2: API Console

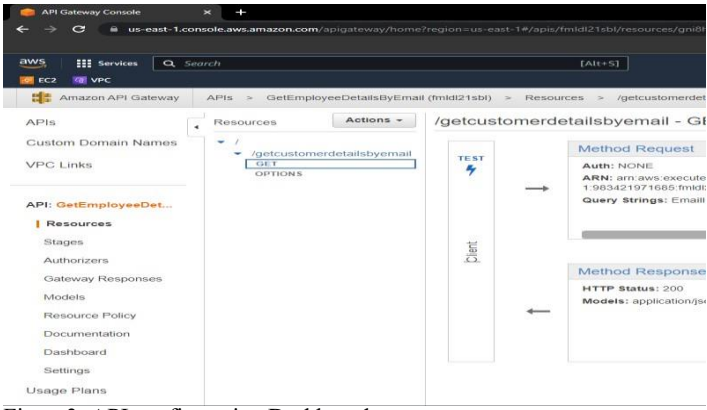

Figure3: API configuration Dashboard

B) We created two Lambda function given as follows:

1) *S*aveCustomerDetails

2) GetCustomerDetailsByEmail

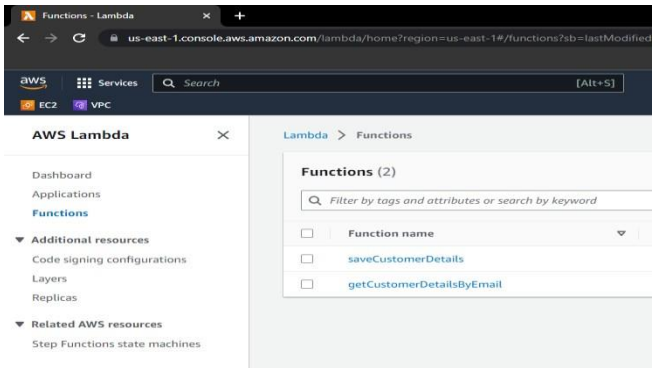

Figure4: Dashboard of Lambda functions

Management

C) Create DynamoDB table for the

D) Upload files to S3 bucket for static resource

II. LITERATURE REVIEW

R.Mishra, M. Kumar, N. Singh and S. Dwivedi proposed that Amazon offers a comprehensive range of IT solutions to let businesses construct their private virtual clouds and maintain total control over their infrastructure. It is possible to use Amazon Web Services for both businesses and IT projects. Security professionals are drawn to the cloud because of its cost savings and efficiency, but it also poses numerous security and compliance issues. EC2 instances, which claim to make cloud computing safe for highly regulated companies, have been introduced as part of Amazon Web Services' (AWS) effort to relieve business security and compliance issues with cloud computing. Cloud computing has its drawbacks; however, these drawbacks also provide an opportunity to study a variety of cloud computing-related topics. The security and privacy of data stored and processed on cloud service providers' servers is a major concern. Several studies on cloud computing security and privacy are reviewed in this study. A better knowledge of cloud computing's security problems has been shown and the techniques and solutions which have been used by the cloud service sector have been highlighted in this article. The objective of this report is to shed light on immersing cloud services market and the different upcoming challenges like network issues[1]

B.Pushpaleela, S. Sankar, K. Viswanathan andS. A. Kumar discussed that In the IT business, cloud computing has recently gained a lot of attention. II businesses are considering embracing the cloud since it offers a simple, affordable method of hosting apps and dynamically scaling them. The purpose of this research paper is to study and discuss about Modernization strategies for the digital transformation of on prime applications to transfer to the AWS cloud for Application with include data base migration with AWS cloud automation deployment using DevOps tools. The Modernization strategy will include numerous stages. The stages are Analysis & Planning, Data Migration, Extraction & Transform, Quality Engineering and Go-Live/Deployment.[3]

N.Mahmoudi and H.Khazaei presented Analytical performance models are very effective in ensuring the quality of service and cost of service deployment remain desirable under different conditions and workloads. While various analytical performance models have been proposed for previous paradigms in cloud computing, server less computing lacks such models that can provide developers with performance guarantees. Besides, most server less computing platforms still require developers' input to specify the configuration for their deployment that could affect both the performance and cost of their deployment, without providing them with any direct and immediate feedback. In previous studies, we built such performance models for steady-state and transient analysis of scale-per-request server less computing platforms (e.g., AWS Lambda, Azure Functions, Google Cloud Functions) that could give developers immediate feedback about the quality of service and cost of their deployments. In this work, we aim to develop analytical performance models for latest trend in server less computing platforms that use concurrency value and the rate of requests-per-second for auto scaling decisions. Examples of such server less computing platforms are Native and Google Cloud Run. The proposed performance model can help developers and providers predict the performance and cost of deployments with different configurations which could help them tune the configuration toward the best outcome[4]

Hassan, H.B., Barakat, S.A. & Sarhan provided useful observation that The contributions of the work presented in this paper are threefold: (a) a methodical review of related literature on the topic of server less computing, to address the issue of the lack of compiling information on the state-of-the-art of the field; (b) a comparison of the platforms and tools used in server less computing; (c) an extensive analysis of the differences, benefits, and issues

related to server less computing, to provide a more complete understanding of the topic. Given the fast evolution and growing interest in the field, this survey focused on gathering the most outstanding trends and outcomes of server less computing, as described by recent researchers. This survey could significantly reduce ambiguity and the entry barrier for novice developers to adapt to the server less environment. Furthermore, the findings presented in this study could be of great value for future researchers interested in further investigating server less computing. Finally, it is worth mentioning that the interest that both commercial and academic efforts fueled into studying,
developing, and implementing server less tools in forthcoming years could help maximize the potential that server less computing could bring to the IT community. [6]

IV .PROPOSED METHODOLOGY

In today world of server computing we are getting very large cost for infrastructure so to remove the obstacle of the server computing we followed the path of server-less computing which allows you to work fast, efficiently and quickly with less no. of resource requirement and cost effectiveness of the server less mechanism. There are certain steps of proposed procedure given as follows:

Step:1 To begin with we need to create API gateway

Step:2 Name of API is PostCustomerDetailsand GetEmployeeDetailsByEmail

Step:3 Deploy API and tested it with API testing platform called POSTMAN

Step:4 Than we created two Lambda function namely saveCustomerDetails and getCustomerDetailsByEmail

Step:5 Creation of a Lambda function and integrating it with the API helps to run the functions

Step:6 Create Dynamo DB table

Step:7 Upload files to S3 bucket for static resources

Step:8 Go to website using the uploaded files in S3 bucket

Step:9 Get the desired result you want either want to get details of employee or save details of the employee

Stepwise Design of Server less web application diagram

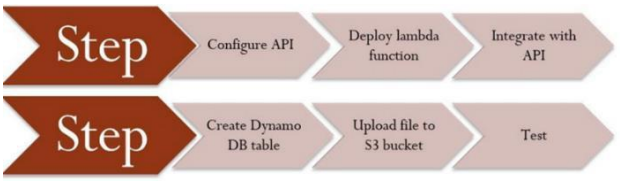

Figure5: Stepwise Design of Server less web application

Application :

Seeverless web application or you can say serverless computing just permits you to produce and run application and services without help of servers. In this type of computing your application will however run on the servers but all the management is done by AWS.

It can be used in any service category where the configuration and the management of servers are invisible to the end user.

Harsh Pandey: This later includes storage, database, messaging,computing,API gateway etc

II. CONCLUSION

This research paper is about using server less web application using AWS platform's different web services such as API gateway, Lambda service, S3 storage service and Dynamo DB service of amazon web services platform. We are creating an application where data of employee is saved and received when required using server less application rather than using server as it
requires lot more cost and infrastructure. In server less application we don't have to worry about the server infrastructure as it is managed by the cloud service providing company have to take care of it. So we have solved the problem for organization expenses they were liable for servers for such small applications which costs them but using server less computing they can cost cut the expenses for server computing in the modern era of digital world.

REFERENCES

[1] S. Mishra, M. Kumar, N. Singh and S. Dwivedi, "A Survey on AWS Cloud Computing Security Challenges & Solutions," 2022 6th International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2022, pp. 614-617, doi: 10.1109/ICICCS53718.2022.9788254.

[2] Philippe Abdoulaye, "Developing World-Class Digital Products and Services Using AWS," in Transforming Your Business with AWS: Getting the Most Out of Using AWS to Modernize and Innovate Your Digital Services , Wiley, 2022, pp.205-206.

[3] R. C. Pushpaleela, S. Sankar, K. Viswanathan and S. A. Kumar, "Application Modernization Strategies for AWS Cloud," 2022 1st International Conference on Computational Science and Technology (ICCST), CHENNAI, India, 2022, pp. 108-110, doi: 10.1109/ICCST55948.2022.10040356.

[4] N. Mahmoudi and H. Khazaei, "Performance Modeling of Metric-Based Server less Computing Platforms," in IEEE Transactions on Cloud Computing, doi: 10.1109/TCC.2022.3169619.

[5] Hai, T., Zhou, J., Jawawi, D. et al. Task scheduling in cloud environment: optimization, security prioritization and processor selection schemes. J Cloud Comp 12, 15 (2023)

[6] Hassan, H.B., Barakat, S.A. & Sarhan, Q. Survey on server less computing. J Cloud Comp 10, 39 (2021)

[7] D. Zhou, H. Chen, G. Cheng, W. He and L. Li, "SecIngress: An API gateway framework to secure cloud applications based on N-variant system," in China Communications, vol. 18, no. 8, pp. 17-34, Aug. 2021, doi: 10.23919/JCC.2021.08.002.

[8] E. Rinta-Jaskari, C. Allen, T. Meghla and D. Taibi, "Testing Approaches And Tools For AWS Lambda Serverless-Based Applications," 2022 IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops), Pisa, Italy, 2022, pp. 686-692, doi: 10.1109/PerComWorkshops53856.2022.9767473.

[9] D. Bardsley, L. Ryan and J. Howard, "Serverless Performance and Optimization Strategies," 2018 IEEE International Conference on Smart Cloud (SmartCloud), New York, NY, USA, 2018, pp. 19-26, doi: 10.1109/SmartCloud.2018.00012.

[10] J. Dantas, H. Khazaei and M. Litoiu, "Application Deployment Strategies for Reducing the Cold Start Delay of AWS Lambda," 2022 IEEE 15th International Conference on Cloud Computing (CLOUD), Barcelona, Spain, 2022, pp. 1-10, doi: 10.1109/CLOUD55607.2022.00016.

[11] S. Roy, S. Kolanu and K. S, "Gaffer: Cloud Computing based Serverless Orchestration Framework for Unprecedented Workflow," 2021 Third International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India, 2021, pp. 1054-1060, doi: 10.1109/ICIRCA51532.2021.9544528.

[12] A. Alalawi, A. Mohsin and A. Jassim, "A survey for AWS cloud development tools and services," 3rd Smart Cities Symposium (SCS 2020), Online Conference, 2020, pp. 17-23, doi: 10.1049/icp.2021.0898.

[13] P. H M, S. Shankaraiah and S. R, "Patient Health Information Framework Using AWS S3 Service," 2022 IEEE 2nd Mysore Sub Section International Conference (MysuruCon), Mysuru, India, 2022, pp. 1-5, doi: 10.1109/MysuruCon55714.2022.9972361.

[14] S. S. Chawathe, "Data Modeling for a NoSQL Database Service," 2019 IEEE 10th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), New York, NY, USA, 2019, pp. 0234-0240, doi: 10.1109/UEMCON47517.2019.8992924.

[15] H. Chen, "Low-latency Serverless Computing: Characterization, Optimization and Outlooking: JCC 2021 Invited Keynote," 2021 IEEE International Conference on Joint Cloud Computing (JCC), Oxford, United Kingdom, 2021, pp. xii-xii, doi: 10.1109/JCC53141.2021.00008.

[16] Zhang, Q., Cheng, L. & Boutaba, R. Cloud computing: state-of-the-art and research challenges. J Internet Serv Appl 1, 7–18 (2010). https://doi.org/10.1007/s13174-010-0007-6

[17] Höfer, C.N., Karagiannis, G. Cloud computing services: taxonomy and comparison. J Internet Serv Appl 2, 81–94 (2011). https://doi.org/10.1007/s13174-011-0027-x

[18] Nagaraju, S., Parthiban, L. Trusted framework for online banking in public cloud using multi-factor authentication and privacy protection gateway. J Cloud Comp 4, 22 (2015). https://doi.org/10.1186/s13677-015-0046

[19] D. Geethika et al., "Anomaly Detection in High-Performance API Gateways," 2019 International Conference on High Performance Computing & Simulation (HPCS), Dublin, Ireland, 2019, pp. 995-1001, doi: 10.1109/HPCS48598.2019.9188100.

[20] S. S. Chawathe, "Data Modeling for a NoSQL Database Service," 2019 IEEE 10th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), New York, NY, USA, 2019, pp. 0234-0240, doi: 10.1109/UEMCON47517.2019.8992924.

A Test Development/Enhancement Methodology for Large Software System

Biswadeb Bandyopadhyay
Assistant Professor, Department of Computer Applications
University of Engineering and Management, Kolkata
E-Mail : biswadeb.bandyopadhyay@uem.edu.in

***Abstract*—Linear sequential waterfall model of Software Development Life Cycle provides clear and well-defined procedures, processes and guidelines that should be followed for any software development. The development begins with user requirement elicitation phase and goes through software requirement specification, high-level design, detailed design, coding, testing, and warranty. The accompanying test planning for this typical development model that begins at the user requirement phase for unit testing, integration testing, system testing and acceptance testing is well known and well practiced for software development. Any test development methodology which does not come under the purview of the above software development model, poses its own challenges in terms of defining a specific test development/enhancement methodology to meet product quality requirements in terms of test objective, scope, entry, exit and validation criteria.**

The following research paper talks about a solution, that can be deployed in coming up with a suitable test development and enhancement methodology for a large software system which is already available in the market and serving a large customer base. The methodology proposes a model for development of tests, targeting specific features perhaps identified as problem areas, having large number of customer reported defects.

1. Introduction

The test development/enhancement methodology needs to make a thorough study of the customer usage of the software, analyze the history of customer reported defects and define an effective test development/enhancement methodology, to meet the test objective.

The large software product that is being considered will typically have some collection of feature test cases, which would have evolved over a period of time.

The methodology proposed here focuses on defining a model where the activity starts with a study to understand the essence of customer scenarios and requirements, to understand the feature, the feature test cases available, how the feature has been implemented, and what the customer expectations are.

2. Critical Test Areas

The first step that needs to be taken up is to undertake a comprehensive analysis of customer defects over a period of time, and came up with a list of most critical test areas where there have been large concentrations of customer reported defects. An analysis of the customer defects identifies a number of commonly occurring problem areas. Assuming that the analysis identified following test areas for which test enhancement or creation of new test suites will be required.

- Feature 1
- Feature 2
- Feature 3
- Feature 4

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3. Test Development/Enhancement Model

Having identified the broad areas of test development/enhancement, it is necessary to came up with a test development/enhancement methodology that would provide a unified approach and a defined processes flow for the test development/enhancement cycle.

The development/enhancement of the tests in the identified test area can follow the development model of

- Defect Analysis & Feature Map Study
- Test Design Specification
- Test Development through Feature Map (Black Box) Model

- Code Coverage data collection and Coverage Map Study
- Test Improvement through Coverage Map (White Box) Model
- Test Reports & Test Metrics

3.1 Defect Analysis & Feature Map Study

This phase of test development/enhancement will consist of study of

- Requirements document
- Feature external specification document
- Feature test specification document
- Defect analysis reports of customer encountered problems
- Existing feature test suites

The study of the above documentations and existing feature test cases will allow the test developer an understanding of the feature, the feature test cases available, how the feature has been implemented, and what the customer expectations are, what the customer encountered problems in the area are.

Based on the study of the above, following analysis documents could be generated at the end of this phase.

- A Defect Analysis document of all customer reported defects in the identified test area to understand the customer scenarios and requirements. The customer defect analysis findings are to be captured in a specific template for subsequent analysis in the test design phase. The customer defect analysis document contains the defect reported in the test area, an understanding of the essence of the problem, severity of the defects, analysis and comments from developers and test engineers. This will provide an understanding about the deficiencies found in the implementation of the feature, from a perspective of customer usage of the feature.

- A Feature Analysis document of relevant feature test cases if available and generation of a feature map containing test scripts that map to a collection of features being tested based on examination of available test scripts and feature specification document. The feature map can be used to identify and analyze the gaps that can be attempted to fill in, from a perspective of implementation of the feature. This is generated in a specific template which will be used during subsequent phases.

Feature map contains the main feature, sub-features tested, the name of the test file in which the corresponding test cases are available, any new feature identified as not being covered in the existing test files, information about existence of any customer defects in the identified area. Information in this document will be used in the subsequent test design phase.

- A Test Plan document would be generated from Defect Analysis document and Feature Map document, containing a list of features identified as not covered in the existing test suite. The document contains list of features to be added while developing new test cases based on examination of Defect Analysis document and Feature Map document.

- Customer Type Data Sets document, containing how customer-like data sets are to be generated for creation of new test cases.

The deliverables from this phase would be

- Defect Analysis Document
- Customer Type Data Sets Document
- Feature Map Document
- Test Plan

3.2 Test Design Specification

Based on analysis of Defect Analysis Document, Customer Type Data Sets document, Feature Map Document and Test Plan generated in the preceding phase, following design specification documents could be generated

- Test Data Design Specification document, containing a description of how customer-like datasets is to be created. The document is used to generate the test setup scripts required for the test development.

- Test cases Design Specification document, containing the features to be tested, test files to contain the specific feature test cases, and description of test cases to be created under each features.

The deliverables from this phase would be

- Test Data Design Specification
- Test cases Design Specification

3.3 Test Development through Feature Map (Black Box) Model

Based on Test Data Design specification and Test cases Design specification generated in the test design specification phase, Test Setup scripts and Test Scripts are developed.

The deliverables from this phase would be

- Test Setup Scripts
- Test Scripts

3.4 Code Coverage data collection & Coverage Map Study

A list of source files, implementing the specific feature is to be identified from relevant Detailed Design document. Code coverage data for developed test cases at the end of preceding phase, are to be collected on all the identified source files.

A Coverage map containing a list of source files and corresponding coverage is to be created, which will be used in the subsequent phase.

3.5 Test Improvement through Coverage Map (White Box) Model

The Coverage map is to be studied to analyze the coverage on each source files. If coverage on some of these files are not sufficiently high, a detailed study of those source files are to be undertaken to understand the specific sub-features being implemented by them, from information available in detailed design document. Existing test cases are to be modified, or new test cases are developed to increase coverage on those files, based on understanding of features being implemented, as given in detailed design document.

Here tests are to be enhanced based on White Box approach, where new test cases will be developed based on study of coverage on the source files, and the features being implemented by them, rather than trying to have a detailed understanding of the code (loops, conditions, flow path).

3.6 Test Reports & Test Metrics

Test Reports & Test Metrics for the test development/enhancement could be generated in terms of

- Number of test scripts written
- Number of setup scripts written
- Number of in-house defects found
- Incremental code coverage
- Overall code coverage

A traceability matrix is to be generated covering all the above development phases to maintain the traceability for all test cases.

3.7 Management Plan for Test Development/Enhancement

Stage	Inputs	Work Products
Defect Analysis & Feature Map Study		
• Defect Analysis • Preparation of Feature Map	• Defect Tracking System • Feature External Specification Document • Feature Test Specification Document • Defect Analysis Reports • Available Feature Test Suites	• Defect Analysis Document • Customer Type Data Sets • Feature Map Document • Test Plan Document
Test Design Specification		
• Test Data Design • Test Specification Document	• Defect Analysis Document • Customer Type Data Sets • Feature Map Document • Test Plan Document	• Test Data Design Specification • Test cases Design Specification
Test Development through Feature Map (Black Box) Model		
• Test Data • Test case Development • Testing	• Test Data Design Specification • Test cases Design Specification	• Test Setup Scripts • Test Scripts
Test Improvement through Coverage Map (White Box) Model		
• Code Coverage Data Collection • Preparation of Coverage Map • Test Scripts Enhancement	• Detailed Design Specification Document • Coverage Map Document	• Enhanced Test Scripts
Test Reports & Test Metrics		
• Metrics Data Collection	• Test Setup Scripts • Enhanced Test Scripts	• Metrics Data • Code Coverage Data (Incremental, Overall)

4. Test Plan

An analysis of Customer reported defects, and study of the feature specification documents and features test suites available in the respective test areas, will bring out the gaps in the existing test areas. These observations are to be documented in the form of Test Plans based on close examination of Defect Analysis Document and Feature Map Document.

5. Feature 1 Test Development

This section provides a brief description of the above test development methodology that can be used for creation of test cases in say for example in Feature 1 test area.

Let us assume that Defect Analysis Document showed that not many customers reported defects existed in this area. In addition, Feature Map document showed the availability of a test suite, where test cases available did not test the Feature 1 adequately. A test plan needs to be therefore created, to develop a comprehensive test suite covering all areas of the Feature 1 test area.

Assuming that following features were identified for Feature 1 test development.

- Feature 1.Sub Feature 1
- Feature 1.Sub Feature 2
- Feature 1.Sub Feature 3
- Feature 1.Sub Feature 4

At the end of development of test cases as per the above plan, code coverage data can be collected for these test cases. Detailed design document would have identified following source files implementing Feature 1 feature, for which code coverage data was analyzed. Generated Coverage map may indicated following source files (highlighted below), whose coverage is not sufficiently high.

Feature 1 Coverage (at the end of Feature Map Phase)

Serial No.	Files	Total Number of Lines	Hit Lines	% Hit Lines
1	..mod1/sub1/file1.c	3419	1391	40
2	..mod1/sub1/file2.c	1077	808	75
3	..mod1/sub1/file3.c	737	277	37
4	..mod1/sub2/file4.c	106	64	60
5	..mod1/sub2/file5.c	130	93	71
6	..mod2/sub4/file6.c	18	17	94
7	..mod2/sub4/file7.c	502	397	79
8	..mod2/sub7/file8.c	364	292	80
9	..mod2/sub7/file9.c	915	763	83
10	..mod2/sub9/file10.c	289	92	31
Total Lines		**7557**	**4194**	**55**

Further study of detailed design document would reveal a set of sub features which have not been adequately covered under the feature map phase, which resulted in low coverage for the above source files.

- Test cases related to Feature 1.Sub Feature 5
- Test cases related to Feature 1.Sub Feature 6
- Test cases related to Feature 1.Sub Feature 7
- Test cases related to Feature 1.Sub Feature 8

Hence, additional test cases can be developed to cover above Sub Features of Feature 1 test area which would result in increased coverage for those source files, for which a representative improvement data is indicated below.

Feature 1 Coverage (at the end of Coverage Map Phase)

Serial No.	Files	Total Number of Lines	Hit Lines	% Hit Lines
1	..mod1/sub1/file1.c	3419	3042	88
2	..mod1/sub1/file2.c	1077	808	75
3	..mod1/sub1/file3.c	737	662	89
4	..mod1/sub2/file4.c	106	64	60
5	..mod1/sub2/file5.c	130	93	71
6	..mod2/sub4/file6.c	18	17	94
7	..mod2/sub4/file7.c	502	437	87
8	..mod2/sub7/file8.c	364	292	80
9	..mod2/sub7/file9.c	915	813	88
10	..mod2/sub9/file10.c	289	232	80
Total Lines		**7557**	**6460**	**85**

Same methodology of initial feature map (black box) approach, followed by coverage map (white box) approach could be adopted for development of test cases in each test areas.

6. Benefits of Test Development/Enhancement

- Enhanced testing ensuring robustness of the code
- Higher test coverage and in-house error detection
- Minimize possibility of regression problems
- Reduced overall customer reported problems
- Higher productivity
- Reduced cost on post-release maintenance, rework
- Increased confidence in the testing process and its completeness

7. Conclusion

With test architecting as an emerging discipline and a key focus area, it should be the constant endeavor of every IT companies to lay a strong foundation for innovative test engineering practices and methodologies for testing complex software projects and products. In a competitive market environment like today, with increasing focus on application migration to offshore, as the preferred business model, it is imperative for IT companies to pay adequate attention in evolving effective product testing methodologies. The above research paper makes an attempt come up with a test development model for a large software system. Even though the approach outlined here has been adopted for test development/enhancement for large software system, it can be extended to any software development and maintenance activities irrespective of the size, application area and domain.

REFERENCES

1. Effective Methods for Software Testing, William E. Perry, Willey Publication
2. Software Engineering: A Practitioner's Approach, Roger S. Pressman
3. Software Testing Concepts and Tools, Nageswara Rao Pusuluri
4. Software Testing in Real Worls, Edward Kit

Meta-Routing Paradigm For Robotic Ad-hoc Networks

Mustafa Ayad
State University of New York (SUNY) at Oswego
Mustafa.ayad@oswgo.edu

Richard Voyles
Purdue University
rrvoyles@purdue.edu

***Abstract*— With the increasing use of robotic networks, communication issues such as maintaining connections between nodes are becoming more prevalent. While previous routing protocols for wireless networks have been developed, they tend to address routing and link maintenance separately. Consequently, leading to increased costs and delays in network communication. Existing routing protocols typically focus on discovering links, connecting them, finding the most efficient path, and reducing costs associated with the path. However, their limitations have led to the development a new routing mechanism for robotic networks called Meta-Routing. Meta-Routing builds on existing routing protocols by incorporating regular routing of packets and maintenance of links in mobile agent environments. This approach aims to improve efficiency and reduce routing and link maintenance costs. In addition, meta-Routing seeks to minimize communication path costs and the overhead cost associated with discovering a route, repairing a link, or creating a new communication path among nodes. This paper presents a method for achieving Meta-Routing by controlling robot motion based on recognizing the radio frequency (RF) environment through Hidden Markov Models (HMMs) and gradient descent methods. Simulation results show that Meta-Routing, based on controlling individual robot motion, can provide self-healing capabilities in mobile robot networks, decrease network latency, and improve network performance.**

Keywords— Link Connectivity maintenance, gradient, RF mapping recognition, nod control movement

I. INTRODUCTION

Multi-robot exploration in Urban Search and Rescue (USAR) relies on routing protocols to efficiently transmit and receive information packets between robots (Voyles et al., 2009; Wu et al., 2020). These protocols are used to establish mobile ad hoc networks (MANETs), enabling the robots to work together effectively. (Devi et al., 2019). The routing process involves finding the most efficient path for transmitting information packets in a network by discovering links with the lowest cost. Routing protocols are responsible for identifying and connecting these communication links to form a path with the least possible cost. In the context of MANETs, the ability to establish a communication path between the source and destination nodes is essential for maintaining effective communication among a highly interconnected network of nodes, as shown in Fig. 1. Generally, routing protocols are responsible for two main activities: finding the optimal path with the lowest cost for transmitting data packets, and actually transferring the data packets along that path. The first activity involves determining the best route by identifying the lowest-cost links, while the second involves physically sending the data packets along that route. (Nabati et al., 2022). Routing protocols use a variety of metrics to determine the most efficient path for transmitting data packets to their destination. These metrics include the number of hops, path speed, packet loss, latency, path reliability, and bandwidth. Routing algorithms use these metrics to evaluate the network's performance and select the best path for sending data packets.

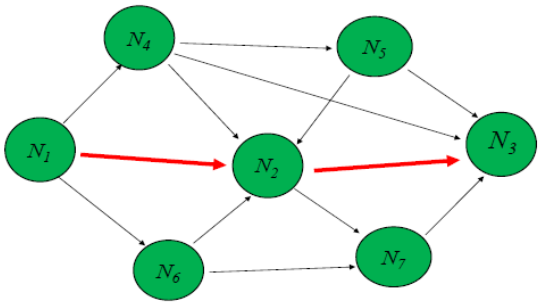


Fig.1. An interconnected network of communicating nodes.

The routing problem occurs when a device or node in a network needs to find a path to another node, but the path is unknown, and the path's complexity is also uncertain. It is a common problem in computer networks and routing algorithms while finding and maintaining the best routes, reducing network congestion, and preventing network failures. (Kumar et al., 2022). For example, Fig. 2 shows that node A attempts to connect to node B, but the path between them is undefined, and the network between node A and node B is unknown. In other words, not knowing the path between communicating nodes nor the complexity of the path are the key points of the routing problem. On the other hand, Link maintenance ensures that communication between a node and its neighboring nodes remains reliable by adjusting their operational characteristics. For example, In most cases of radio frequency (RF) communication, effective communication is typically achieved when the signal-to-noise ratio (S/N) is above a certain threshold. The S/N ratio is a measure of the strength of the signal compared to the amount of background noise, and a higher ratio indicates a more robust and precise signal. However, the ultimate goal of communication is that the robot can successfully transmit

messages to its neighbor. Therefore, many reasons cause changes in the S/N ratio and lead to an adjustment of a node's operational characteristics. For example, in a static cell phone network, the mobile phone cannot move by itself, but it can increase its output power to increase the *S/N* ratio to regain communication with the base station. Another example is if it rains, the mobile phone must increase its output power to lift the S/N ratio above some threshold to maintain communication with the base station. In addition, tuning the antenna either by changing the direction of the antenna or manipulating the parameters characteristics of the antenna will vary the operating characteristics of a node.

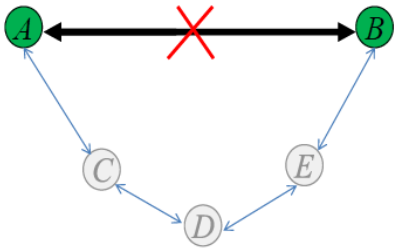


Fig. 2. Node A cannot communicate directly with node B, but it might have an indirect path.

In a wireless ad hoc network, devices communicate directly with each other without the need for a central router or access point. These networks can be helpful in situations where traditional infrastructure is unavailable or is challenging to deploy, such as in emergency response or military operations. They are also commonly used in personal area networks and in mobile ad-hoc networks (MANETs). Mobile nodes must be able to discover and connect with nearby nodes in order to establish communication and form the network. Due to the limited transmission range of wireless network nodes, it may be necessary for data to be passed through multiple intermediate nodes, or "hops," to reach its destination, which is called multi-hop communication. MANETs are composed of mobile devices that can connect and disconnect from the network at any time, creating a highly dynamic network topology. Because of this, they are well-suited for multi-robot systems and USAR (Urban Search and Rescue) scenarios, where mobility and flexibility are essential. In these scenarios, the robots can communicate with each other without the need for a fixed infrastructure, allowing for efficient coordination and information sharing. (Queralta et al., 2020). In MANETs, mobile robots act as both communication nodes and mobile platforms. They provide the network with a robust communication infrastructure by relaying data between other nodes and maintaining network connectivity. It allows for efficient communication and coordination among the robots, which is crucial in applications such as USAR, where the robots need to work together to accomplish a task. Additionally, the mobility of the robots allows them to move to areas with better connectivity or to avoid communication obstacles, which improves the overall performance of the network. In our case, if a mobile robot moves too far from the base station and causes a decreased S/N ratio, one solution would be to instruct the robot to move to a position within the transmission range to improve communication with other robots or the base station. Therefore, it ensures that the robot can continue to receive and transmit data effectively and perform its assigned tasks. Thus, the S/N ratio goes below some threshold when the robot is too far; consequently, the robot must move back into the communication signal coverage. These are examples of how the node can adjust its operating characteristics to maintain link quality above the noise threshold. This paper will focus on robot movement throughout the environment while not changing the output power, which is appropriate for static nodes.

MANETs are a type of wireless network where nodes can move around and connect to each other without needing a pre-existing infrastructure. These networks are useful in emergencies such as disasters or military attacks when traditional network infrastructure may be damaged or unavailable. Researchers have been working to improve the performance and security of these networks to ensure they can function well in critical scenarios (Tripathy et al., 2020). Another important characteristic of mobile ad-hoc networks is their ability to adapt to sudden changes in network topology. It is a critical feature as the nodes in the network are mobile and can move around, change positions and connect or disconnect from the network at any time. To handle these dynamic changes, routing protocols for MANETs are designed to be flexible and able to adjust quickly to new network topologies. These protocols are responsible for managing the routing of messages and maintaining links between nodes independently. Routing protocols for MANETs use route discovery to find new nodes in the network when connections are broken. However, this process can take a significant amount of time, especially when there is high contention for the communication medium. To address this issue, researchers have proposed the idea of combining self-mobile link maintenance with a traditional routing protocol. This approach utilizes the mobility of the nodes to improve the network more quickly or at a lower cost than the conventional route discovery process. This approach aims to reduce data delivery latency and enhance the network's overall efficiency by including link repair as a tool in the routing protocol. The key point in this paper is based on the fact that if self-mobile nodes exist in the network, in some cases, it is faster to relocate a node rather than discover an unknown node.

The discovery phase in routing protocols is time-varying, consumes a large amount of energy and bandwidth, and incurs latency that affects the network throughput. Research has shown that, in some cases, higher network performance can be achieved by focusing on link repair rather than running a node discovery phase. With this in mind, the idea of combining self-mobile link maintenance with a standard routing protocol was proposed to reduce discovery latency and improve network throughput. This approach aims to make the network more efficient by utilizing the mobility of nodes to repair links quickly rather than spending a lot of time, energy, and bandwidth searching for new nodes

This paper presents the Meta-Routing protocol, which is a new concept for managing mobile robots and ad-hoc network infrastructure. The Meta-Routing protocol is not only presented as a packet routing scheme but also as a new strategy for maintaining communication links. The main contributions of this paper are: Therefore, the main contributions of this paper are summarized as follows:

- Meta-Routing incorporates link maintenance directly into the routing protocols' cost function as an alternative to route discovery for robust network connectivity. It aims to reduce the total path cost compared to the standard routing protocols.

- The introduction of *hypothesized nodes* into the *augmented connection graph* implements a unified syntax of the message routing protocol and the link maintenance mechanism that allows the overhead costs of routing to be merged with the direct link costs of routing.

II. Related Work

Measuring network connectivity and signal strength are crucial for maintaining the quality of communication networks. Network connectivity refers to the ability of devices to connect and communicate with one another, while signal strength measures the power of the wireless signal being transmitted. These measurements are used to monitor and ensure the proper functioning of the network and to identify and fix any issues that may arise (Ayad et al., 2019; Thrane et al., 2020). Furthermore, maintaining node connectivity is crucial for robotic networks to ensure that data can be transmitted and received while the robots perform their assigned tasks. It is vital for the proper functioning of the network and ensuring that the robots can complete their duties effectively. Without proper node connectivity, the robots may not be able to communicate with each other or with the central control system, which could lead to delays or failures in completing their assigned tasks (Cardona et al., 2019; Ayad et al., 2022). In (Thiagarajan et al., 2017), an efficient routing protocol is presented for use in ad-hoc networks. The protocol utilizes a dynamic source routing scheme to transfer data from the source to the receiver node. The paper's authors have compared their proposed scheme with a conventional routing scheme to evaluate the performance in terms of throughput, energy consumption, and overhead. By comparing the two schemes, the authors aim to demonstrate the advantages and improvements provided by their proposed routing protocol. In (Malar et al., 2021), The authors proposed a multi-objective routing technique for MANET that uses Ant Colony Optimization (ACO) to find energy-efficient routes while considering constraints such as the residual energy of mobile nodes, number of packets in the path, and dynamic changes in the network topology. The technique, called MCER-ACO, aims to reduce transmission energy, adapt to changes in the network topology, and minimize path overhead. The authors of the paper evaluated the performance of the proposed MCER-ACO technique and compared it to two existing methods. The evaluation results showed that the MCER-ACO technique is more energy efficient and better at selecting optimal routes in a MANET than the other methods. In (Zhang et al., 2019), the authors proposed algorithm reduces the network's energy consumption, improves the delivery rate of data packets, reduces the network delay, and prolongs the network lifetime. In the greedy forwarding phase, the reliable communication area is calculated, and then the quality of the link is evaluated according to the relative displacement between the nodes and the maintenance time of the link. Then, according to the link quality, the distance between the candidate node and the destination node, and the number of the neighbor nodes, the metric value is obtained, and the node with the large metric value is selected as the next hop. Younis et al., 2021, present a comparison of existing routing protocols in MANET, indicating that overhead in Proactive and Geographic is competitive with delay in Reactive and *Delay Tolerant Network* (DTN) routing.

Alani et al.,2020, proposed the dynamically probabilistic route discovery scheme for MANET. The scheme aims to improve network performance and resolve the problem of frequent link breakage. The scheme selects the reliable node of the route discovery process to avoid the link break and eliminate redundant retransmission to achieve the lowest value of congestion, reducing the overhead in the network. Khudayer et al., 2020, proposed two mechanisms to enhance on-demand source routing protocols, a zone-based route discovery mechanism (ZRDM) and a link failure prediction mechanism (LFPM). ZRDM aims to control the flooding of route requests, and LFPM aims to avoid route breakages caused by node mobility. Raj, 2020, proposed a routing strategy suitable for dynamic and static environments as a hybrid optimization model that reduces link establishment issues. Nature-inspired bee colony optimization is used with conventional routing algorithms such as optimized link state routing protocol and Dynamic Source Routing Protocol to improve link discovery. The proposed routing scheme reduced the delay and communication overhead of the network. Zhu et al., 2020, presented an innovative, collaborative routing protocol with low delay and high reliability to accommodate mixed link scenarios. First, they establish a one-hop delay model to investigate the potential effects of Media Access Control (MAC) layer parameters. Then, forwarding, maintenance, and efficiency strategies are created to construct the basic functionalities for the proposed routing protocol.

III. Meta-routing Fundamentals

Network researchers address message routing of information packets distinctly from the link maintenance process, which is creating and keeping links. Meta-Routing combines the concept of message routing of information packets, which is finding the lowest path cost, and link maintenance, which is creating and improving paths (a path consists of links). Therefore, Meta-Routing integrates logical message routing and physical link maintenance to transmit information packets from node A to node B at the lowest cost.

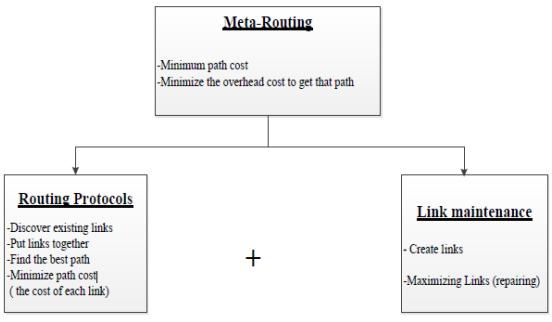


Fig.3. Meta-Routing cost diagram.

Algorithmically, Meta-Routing takes existing methods of computing path cost and augments them with the costs of overhead and maintenance to develop a more comprehensive

cost metric. Meta-Routing includes links cost, route discovery cost, and link tuning/adjustment cost, as in Fig. 3. Meta-Routing applies to the entire gamut of available link maintenance mechanisms, including controlled motion of nodes, transmit power adjustment, antenna pointing, and other antenna tuning forms that vary the nodes' operating characteristics (Ayad et al., 2019). Regardless of the array of maintenance options available, the mechanism can be incorporated into the paradigm if the costs and likelihood of success can be quantified.

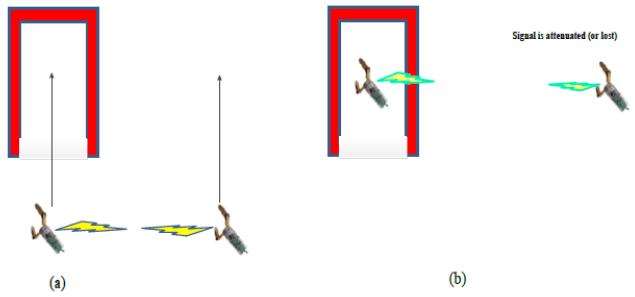


Fig. 4. Two crawler robots in an unknown environment, robots are (a) maintain signal and (b) signal lost.

A. *Meta-routing insight*

A particular scenario involving two crawler robots moving in an unknown environment, communicating and exchanging messages packets provided the insight from which Meta-Routing was born (see Fig, 4(a)). While these robots explore an unknown environment and exchange message packets, they approach a Faraday cage-like obstacle. As they move forward, the communication signal strength decreases until communication is lost (Ayad et al., 2019). Finally, the robots can not communicate anymore as a result of the RF obstacle effects on the communication signal, as shown in Fig. 4(b).

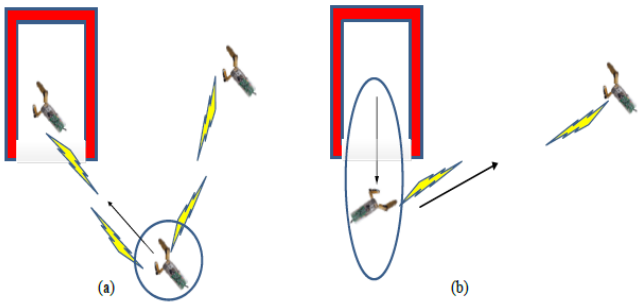


Fig. 5. (a) Discovering a new node (b) controlling the motion of an existing node.

There are two choices to reestablish communication between the two crawler robots: discover a new node that might re-connect the route or move existing nodes to re-connect the route. The first choice is to discover a new node in the network to act as a bridge between the two nodes that lost communication. This action requires performing the route discovery phase to find an intermediate node that acts as a bridge, as shown in Fig.5(a). In our work with Locally Selectable Protocol (LSP) over Bluetooth (Voyles et al., 2009), this process costs up to 39 *seconds* in the simulation experiment, as shown in Fig. 6. On the other hand, we realized that turning the robot around and crawling backward to regain signal was significantly faster (lower cost). Therefore, physically moving the nodes to regain the communication route is significantly lower cost than node discovery, in this case! Furthermore, node discovery is highly uncertain. If no new node is present, the cost is wasted.

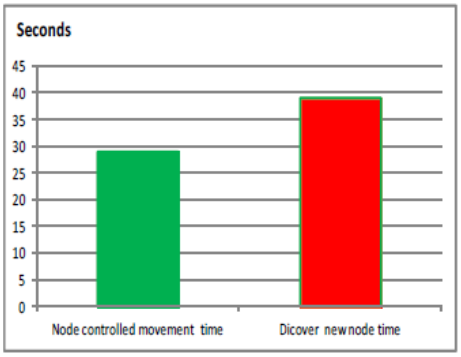


Fig. 6. Controlling the motion of an existing node and discovering a new node cost estimation comparison.

Meta-routing is best illustrated when a link disappears somewhere in the middle of the network and no known alternate route exists. In other words, the path the routing protocol thought was the best is now broken. Therefore, there is a subproblem; instead of going from node *A* to node *B*, it is going from node *C* to node *B*. Thus, the routing protocol does not know what the path is, and now we are going to compute both the total cost to that path (not only the individual links), but also what is going to cost us to find a path or create a new path or strengthen an existing path. Thus, this is what Meta-Routing is about. As a result, we will not change the basic routing protocols; we could use proactive, reactive, or hybrid protocols. The point is we will show how we will integrate link maintenance into a standard routing protocol. One of the advantages of the Meta-Routing approach is that we will include the cost of moving a node in the cost function of estimating the lowest total path cost. Therefore, all links are strong enough to have a path from node *A* to node *C*, then to node *B*. On the other hand, the cost of strengthening links is related to the overhead cost of node movement, which takes time and energy to move the node. In summary, using node movement and computing the gradient (Ayad et al., 2022) while robots move is one way to achieve the Meta-Routing protocol.

In Fig.7 (a), node *A* communicates with node *C*. There are two possible routes: $A-B-C$ and $A-D-B-C$. The lower cost route is $A-B-C$. In this scenario, we assume that node *C* wants to move to the right, as the arrow indicates, but node *D* also moves in the direction of its arrow, as shown in Fig.7 (a). As a result of this movement, node *C* has moved out of the range of node *B*, but node *D* has moved into the range of node *C*; consequently, node *C* and node *D* can communicate with each other *but don't know yet.* (The link between nodes C and D is not established until the link discovery protocol is initiated.) Besides, node *B* can not communicate with node *C*, as shown in Fig.7 (b). For this scenario, there are two possible

solutions for maintaining communication between the mobile nodes. First, when node *C* moves out of the range of node *B*, node B triggers the route discovery algorithm to find a new link to node C, which is what traditional routing protocols do.

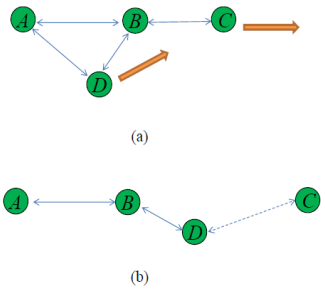


Fig.7. (a) Node *C* and node *D* are moving in the direction of the arrows (b) Node *C* moves out of the range of node *B*, but node *D* has advanced in such a manner that it is within range of node *C*.

Therefore, node B can communicate with node C through node D because node D and node C are within range and can communicate with each other, as shown in Fig. 8 (a). Second, node B can be moved along with node C (at half speed), so node B will remain in the range of nodes A and C and then maintain links, as shown in Fig. 8 (b). This is precisely what link maintenance does for the connectivity maintenance of the network.

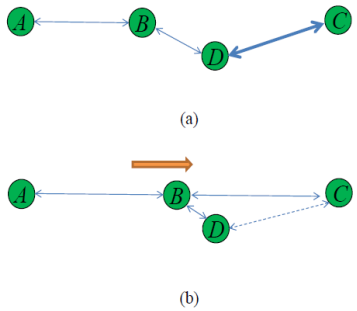


Fig.8. (a) Node D is in the range of node C (b) B moves toward node C.

B. Meta-Routing and the Conventional Routing Paradigm

Traditional routing protocols find paths (a series of links) in a connection graph, then choose the lowest-cost path to send information packets. Traditional routing protocols trigger an automatic route discovery when there is no direct path to the destination, as shown in Fig.8(a). In the Meta-Routing protocol, we are willing to augment the graph with hypothesized node, which will be our trigger to find paths in the augmented graph and compute the cost function for each path. Hypothesized nodes augmented in a graph are shown in Fig. 9, where φ_D represents the route discovery hypothesized node and φ_B represent the controlled motion hypothesized node.

C. Meta-Routing Protocol Path Cost

Fig.9 results from augmenting two hypothesized nodes φ_B and φ_D, which are virtual nodes, into the traditional routing protocol graph of Fig.7. The resulting graph in Fig. 9 represents the Meta-Routing augmented graph, where φ_D represents the route discovery hypothesized node (*virtual node*), which results from running the route discovery algorithm by node *B* to communicate with node *C*, and φ_B represents the controlled motion hypothesized node (*virtual node*), which results from moving node *B* to the position shown in Fig. 9, so that node *B* can communicate with node *A* and *C* (Ayad et al., 2019). Because both nodes φ_B and φ_D are hypothesized, they are uncertain. Hence, it is appropriate to consider their likelihoods of success of route discovery L_{Rd} and controlled motion L_{Mov}. Meta-Routing protocol total path cost represents the sum of the message routing protocol cost, which is the minimum links cost of a communication path (C_{Ls}), and the link maintenance path cost, which is the minimum overhead cost to find the path (C_{Oh}).

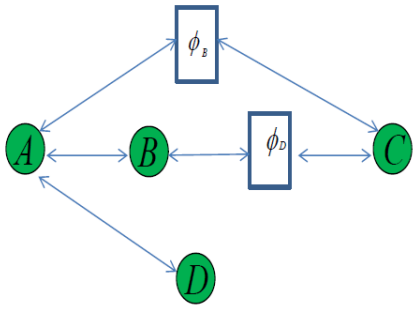


Fig. 9. Meta-Routing augmented graph with hypothesized nodes, φ_B, and φ_D.

In fact, Meta-Routing estimates the overhead cost of route discovery (C_{Rd}) and the overhead cost of node movement (C_{Mov}). Therefore, meta-Routing chooses the best total cost estimate, representing the lowest total path cost. In case the lowest overhead cost estimate is the cost of node movement, Meta-Routing uses the controlled motion algorithm when signal strength goes below some threshold, and a link failure occurs. The controlled motion algorithm moves communicating nodes in the field to a favorable position to regain a strong communication signal (Ayad et al., 2022). The controlled motion algorithm performs this to reduce the overhead cost that results from route discovery. Thus, the total path cost (C_{Tmeta}) is the sum of the node movement cost, which is the time and energy costs to move a node, and the minimum links cost (communication cost), which is the shortest path or a path with less hop count number. On the other hand, when the node movement cost is higher than a new node's discovery cost, Meta-Routing's total path cost will be the sum of the minimum communication links cost and the route discovery cost. Therefore, Meta-Routing's lowest total path cost is the sum of the minimum communication cost of links and the minimum overhead cost, as in equation 1.

$$C_{T_{meta}} = \Sigma C_{Ls} + \Sigma C_{Oh} \quad (1)$$

The graph in Fig. 9 shows two hypothesized nodes to create links from node *A* to node *C*, which is φ_B, and from node *B* to node *C*, which is φ_D. Traditional protocols trigger route discovery automatically when a link failure occurs. On the other hand, Meta-Routing goes to hypothesis mode to trigger the optimal cost choice based on the cost function and likelihood of success for discovery, $L_{Rd,}$ or likelihood of success for movement, L_{Mov}. According to this, two hypotheses are discussed below.

D. Meta-Routing Hypothesis Generation

The novelty of Meta-Routing is in creating hypothesized graphs. Therefore, Meta-Routing is about hypothesizing new graphs and then applying the traditional routing protocols to the hypothesized graphs to choose the lowest path cost. Thus, Meta-Routing injects new hypothesized nodes into the graph to create different communication paths. For example, the hypothesized node could represent discovering a route, increasing the power, tuning an antenna, or moving a node, as shown in Fig.10. Consequently, Meta-Routing can trigger any hypothesized option using all types of link maintenance for all networks. In this paper, we will use the node movement and route discovery hypothesis.

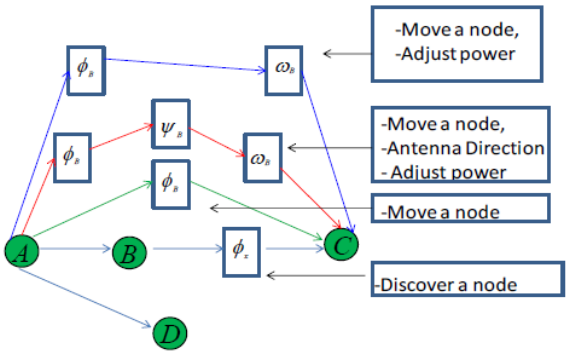


Fig.10. Meta-routing hypothesis generation graph.

E. Link Discovery Hypothesis H_1

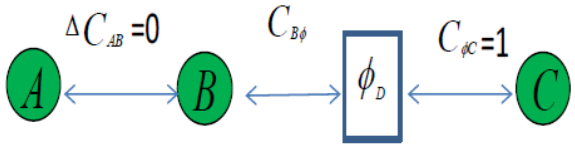


Fig.11. Hypothesized path for route Discovery.

In Fig.11, a hypothesized node φ_D is inserted between node B and node C. Therefore, the cost change of the link between node A and node B, ΔC_{AB}, equals 0 because node B does not move. Without loss of generality, we assume that the communication cost between the hypothesized node φ_D and node C is equal to 1. As a result, the Meta-Routing total cost of the first hypothesis H_1 is given by equation 2.

$$C_{T_{meta}}(H_1) = C_{AB} + \Delta C_{AB} + C_{B\phi_D} + C_{\phi_D C} + C_{Rd} \quad (2)$$

Where C_{AB} is the communication cost between node A and node B, ΔC_{AB} = 0, $C_{B\varphi_D}$ is the communication cost between node B and node φ_D, $C_{\varphi_D C}$ is the communication cost between hypothesized node φ_D and node C and the overhead cost, which is the route discovery cost, C_{Rd}. C_{Rd} is the overhead cost that node B takes to discover the hypothesized node φ_D. To ensure that node B can find another node when it runs the route discovery process, we need to compute L_{Rd}, and then divide the route discovery overhead cost by the L_{Rd}; and that is a way to normalize that cost because we do not know that node B is going to find another node. Therefore, equation 2 is enhanced as in equation 3.

$$C_{T_{meta}}(H_1) = C_{AB} + \Delta C_{AB} + C_{B\phi_D} + C_{\phi_D C} + C_{Rd}/\mathcal{L}_{Rd} \quad (3)$$

F. Controlled Motion Hypothesis H_2

In Fig.12, a hypothesized node φ_B is moved between node A and node C. Therefore, the cost change of the link between node A and hypothesized node φ_B, $\Delta C_{A\varphi_B}$, is not equal to 0 because node B moves. Therefore, without loss of generality, we assume that the communication cost between the hypothesized node φ_B and node C is equal to 1. As a result, the Meta-Routing total cost of the second hypothesis H_2 is given by equation 4.

$$C_{T_{meta}}(H_2) = C_{A\phi_B} + \Delta C_{A\phi_B} + C_{\phi_B C} + C_{Mov} \quad (4)$$

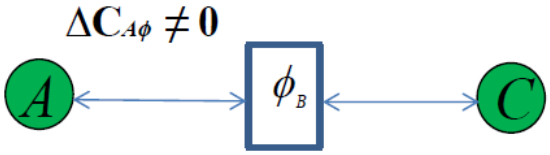


Fig.12. Hypothesized path for controlled motion of a node.

Where $C_{A\varphi_B}$ is the communication cost between node A and node φ_B, $\Delta C_{A\varphi_B}$ is the cost change between node A and node φ_B , $C_{\varphi_B C}$ is the communication cost between node φ_B and node C, and the overhead cost, which is the movement cost, C_{Mov}. C_{Mov} is the overhead cost that node B takes to move to the position of node φ_B. We have to compute the likelihood of success, L_{Mov}, when we control node B movement so that it will move in the right direction and not lose a connection with node A. In fact, there are some likelihoods of success to guarantee link repair when we move node B, so we have to consider the L_{Mov}. Therefore, we divide the overhead cost of movement by the likelihood of success, L_{Mov}, to normalize the cost. Consequently, equation 4 is enhanced as in equation 5.

$$C_{T_{meta}}(H_2) = C_{A\phi_B} + \Delta C_{A\phi_B} + C_{\phi_B C} + C_{Mov}/\mathcal{L}_{Mov} \quad (5)$$

In summary, after computing $C_{Tmeta}(H1)$ and $C_{Tmeta}(H2)$, Meta-Routing will choose the lowest total cost and decide whether to control the movement of a node to repair a link or discover a new node to maintain the network connectivity.

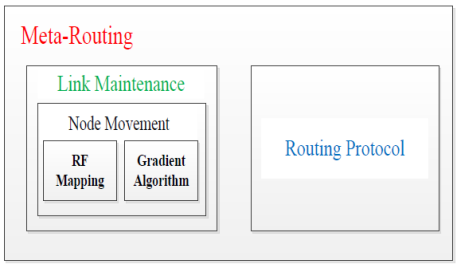


Fig. 13. Meta-Routing protocol block diagram.

IV. META-ROUTING DESIGN

The Meta-Routing combines routing protocol strategies such as proactive, reactive, hybrid, and link maintenance approaches. We believe the combination of routing protocol and link repair can achieve higher network performance than running the node discovery phase. Therefore, to incorporate link maintenance into the routing protocol to achieve Meta-Routing, as shown in Fig.13.

In a typical network situation, the Meta-Routing works and acts as a traditional routing protocol. Therefore, it infrequently applies a message routing protocol to the local network to transmit packet messages between nodes in the communication network. Meta-Routing computes the route repair and the route discovery cost functions and the likelihood of success for route repair and route discovery for achieving robust network connectivity and minimizing the overhead path cost. The Meta-Routing protocol triggers the hypothesis generation process when a critical error occurs on the communication path during message transmission and computes the cost function. Then, meta-Routing runs the route repair algorithm or the route discovery algorithm to maintain the network connectivity. It decides the route discovery or the route repair algorithm based on the estimated total path cost produced by the cost function and the likelihood of success for route repair, L_{Mov}, and route discovery, L_{Rd}. The Meta-Routing protocol will perform the route repair algorithm for link maintenance if the total path cost to repair a broken link is lower than the total path cost to discover a route and the L_{Mov} is higher than that of route discovery. Otherwise, Meta-routing performs the route discovery process. In summary, estimating the cost function and the likelihood of success are highly essential to decide whether the route repair or the route discovery algorithm will be executed (Ayad et al.,2019; Ayad et al., 2022). Fig.14 shows the flowchart for the Meta-Routing protocol.

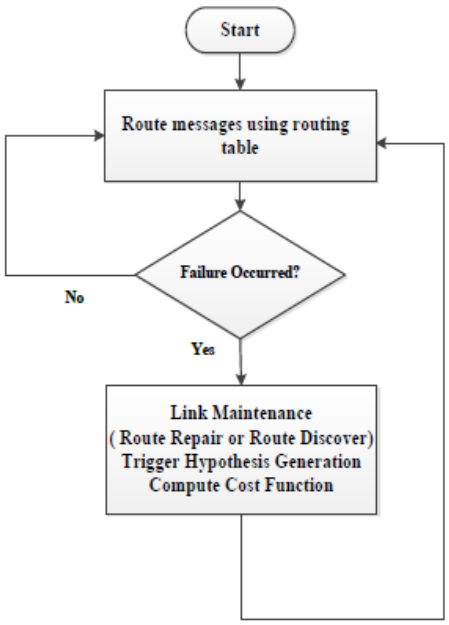


Fig.14. The Meta-Routing protocol flowchart.

A. Movement in Meta-Routing

A critical goal of Meta-Routing is to repair failed or broken links in an adverse environment. In fact, various locations will satisfy the criteria of a good-quality link. However, robots do not necessarily know where they are nor know when they last had a strong link signal. Therefore, Robots could go back to a known location; however, it is problematic because this requires having an accurate location. Robots need to know exactly where that place was and where they are now, which could mean there may have been an error as they moved along. Therefore, moving robots back is harder than it sounds because of air propagation and incidents where robots do not know where they were and do not know where they are now. As a result, robots try to move back to a wrong position from another wrong one and may be further away from the correct one. In fact, work from (Ludwig et al., 2006) demonstrates that the random walk is often better than moving back due to the uncertainty of where the back is, so moving in the reverse direction is one option, but it is sometimes dangerous.

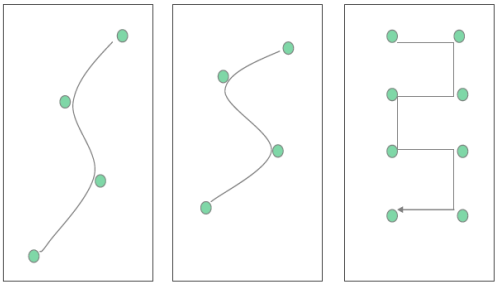


Fig.15.Different movement modes.

Meta-Routing uses movement back through free locomotion when the robot's signal strength goes down, and the robots start to lose communication signals. In typical scenarios, the robot would take the shortest straight-line path to reach the destination. However, this leads to unsuitable signal strength gradient estimates because the sampling locations cannot be co-linear (Ayad et al., 2013; Ayad et al., 2019). Therefore, rather than travel in straight-line trajectories, the robot introduces gentle oscillations to its path (see Fig.15). This makes the gradient estimate more potent than traveling in a straight line at the cost of greater distance traveled.

B. Link Maintenance for Meta-Routing

Despite the array of link maintenance options available for wireless communication, if the communication costs and likelihood of success can be quantified, the mechanism can be incorporated into the Meta-Routing mechanism. Traditionally, conventional routing protocols generate an automatic route discovery when there is no path to the destination. Meta-Routing protocol augments hypothesized nodes into the routing graph. It triggers the lowest cost path in the augmented graph by computing each path's cost function and the likelihood of success. In this paper, we will focus on the controlled motion of mobile nodes in experimental fields. Therefore, the Meta-routing protocol

uses controlled node motion as one option to achieve link maintenance to maintain network connectivity while the network performs assigned tasks in a harsh environment. The controlled motion of the mobile robots is achieved by driving them to favorable link positions where they can maintain their connectivity (Ayad et al., 2019). Therefore, this will lead us to develop a routing control mechanism to control the node movement. This control mechanism requires knowledge about the direction of where the node should move while it is performing its task. One way to achieve this is to use the gradient descent method. The gradient method is used to determine the direction of movement of the mobile node in the field toward the most robust RF signal strength to maintain network connectivity (Ayad et al., 2022). To reduce the total path cost estimate, the node-controlled motion algorithm should utilize the knowledge that is learned from the RF environment recognition based on the RF signal strength measurements (Ayad et al.,2013). Therefore, this will guide us to explore the relationship between known RF obstacle types and their impact on RF signal strength measurements to minimize Meta-Routing total path cost. The information learned from the RF environment could be employed as the features for identifying the RF obstacle type, size, and the resulting RF environment. Once the robot determines the RF environment type and size, the node-controlled motion algorithm will drive the robot toward a favorable position predicted by the RF environment recognition method. Then, by applying the gradient method, which is used to extract the multi-dimensional gradient of the RF signals, a decision is made on the direction and control of the robots' motion (Ayad et al., 2019). The main steps of the node-controlled motion algorithm can be summarized as

1. Move robots to a favorable position in the field where they can gain strong RF signal strength to maintain their network connectivity.
2. Apply the gradient descent method to decide on the direction of the robot motion in the experimental field.
3. Utilize the knowledge learned from the RF environment recognition method to identify the RF obstacle type and size.

As mentioned in the previous section, robots will move back through free locomotion when the signal strength goes below some threshold, and a communication error occurs. The details of the gradient method used to drive robots to the most robust signal strength are discussed in detail in our work (Ayad et al., 2022). Also, the RF environment recognition method (RF mapping) used to identify different RF obstacle types and sizes is detailed (Ayad et al., 2013; Ayad et al., 2019). Lastly, the node movement, RF mapping, and gradient descent method are augmented into a controlled node motion algorithm to achieve Meta- Routing protocol to minimize the total path cost by reducing the overhead cost to maintain this path.

V. Gradient Descent for Intelligent Controlled Motion Algorithm

An essential part of Meta-Routing is the ability to move nodes intelligently, which maintains the communication links. Therefore, no assumption is made on the locations of RF obstacles or RF "dead zones." Instead, planned motions must be inferred from RF signal strength measurements. In our work, a multi-dimensional gradient approach is used to reduce the error in the signal strength because the robots estimate the signal strength gradient while they are moving (Ayad et al., 2019). The gradient method is applied in a way that helps minimize the total path cost function and increases the likelihood of success in controlling the direction and the robots' motion. Therefore, the gradient process significantly impacts the performance of the Meta-Routing protocol. The gradient method allows the robot to move in the direction of the strong RF signal strength; eventually, it affects the cost function of computing the total lowest path. Simultaneously, the likelihood of success L_{Mov}, in moving robots in the direction of communication coverage, becomes high. Therefore, the gradient descent method affects the overhead cost, C_{Mov}, which is a dominant part of the total path cost of the Meta-Routing protocol in our specific scenarios. In summary, the gradient method significantly impacts C_{Mov} and L_{Mov}, which affects the overhead cost and would eventually affect the total path cost of the Meta-routing protocol. Different RF signal strength gradient scenarios were tested and examined. The overall results for all experiments showed that the gradient method could potentially support robots moving toward the direction of strong signal strength for their connectivity maintenance. Furthermore, the gradient results can help the robots map the RF obstacles and determine the direction of the robots' movements(Ayad et al., 2022).

A. Gradient Algorithm Scenarios Using Network Simulator

Table I. Simulation Environment.

Parameter	Value
Channel	WirelessChannel
Topology	2×2
Nodes	2
Mac layer	$Mac/802-11$
Routing protocol	AODV
Traffic Type	FTP

In this simulation scenario, an area of 2×2 m^2 was chosen. The freeway motion model of the nodes was defined as a movement model for our experiments. The simulation uses two nodes. The maximum speed was set to 2.2 *cm/s*, and the minimum speed was set to 1.5 *cm/s*. The traffic generated was the FTP (File Transfer Protocol) on the TCP (Transmission Control Protocol) agent. The MAC layer was set to MAC/802.11. The AODV protocol was simulated with a source-destination pair. Nodes generate packets at different times. After running the simulation, the network animator (NAM) was used to show the data transfer between nodes. The trace files were analyzed for moving nodes. Utilizing the trace file, the node movement time was calculated. The scenario in Figure 5.16 (a) shows two mobile nodes. One node moves at a speed of 2.2 *cm/s*, and the other node moves at a speed of 1.5 *cm/s*. The nodes are moving and transmitting data packets. The nodes and simulation environment parameters are shown in Table I. As the two nodes move, they

approach an RF obstacle. The RF obstacle affects the communication signal between the mobile nodes. Therefore, the *S/N* goes down below the communication threshold. As a result, the nodes can not communicate anymore, as shown in Figure 5.16 (b).

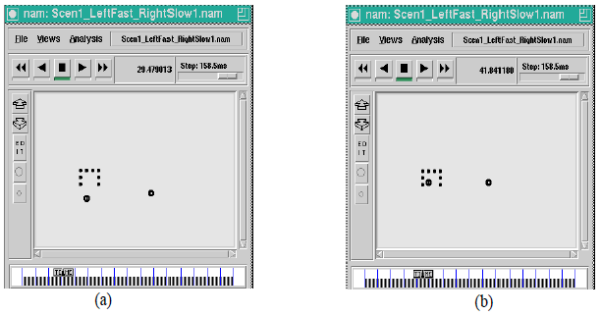


Fig.16. Two robots in (a) are transmitting data packets, and in (b) are losing communication.

In Fig.17 (a), the mobile trapped node has started to move back through free locomotion into a position where it can gain a strong signal strength to regain communication with the other node. According to the gradient algorithm, both nodes start calculating the gradient to decide the strong signal direction when the signal strength goes below some threshold. The node with the higher gradient would move first in the direction of its gradient, as shown in Fig.17(a). If the signal strength is above the threshold, the nodes would regain the communication signal and would start transmitting the information packet again; consequently, both nodes would move in the direction of their normal velocity, as shown in Fig.17 (b).

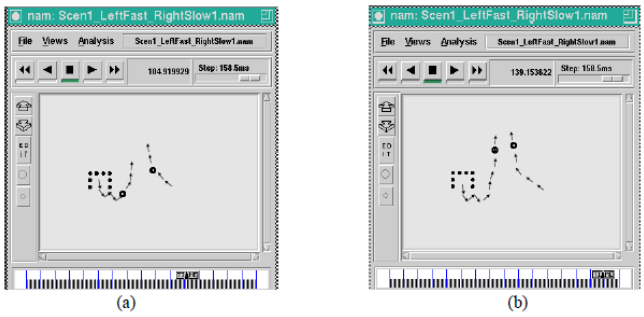


Fig.17. The robots in (a) are moving back, and in (b)are regaining communication.

We run multiple scenarios where the trapped node moves at a lower speed than the rightmost node and when the two nodes move at the same speed. The conclusion is that the node movement velocity is scaled as the nodes calculate the gradient to determine the direction of motion to maintain the network connectivity.

Besides, the RF recognition approach based on partial signal strength measurements along the robot's trajectories is used to identify RF shadows in RF environments (Ayad et al., 2022). This approach assists with the utilization of fading characteristics of known RF obstacle types on the RF signal measurements. The gradient descent method in (Ayad et al., 2022), augmented with the RF recognition method, is developed to achieve the Meta-Routing.

B. Gradient and Node Movement based on RF Mapping and Classification

The robot-controlled movement can drive the robots to favorable positions in the field. Once the robots reach strong signal-strength positions, they can regain communication with the robotic network. The robot control mechanism performs this to accomplish tasks assigned to the robots and maintain their network connectivity. An appropriate robot-controlled motion algorithm can manage the network faster than discovering a new node when there is a network failure in some cases. Concerning robot-controlled motion, the gradient descent method is required for connectivity maintenance of the robotic network. The gradient descent algorithm will determine the trends of the strong signal strength for robots; eventually, the robots will move in the direction that supports their connectivity.

The proposed Meta-Routing relies on the node-controlled movement and the gradient algorithm by reducing the total path cost function and increasing the likelihood of success in repairing links to improve the quality of communication links and maximize the broken communication links. The robots can map the RF obstacles in a harsh RF environment a priori by knowing the gradient magnitude and direction. Therefore, if a robot starts moving into the RF obstacle shadow, can it realize that it is moving into a temporary shadow? In other words, can the robot move into the RF shadow quickly, or will the RF shadow go deeper? As a result, the robot will lose connection with the other robots. Knowing the depth of the RF shadow, it is possible to estimate and reduce the overhead cost, consequently increasing the likelihood of success of moving robots away from that shadow, and then this will lead to lowering the total path cost of the Meta-Routing protocol.

The RF shadow recognition and classification concern the mapping of RF obstacles in an RF environment for estimating the depth of an individual RF shadow to reduce the total path cost of the Meta-Routing protocol. The estimation process will minimize the routing overhead cost resulting from moving deeper into the RF shadow. Why do we need RF mapping? Another vital question arises. In fact, we can achieve Meta-Routing using node movement and applying gradient descent. However, we still need to find the best cost estimate for repairing a broken link or discovering a new connection or node. For example, when two robots are moving in an unknown environment and start losing the communication signal, could we know the effects of the environment (RF obstacle) on the communication signal between robots? Also, could we estimate the depth of the RF shadow affecting the communication? In addition, could we recognize and classify the RF environment so that we can put the best cost estimate of repair specifically on this link, but not the likelihood of average links like hybrid protocols did? The following sections will present the answer to the questions above and other questions. The RF environment recognition method, the robot-controlled motion algorithm, and the gradient method will help reduce the overall path cost estimate compared to the route discovery phase for achieving Meta-Routing.

C. RF Shadow Primitives Classification

The block diagram in Fig.18 summarizes the significant steps of our algorithm for achieving the RF environment recognition method from partial data. First, each measurement vector obtained from different robot trajectories is segmented into small segments (Ayad et al., 2022; Ayat et al., 2013). Each segment is then transformed into the frequency domain for extracting features using a fast Fourier transform (FFT). We use a subset of all feature vectors for training, and the remainder is used for testing. Next, the extracted feature vectors for training are clustered using a clustering algorithm to generate observation sequences. The generated observation sequences train three Hidden Markov Models (HMMs), one for each RF obstacle type. Each HMM model consists of five states, corresponding to five concatenated segments of the robot's movement through a specific trajectory. As described above, each model was trained using a set of observation sequences. Finally, the HMMs classification models were tested using the testing set of feature vectors. Using the trained HMMs results, the RF environment recognition is achieved and utilized by the robot-controlled motion algorithm aiming at robot connectivity maintenance (Ayat et al., 2013).

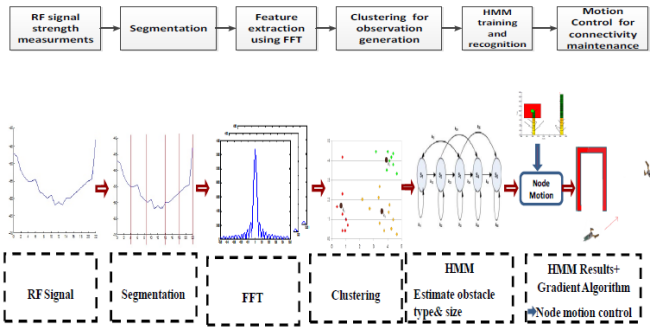


Fig.18. Block diagram of RF environment recognition processing steps.

D. Controlled Motion Mechanism for Meta-Routing

The controlled motion algorithm has two decisions for maintaining the robot's connectivity. The controlled motion algorithm takes the first decision; therefore, it drives the robots to move across the RF obstacle shadow toward a favorable position to maintain their connectivity based on the RF recognition through the HMMs results. On the other hand, suppose the controlled motion algorithm chooses the second decision. In that case, the robots move back through free locomotion and start computing the signal strength gradient to find the direction of the strong signal strength and then maintain their connectivity. We use the gradient-based controlled motion algorithm, which extracts the multi-dimension gradient of the RF signal measurements for controlling robot direction around the RF obstacle. In other words, depending on the HMMs results that estimate the type and the approximate size of the RF obstacle, the controlled motion algorithm decides whether to extend the movement through the RF obstacle shadow or to move back through free locomotion to a position in the field that has a strong enough signal strength and then it computes the gradient to determine the direction of robots' movements to maintain their connectivity. Algorithm 1 summarizes the main steps of the controlled motion algorithm. The whole picture of the Meta-Routing flowchart, including message routing protocol, link maintenance through node-controlled motion (link repair), and route discovery process, is summarized in Fig.19.

Algorithm 1 Controlled Motion Algorithm.

```
Input: RF environment recognition results.
Output: Maintaining connectivity of mobile robots.
Get RFRecognitionResults()

if (Obstacle type and size are estimated) then
    if Segments length ≥ (estimated width/2) then
        MoveCurrentPath()
        GradientDecsentAlgorithm()
    else
        MoveBack()
        GetStrongSignalPos()
        GradientDecsentAlgorithm()
    end if
else
    MoveBack()
    GetStrongSignalPos()
    GradientDecsentAlgorithm()
end if
MaintainConnectivity()
```

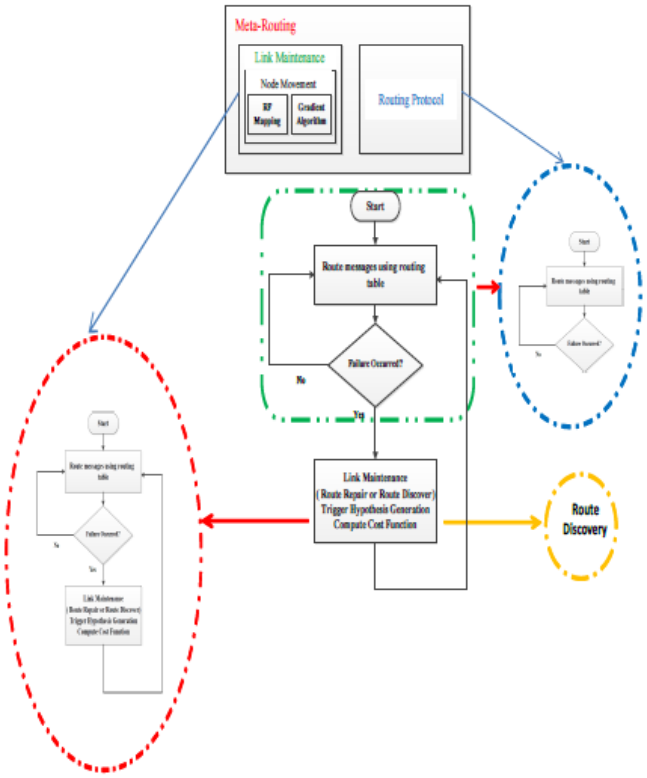


Fig. 19. Meta-Routing overall picture.

The controlled motion algorithm utilizes the HMMs results to drive robots to continue moving forward through the current trajectories if the length of the segment traveled by the robots are greater than or equal one half of the estimated RF obstacle size (Ayad et al. 2022; Ayat et al., 2013). Otherwise, the robots stop movement and move back through free locomotion to a position where it can gain strong signal strength. Then, the robots run the gradient algorithm to define the direction of the most robust signal strength. Afterward, the robots move in the direction of the gradient and attempt

to regain communication (Ayad et al., 2022; Ayat et al., 2013).

VI. Link Maintenance Based on RF Recognition Cost Estimation

The robot-controlled motion algorithm utilized the HMMs results to achieve robot connectivity maintenance. The time cost estimates for the link maintenance based on the RF environment recognition method are calculated in the following subsections.

A. Estimated Cost of Link Maintenance

The total estimated time for our link maintenance method $T_{(TOT)}$ is the sum of the segmentation time $T_{(SIG)}$ (the time to segment signal strength measurement vector), the FFT transform time $T_{(FFT)}$ (the time to perform FFT transform), the time for *K*-means algorithm T_k(the time to cluster the extracted feature vectors), the time for HMMs classification $T_{(HMM)}$ (the time for HMMs training and recognition), and the time for robot movement $T_{(MOV)}$, the time to move the robot back through free locomotion. The total estimated time is summarized as

$$T_{(TOT)} = T_{(SIG)} + T_{(FFT)} + T_{(K)} + T_{(HMM)} + T_{(MOV)} \quad (6)$$

We created different MATLAB programs and functions to estimate the time cost for our link maintenance method. We ran these programs on a DELL desktop computer, model Optiplex980. The Desktop runs Windows, 64-bit Operating System. The Desktop uses the Intel(r) Core(TM) i7 CPU, which runs on 2.93 *GHz*. The installed memory (RAM) capacity for the Desktop is 8 *GB*. In the experiments, the segmentation and FFT transform times were $T_{(SIG)}$ + $T_{(FFT)}$=0.3 seconds, and the *K*-means and HMMs times were $T_{(K)}$ + $T_{(HMM)}$= 6 seconds. Therefore, for a crawler robot that moves back a distance of 0.5 meters at a speed of 0.022 meters/second, the total estimated time $T_{(TOT)}$ = 0.3 + 6 + 0.5 / 0.022 = 29.027 seconds, as shown in Figure 8.9. If the robot's speed increases to 0.15 meters/second, the total estimated time is T_{TOT} = 0.3 + 6 + 0.5 / 0.15 = 10 seconds. The results show that the time cost estimate is affected directly by the robot's speed in the field. Thus, as the robots move fast, the time cost decreases.

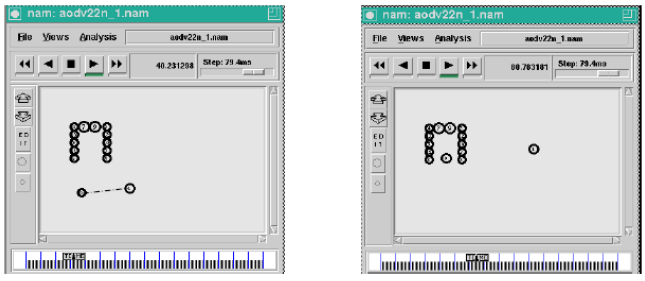
B. Estimated Cost for Node Movement

We will show a scenario on how node movement time can be estimated by explaining simulation environment specification and node configuration. The simulation was completed to assess the time required to move two disconnected nodes back through free locomotion to regain communication while running the AODV routing protocol. The simulation was performed on the NS2 simulator. In the simulation, an area of 2×2 m^2 was chosen. The freeway motion model of the nodes was defined as a movement model for our experiments. The simulation uses two nodes. The maximum speed was set to 2.2 *cm/s*. The traffic generated was FTP on the TCP agent. The MAC layer was set to MAC/802.11. The AODV protocol was simulated with a source-destination pair. They generated packets at different times. After running the simulation, the NAM was used to show the data transfer between nodes. The trace files were analyzed for moving nodes. Utilizing the trace file, the node movement time was calculated.

Table II. Simulation Environment.

Parameter	Value
Channel	WirelessChannel
Topology	2×2
Nodes	2
Mac layer	$Mac/802-11$
Routing protocol	AODV
Traffic Type	FTP

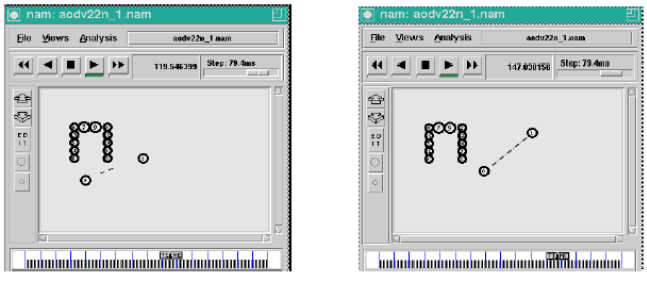
The scenario in Fig. 20(a) shows two mobile nodes. The nodes are moving and transmitting data packets. The nodes and simulation environment parameters are shown in table II. As the two nodes move, they approach an RF obstacle. The RF obstacle affects the communication signal between the mobile nodes. Therefore, the S/N goes down below the communication threshold. As a result, the nodes can not communicate anymore, as shown in Fig. 20(b).



(a) (b)

Fig. 20. Two robots in (a) are transmitting data packets, and in (b) are losing communication.

In Fig. 21(a), the mobile nodes are moving back through free locomotion into a position where they can regain the signal strength to communicate. The node movement time spent to retrieve the communication between the nodes was 29 seconds. Finally, the nodes regained the communication signal and started transmitting the information packet again, as shown in Fig. 21(b).



(a) (b)

Fig. 21. The robots in (a) are moving back, and in (b)are regaining communication.

C. *Estimated Cost for Route Discovery*

The route discovery time is a function of the distance to the destination, the size of the network, and the number of nodes in the network. The size of the transmitted data packet does not affect the route discovery time. A good route discovery process should have a short response time, which is how long the discovery mechanism takes to reach the destination, and should do so with a minimal time cost.

In communication networks, the total delay for the application data packet as it is transmitted from source to destination plus the route discovery time, which is the round trip time from sending a route request until receiving the route reply, is called the end-to-end delay. The total route discovery latency ($T_{(RDL)}$) is the sum of the request time ($T_{(req)}$), which is the time it takes for the first request message to traverse from the source to the destination, the reply time ($T_{(rep)}$), the time it takes for the first reply message to traverse from the destination back to the source, and the soft latency ($T_{(soft)}$), an extra waiting time happens at the source side after receiving the reply message. The total route discovery latency ($T_{(RDL)}$) is summarized in the Equation below:

$$T_{(RDL)} = T_{(req)} + T_{(rep)} + T_{(soft)} \qquad (7)$$

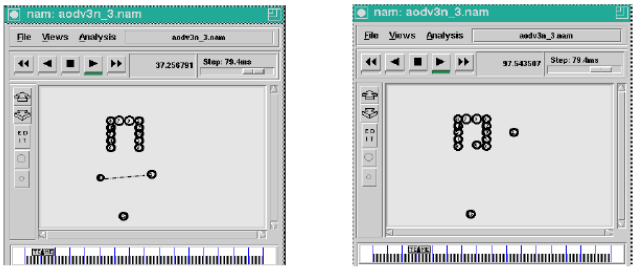
In the following sections, we will show a scenario of how to route recovery time can be estimated. First, the simulation environment specification and node configuration will be detailed. Then, the simulation is done to evaluate the route discovery time of the AODV routing protocol. The simulation was performed on the NS2 simulator.

In this simulation, the areas of the 2×2 m^2 were chosen. The freeway motion model of the nodes was defined as a movement model for our experiments. The maximum speed was set to 2.2 *cm/s*. The traffic generated was FTP on the TCP agent. The MAC layer was set to 802.11. The protocol has been simulated with three nodes. They generated packets at different simulation times. After running the simulation, the NAM shows the data transfer between nodes. The trace files are analyzed for moving nodes. Utilizing the trace file, the node route discovery time is calculated.

Table III. Simulation Environment.

Parameter	Value
Channel	WirelessChannel
Topology	2×2
Nodes	3
Mac layer	$Mac/802-11$
Routing protocol	AODV
Traffic Type	FTP

The scenario in Fig. 22 (a) shows two mobile nodes. The nodes are moving and transmitting data packets. The nodes and the simulation environment parameters are shown in table III. In the beginning, two nodes move in the experimental field and approach the RF obstacle. However, the RF obstacle affects the communication signal between the mobile nodes. Therefore, the *S/N* goes down below the communication threshold. As a result, the nodes can not communicate anymore, as shown in Fig. 22 (b).



(a) (b)

Fig. 22. Two robots are (a) transmitting data packets and (b) losing communication.

(a) (b)

Fig. 23. A new node (a) moved to the network (b) Regained communication with other nodes.

In Fig. 23 (a), when the nodes lost communication, they started executing the route discovery phase. A third new node from the base station was moved to join the network. The trapped node detected the new node. The new node acted as a bridge between the disconnected nodes. Therefore, the disconnected nodes regained the communication signal and started to transmit information packets, as shown in Fig. 24 (b). The route recovery time spent to retrieve the communication between the nodes was 39 seconds, which is higher than the time cost of moving nodes back through free locomotion, as shown in Fig. 24. In summary, the time spent to move nodes back through free locomotion is shorter than the time spent to recover a new node. Thus, the node-controlled algorithm is more effective than the route recovery phase in some cases.

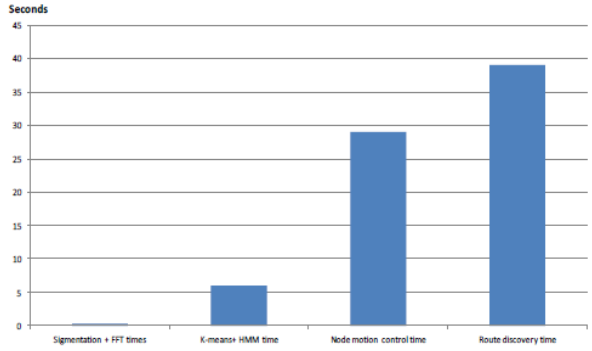


Fig. 24. Node movement and route discovery time comparison.

VII. Conclusions

This paper presents a new concept for a mobile robot routing protocol named Meta-Routing protocol. Meta-Routing merges a message routing protocol and a link maintenance protocol in mobile robot ad hoc networks. It achieves message routing using LSP hybrid routing protocol and performs link maintenance using the controlled motion of nodes. The motion control algorithm utilizes the RF mapping recognition and gradient algorithm results. The simulation results demonstrate the ability of the proposed Meta-routing protocol to achieve link maintenance through controlled node movement based on RF mapping and gradient algorithms. We expect that the proposed methods can be a competitive alternative for broken link replacement and maintaining robot connectivity in robotic networks.

References

Wu Y., Ren X., Zhou H., Wang Y., and Yi X. (2020). *A Survey on Multi-Robot Coordination in Electromagnetic Adversarial Environment: Challenges and Techniques in IEEE Access, vol. 8, pp. 53484-53497.*

Devi, Munisha, and Nasib Singh Gill. (2019). Mobile ad hoc networks and routing protocols in IoT enabled. Journal of Engineering and Applied Sciences 14.3: 802-811.

Voyles, R. M., Bae, J., Larson, A. and Ayad, M. (2009). Wireless video sensor network for sparse, resource-constrained, multi-robot teams. In Journal of Intelligent Service Robots, vol. 2, no. 4, pp.235--246.

Nabati, Mohammad, Mohsen Maadani, and Mohammad Ali Pourmina. (2022). AGEN-AODV: an intelligent energy-aware routing protocol for heterogeneous mobile ad-hoc networks. Mobile Networks and Applications 27.2: 576-587.

Kumar, G. Hemanth, and G. P. Ramesh. *(*2022). Node localization algorithm for detecting malicious nodes to prevent connection failures and improve end-to-end delay. Computer Communications 190: 37-47.

Queralta, J. P., Taipalmaa, J., Pullinen, B. C., Sarker, V. K., Gia, T. N., Tenhunen, H., ... & Westerlund, T. (2020). Collaborative multi-robot search and rescue: Planning, coordination, perception, and active vision. *Ieee Access*, *8*, 191617-191643.

Tripathy, B. K., Jena, S. K., Bera, P., & Das, S. (2020). An adaptive secure and efficient routing protocol for mobile ad hoc networks. *Wireless Personal Communications*, *114*(2), 1339-1370.

Ayad, M., and Voyles, R. (2019). Physical Link Maintenance and Logical Message Routing Integration for Robotic Network Connectivity. *Vehicular Technology Conference, IEEE. Hawaii.*

Thrane, J., Sliwa, B., Wietfeld, C., & Christiansen, H. L. (2020, December). Deep learning-based signal strength prediction using geographical images and expert knowledge. In *GLOBECOM 2020-2020 IEEE Global Communications Conference* (pp. 1-6). IEEE.

Cardona, G. A., & Calderon, J. M. (2019). Robot swarm navigation and victim detection using rendezvous consensus in search and rescue operations. *Applied Sciences*, *9*(8), 1702.

Ayad, M., Voyles, R., & Ayad, M. (2022). Robotic Ad-hoc Networks Connectivity Maintenance based on RF Signal Strength Mapping. *International Journal of Advanced Computer Science and Applications*, *13*(2).

Thiagarajan, R., & Moorthi, M. (2017, February). Efficient routing protocols for mobile ad hoc networks. In *2017 Third International Conference on Advances in Electrical, Electronics, Information, Communication, and Bio-Informatics (AEEICB)* (pp. 427-431). IEEE.

Zhang, D. G., Zhao, P. Z., Cui, Y. Y., Chen, L., Zhang, T., & Wu, H. (2019). A new method of mobile ad hoc network routing based on greed forwarding improvement strategy. *IEEE Access*, *7*, 158514-158524.

Younis, Z. A., Abdulazeez, A. M., Zeebaree, S. R., Zebari, R. R., & Zeebaree, D. Q. (2021). Mobile Ad Hoc Network in Disaster Area Network Scenario: A Review on Routing Protocols. *International Journal of Online & Biomedical Engineering*, *17*(3).

Alani, H., Abdelhaq, M., & Alsaqour, R. (2020). Dynamic routing discovery scheme for high mobility in mobile ad hoc wireless networks. *International Journal of Electrical & Computer Engineering (2088-8708)*, *10*(4).

Khudayer, B. H., Anbar, M., Hanshi, S. M., & Wan, T. C. (2020). Efficient route discovery and link failure detection mechanisms for source routing protocol in mobile ad-hoc networks. *IEEE Access*, *8*, 24019-24032.

Raj, J. S. (2020). A novel hybrid secure routing for flying ad-hoc networks. *Journal of trends in Computer Science and Smart technology (TCSST)*, *2*(03), 155-164.

Ludwig, L., & Gini, M. (2006). Robotic swarm dispersion using wireless intensity signals. In *Distributed autonomous robotic systems 7* (pp. 135-144). Springer, Tokyo.

Ayad, M., Zhang, J. J., Voyles, R., Mahoor, M. H. (2013). Mobile robot connectivity maintenance based on RF mapping. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE

Bae, J. and Voyles, R. M. (2006). Wireless video sensor network from a team of urban search and rescue robots. *International Conference on Wireless Networks*.

Michael, N., Zavlanos, M.M., Kumar, V. and Pappas, G. J.(July, 2009). Maintaining connectivity in mobile robot networks. *In International Symposium on Experimental Robotics*. Athena, Greece.

Hahnel, D., Ferris, B. and Fox, D. (2006). Gaussian processes for signal strength-based location estimation. Proceeding of Robotics: Science and Systems, Philadelphia, PA.

Maya Nayak and Bhawani Sankar Panigrahi (April, 2011). Advanced Signal Processing Techniques for Feature Extraction in Data Mining. *In International Journal of Computer Applications, vol. 19, no. 9, pp. 30-37.*

Kanungo, Tapas., David, M., Nathan, S. Netanyahu, Christine, D., Ruth, Silverman, and Angela, Y. (July, 2002). An efficient k-means clustering algorithm: Analysis and implementation. *IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 24, no. 7, pp. 881--892. IEEE*

Rabiner, LR. (Feb, 1989). *A tutorial on hidden Markov models and selected applications in speech recognition*, vol.~77, pp. 257 --286.

Easttom, C. (2018, March). The Role of Weaponized Malware in Cyber Conflict and Espionage. In *ICCWS 2018 13th International Conference on Cyber Warfare and Security* (p. 191). Academic Conferences and publishing limited.

Easttom, C. (2018, May). An Examination of Inefficiencies in Key Dependent Variations of the Rijndael S-Box. In *Electrical Engineering (ICEE), Iranian Conference on* (pp. 1658-1663). IEEE.

Loscri, V., Natalizio, E. and Costanzo, C. (July , 2010). Simulations of the impact of controlled mobility for routing protocols. *EURASIP Journal on Wireless Communications and Networking*.

Purohit, A., Zheng, S., Mokaya, F., and Zhang, P. (2011). Sensorfly: Controlled-mobile sensing platform for indoor emergency response applications. *In Information Processing in Sensor Networks (IPSN), 10th International Conference.*

Ghaffarkhah, A. and Mostofi, Y. (July, 2012)Path Planning for Networked Robotic Surveillance. *In Signal Processing, IEEE Transactions, vol. 60, no. 7, pp. 3560-3575.*

Sweeney, J., Brunette, T. J., Yang, Y., and Grupen, R (2002). Coordinated teams of reactive mobile platforms. International. *Conference on Robotics and Automation (ICRA). IEEE, vol.~1, pp. 299--304.*

Fink, J. and Kumar, V. (2010). Online methods for radio signal mapping with mobile robots network *Conference on Robotics and Automation(ICRA).*. IEEE.

Twigg, J. N., Fink, J. R., Yu, P. L. and Sadler, B. M. (May, 2012). RSS gradient-assisted frontier exploration and radio source localization. International. *Conference on Robotics and Automation(ICRA). IEEE, pp. 889--895.*

Sun, Yi, Jizhong Xiao, Xiaohai Li, and Cabrera-Mora, F. (2008). Adaptive source localization by a mobile robot using signal power a gradient in sensor networks. IEEE Global Telecommunications Conference, pp. 1 --5.

Yuan, Yan, and Mostofi, Y. (Nov. , 2011). Co-optimization of communication and motion planning of a robotic operation in fading environments. *Signals, Systems, and Computers (ASILOMAR) Conference* Record of the Forty Fifth Asilomar Conference, pp. 1455--1460.

Fink, J., Kumar, V., Michael, N. and Kushleyev, A. (2009). Experimental characterization of radio signal propagation in indoor environments with application to estimation and control. *IEEE International Conference on Intelligent Robots and Systems.*

Ani Hsieh, M. , Anthony Cowley, Vijay Kumar, and Camillo, J. Taylor (2008). Maintaining network connectivity and performance in robot teams: Research articles. *Journal Field Robot.*

Zavlanos, M. M. and Pappas, G.J. (Dec., 2008). Distributed connectivity control of mobile networks. *IEEE Transactions on Robotics, vol. 24, no. 6, pp. 1416 --1428.*

Zavlanos, M. M. and Pappas, G.J. (Dec., 2008). Distributed connectivity control of mobile networks. *IEEE Transactions on Robotics, vol. 24, no. 6, pp. 1416 --1428.*

Spanos, D.P. and Murray, R.M. (Dec., 2004). Robust connectivity of networked vehicles. *IEEE Conference on Decision and Control Conference,vol.~3, pp. 2893 --2898 Vol.3.*

Meng, Ji and Egerstedt, M. (Aug., 2007). Distributed coordination control of multiagent systems while preserving connectedness. *IEEE Transactions on Robotics, vol. 23, no. 4, pp. 693 --703.*

Hsieh, M.A., Cowley, A., Kumar, V., and Taylor, C.J. (May, 2006). Towards the deployment of a mobile robot network with end-to-end performance guarantees. *Proceedings IEEE International Conference on Robotics and Automation (ICRA), pp. 2085 --2090.*

Zeiger, F., Kraemer, N. and Schilling, K. (2008). Commanding mobile robots via ad-hoc wireless networks - a comparison of four ad-hoc routing protocol implementations. *IEEE International Conference on Robotics and Automation (ICRA).*

Mostofi, Y., Malmirchegini, M. and Ghaffarkhah, A. (May, 2010). Estimation of communication signal strength in robotic networks. *IEEE International Conference on Robotics and Automation (ICRA), pp. 1946 --1951.*

Software Engineering Methodology for Smart Healthcare Security and its Application in Bangladesh

Mahmud Hasan*[1], Mohammed Mofizur Rahman [2], Arian Rahman [2] , Md. Ahasanul Islam [2] and Md. Mazid-Ul-Haque [2]

[1] *Dept. of Computer Science, Jahangirnagar University, Dhaka, Bangladesh.*
[2] *Dept. of Computer Science, American International University-Bangladesh, Dhaka, Bangladesh.*

Abstract- **In the modern day, producing new software requires utilizing the most cutting-edge tools and techniques. Due to the growing complexity of technology, effective software development increasingly depends on well-managed development processes. A software development project has its own distinctive features. There is no one software process model that can manage all the many types of software development projects because there are so many distinct sorts of them. Whatever paradigm is utilized, there will always be limitations. The goal of the healthcare system security and its application is to provide the best possible clinical treatment and to receive the best possible assistance for patient care and security. The healthcare structures need to support good health, honest economic contribution, and top-notch services. The healthcare business has quickly expanded over the past ten years, especially in developing nations. Implementing medical software programs is one of the most significant future challenging scenarios in the healthcare industry. Utilizing healthcare data structures will expand the availability of fitness services, improve patient satisfaction with care, and reduce clinical errors. We are providing a fresh approach to software engineering for healthcare programs called SDLC as a result. This approach is intended to address the software-improvement issues and challenging circumstances that exist outside the healthcare area. The need to create durable, steady, and high-performing healthcare equipment is the main driver behind the development of a new software engineering methodology for the industry, including SDLC.**

Keywords— Software Development Lifecycle (SDLC), Agile Methodology, Healthcare System, Healthcare Application, Secure Software System, Interact Enhancement

1. INTRODUCTION

The smart healthcare system's aim is to achieve the best possible solution for patients, physicians, any kind of physician's serial, buy medicine, medical translator, same generic different company's medicine, diagnostic center's portal and to provide optimal medical support. The healthcare industry is rapidly grown up. Software engineering is a diverse field that aims to develop high-quality software systems adopting systematic techniques growing project management that are linked to the principles of user-centered design [8]. A set of fundamental aspects used in the design, development, and testing of software applications is named the Software Development Life Cycle (SDLC), which facilitates it. There are some SDLC models such as the waterfall model, spiral model, rapid application model, agile model, Big Bang m,odel etc. Implementing medical healthcare software is one of the major challenges facing Bangladesh's smart healthcare sector in the coming years.

Software engineering practices can be thought of as a group of ideas, techniques, and tools that software engineers use on a regular basis to give the technical and management team a clear picture of how the job is done and to change a disorganized, unfocused approach into one that is more organized and targeted [7].

Currently, devices are found in each home and on every hand. People are using excellent mobile applications as a result to simplify their everyday live.

The creation of a mobile application (app) to aid in the implementation of an efficient healthcare system is the key topic of this paper. People who utilize this app can take advantage of a wide range of advantages, including finding local hospital information, cabin information, booking a cabin with payment, intelligent hospital recommendations, finding a physician, emergency service calls, first aid information, medication alarms, a BMI calculator, medical translation, scheduling as well as reminders, a 24/7 chat system, a photo gallery, push notifications, mental health, and more. By using Agile Methodology, we can use different types of features in the smart healthcare application. An emerging field for Bangladesh's economy is the IT sector. This sector is being given special attention by the government because it is estimated to boost GDP growth by 7.28 percent by the end of 2021 [5].

Applying innovative medical software to healthcare organizations successfully is challenging. A growing industry for software engineers and IT experts is software engineering for healthcare systems. Smart healthcare information systems will boost the availability of healthcare services, enhance the standard of care, and lower medical errors. A growing industry for software engineers and IT professionals is software engineering for medical practices. The following step will cover a systematic examination of applications for smart healthcare security and its application. This research shows us which SDLC model is proper for the healthcare system. This research cover how planning, analysis, design, Implementation, Testing, Deployment and Evaluation properly works in the healthcare system. The research can show us how it can reduce the medical errors

The rest of this paper is organized as follows: Section 2 presents the literature review to know about software engineering-related work, Section 3 presents the methodology of this paper; Section 4 describes the survey of the proposed model-related issues; Section 5 provides a detailed explanation and result of this paper; finally, Section 6 provides conclusions and future work.

2. LITERATURE REVIEW

In the literature review, several articles compare with software engineering methodology for healthcare security and its application in Bangladesh. Next, we present the risk management of the software and different types of software engineering methodology, pros and cons and their limitations:

The tremendous development of technology has resulted in the widespread use of software systems. Smart health systems require a software engineering methodology. Software engineering methods to help achieve smart and consistent healthcare systems[37]. Software Engineering aims to create high-quality software. It is based on the systematic methodologies of the high-quality project. An intelligent healthcare system greatly reduces costs, and many factors cannot be quantified accurately[31]. To understand this superior healthcare technology and system, Model SDLC is applied. It can be done using the SDLC model. This SDLC model can stimulate the development of a software application that also adds a new dimension to the healthcare sector. The healthcare

The System needs to provide the best possible contribution to the patient. The SDLC model can easily provide these services. Implementing smart healthcare is difficult. SDLC Model contains multiple phases of software development and deployment [26].

It is essential to have a thorough understanding of the roles that each stage of the SDLC plays. The SDLC is divided into six phases: requirement analysis and planning, design, implementation, testing, deployment, and maintenance. There are specific security precautions that must be taken at each stage. Throughout the requirements and planning phases, the project team receives all project information from stakeholders or customers [8].These aids determine the level of software security required and also solves the software application bug. The following phase is the design phase, which includes all of the tasks that must be completed prior to any coding.

Modern improvement methodologies such as component-primarily based total improvement and allotted software program environments may bring about insecure merchandise if now no longer monitored and cautiously constructed [21]. As a result, safety functions need to be included at each level of the software program improvement process.

Software risk assessment is a method for locating, evaluating, and prioritizing threats and dangers. In general, there are large, medium, and small software program tasks that each of them may be encouraged via way of means of a threat. In the literature, there is a huge variety of threat evaluation research carried out closer to software program tasks[29]. But there may be at the least view researchers specializing in threat evaluation of small and medium software program tasks[34]. The primary awareness of the paper is to present researchers with a perception of the contemporary stage of threat evaluation for small and medium software program improvement tasks [17].

Risk management and software development classification, we are able to consciousness our paper specifically on the hazard evaluation stage for software program improvement projects. On the alternative hand, the essential goal of this evaluation is to present researchers with a perception of the present-day stage of hazard evaluation for Smart Healthcare Applications in Bangladesh [12]. Additionally, the paper gives facts about the unique forms of hazard evaluation fashions and strategies that are determined in the literature primarily based totally on the context of hazard evaluation for Smart Healthcare Security and its Applications in Bangladesh Using Software Engineering Methodology.

Software security testing is an essential approach to make certain software program protection and trustiness. Identifying vulnerabilities and making sure protection capability via way of means of protection trying out is a broadly implemented degree to assess and raise the software's safety[16]. Due to the openness of modern software-based systems, using appropriate security testing methods is becoming increasingly

A system, piece of software, or online utility is subjected to security testing to search for flaws and different assault routes [13]. It is made of several approaches that make certain the utility's code works as supposed and does now no longer take any accidental actions. There are numerous methods that are offered. If an entry affects a sudden final result even as evaluating preset inputs towards preferred outputs, a hassle is discovered[39].

A developer wishes to be privy to the facts domain's needed functions, actions, and techniques for chance mitigation to be able to draw close the nature of the chance document received withinside the first phase. The evaluation phase's purpose is to decide the probability and length of every chance item's loss.

The system and software design documents are created in the third phase in accordance with the requirement specification document. This clarifies the architecture of the entire system. The model's subsequent phase is informed by the design phase. To implement the risk management plan with the proper priority, it is crucial to make the best decisions possible during the assessment phase. A plan for risk mitigation would minimize or eliminate the hazards with the highest priority.

Building the code and documentation for the solution additives is the primary goal of the growing phase. Throughout the phase, the group continues the song of each chance and offers any new ones as they appear. There are three steps in this procedure. Code reviews: A code evaluation may be a beneficial device for groups to decide whether or not their code complies with local requirements and can even assist them to discover capacity troubles earlier than compiling[35]. Programming in pairs: Pair programming lowers the risk of employee loss [28]. By using unit exams and dynamic evaluation, builders might also additionally test the safety capability of components and make sure that any safety dangers formerly located via threat modeling and supply code evaluation are mitigated with the aid of using any countermeasures now being built.

The final deployment process begins after the software testing phase is complete and there are no bugs or errors still present on the device. The most recent software is launched and examined for deployment issues, if any, based on the comments provided through the use of the project manager.

Many models have been established in the world of software building based on SDLC. The advantages and disadvantages of these models, risk, and security are discussed in the comparative discussion of some models in this paper.

3. METHODOLOGY

The research goal is the final objective that must be attained while the research is being conducted. It might be to fill a knowledge gap, add to the body of current information in the field, develop and test a solution to an issue, or any number of other reasons. In this chapter, we spoke about the methods we use to build up and diversify our knowledge. The thesis work's general look and feel, as well as the methods that were employed to create it. This chapter discusses the research methodology as well as a general overview of the relevant theory. This study's steps include SDLC and model regulation, as well as the current situation and how to solve the problem of smart healthcare Security and its applications in Bangladesh using Software Engineering Methodology. This research is part of a larger project. A review of prior research findings, the development of a survey questionnaire, qualitative and quantitative analysis based on the survey review, survey results, and a recommended best Software Engineering Methodology for Smart Healthcare Security and its Application in the Bangladesh software sector are presented here.

Figure 3.1: Methodology

In problem formulation part in this research, there are different types of problem findings regarding healthcare sector in Bangladesh. There are different types of healthcare applications are available in Bangladesh. But there is no application which are fully designed with proper features. Suppose in telemedicine application in Bangladesh's perspective find that only medicine sales in these types of application. There are many applications of physician's appointment booking. No proper Mobile application for healthcare system with many features. In Bangladesh Healthcare systems follow pluralistic model, for that reason no mobile application doesn't have many features. It is very much useful application for a patient if an application is well designed and add all features in one application. Many Patients lost their previous medical reports, physician's prescription etc. There is no application that can save patients past medical reports and physicians prescriptions. There is no emergency call system to near hospital like uber or Pathao only for patient's emergency. One of the biggest problems is to understand physicians handwriting, many pharmacists can't understand this, and this is one of the main problems. Many medicines have same generic but their companies are different. There are many applications but maximum application doesn't add these features. To ensure proper healthcare system in Bangladesh it is mandatory to add many features in an application that helps patients, physicians, diagnostic centers. However, there are also some issues such as Poor Amenable Survival Rates, Lack of Transparency, and Difficulty Getting a Good Physician.

Security is one of the most important factors for healthcare systems. Healthcare systems data security is very essential. Healthcare systems data and medical entitles are logged by various malicious actor and cyber attackers. Data need to be protected. A large amount of data is stored in the system. As a result, many personal information is stored. Malicious actors attack the system with spam mail, virus, and other worms. They perform identity theft, phishing, and infiltration of networks. These issues are most common in healthcare systems. This security issues can be solved using two factor authentication. Network security can be improved. End to end security can provide and maintain security in the healthcare. Secure software development framework can play a vital role. Encryption system can help to protect this large amount of data. It can easily provide security in the systems. PACS is Picture Archiving and Communication Systems (PACS) which is helpful for transmission and storage of medical records. If healthcare applications security is not properly provided it will be difficult to determine if any attack has performed and what necessary steps need to take. It can lead serious damage and security breach. As a result, Security logging and monitoring is necessary for healthcare application. Broken authentication, Injection flows and session management are threat issues for the healthcare. As a result, security is very obligatory for the healthcare system.

Bangladesh perspective there are no application which is well developed and all service in one application. If in the research follow the agile methodology for smart healthcare application in Bangladesh perspective, this is really very useful application and all the service will find in one application. In this research, different service such as physicians review, medicine sales, one click emergency service, health tracking system, mental health, image processing, EHR, EMR etc. will be added in the system. Physician Review is very important for a patient because which physician's ratings are high that ensures that their treatment is too much better. Medicine Sales system's main goal is to sale medicine by its generic. It will very helpful for all because same medicine different generic different company's prices are different. There are many companies in Bangladesh that their medicine price is too much high. A Patient can easily buy a medicine by its generic and also find the low price of the medicine. Many physicians handwriting can't clear properly so here in this system add a machine learning image processing system so that a patient can easily take a picture of prescription and the system will read it and show the output of the prescription as a clear picture. All of the features can be added possible for Agile Methodology. Adding to many useful features Smart Healthcare Application will be a play a Vital Role in Bangladesh Healthcare System.If agile methodology followed in Bangladesh perspective it will be also helpful for the security of healthcare systems. As a result, data can be secured. These malicious actors cannot log, monitor data and steal data of the system. System becomes more secure. Many unauthorized access and Outdated component cannot perform vulnerabilities to the healthcare systems. Server-side request forgery flaws can break the protocol of the healthcare application. Sensitive data can be unsecure through internal and external servers these problems are resolved by this Agile methodology software system.

Most software applications share certain universal traits while also having some of their own distinctive properties. On the other hand, the developer can make the product using a process model that takes these shared traits into account. The software business uses a variety of models at the moment. The agile methodology stands out among them for smart healthcare security and its application in Bangladesh. Additionally, this research has attempted to develop a model to offer security at each level of the SDLC by evaluating the structure and features of previous models. Accordingly, the model have proposed is user-friendly and has a lot of useful features that leverages other conventional specialized models that are derived through human input, according to the findings of previous studies and survey results. Among the models used to support the agile model. In this study, both qualitative and quantitative methods were employed. Everything is laid out in a way that is simple to understand. Additionally, this research made a lot of effort to include all the data. On the basis of the literature review, the study issue's current state is described, after which the suggested

methodologies and analyses are used. In conclusion, a synthesis of the study's findings is presented.

4. PROPOSED MODEL

A survey of eleven questions were formed in the Google form and forty-four responses were gathered from Software Developers, Software Quality Testers, IT Engineers and Software Engineers of some of the Top Software Companies in Bangladesh. The survey's results are shown and described with the graphs below.

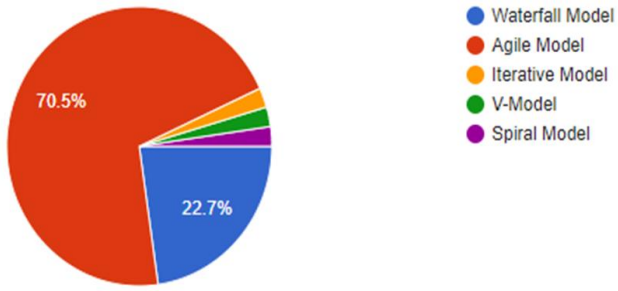


Fig 4.1: Popularity of SDLC Model In Bangladesh

If we see the above pie chart it can be seen that 70.5% engineers agreed Agile model which is most commonly used in Bangladesh.

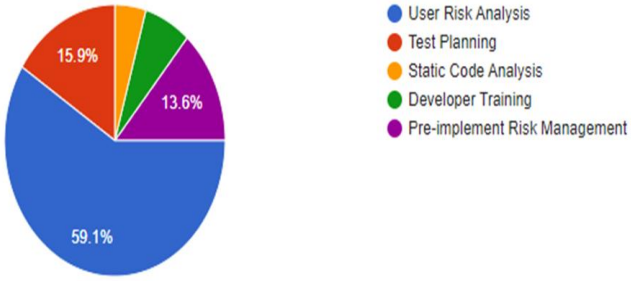


Fig 4.2: Risk Analysis Increasing In Bangladesh Healthcare Sector

For the Security of the healthcare system, 59.1% of engineers think user risk analysis increases more security for healthcare applications.

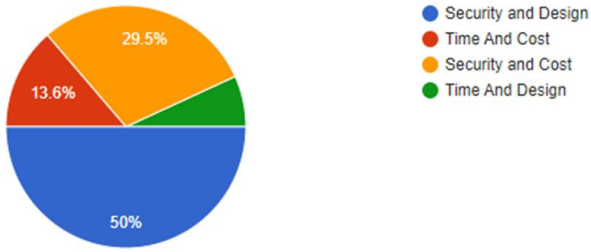


Fig 4.3: Most Important Factor in the Development process in Bangladesh Healthcare Sector

Security and Design is really important and 50% of the engineer think security and design is the most important factor in development process of healthcare system.

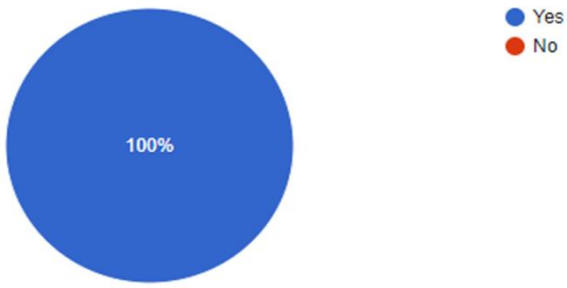


Fig 4.4: Importance of more security Testing

100% of Engineers think that this system needs more security testing in the SDLC process.

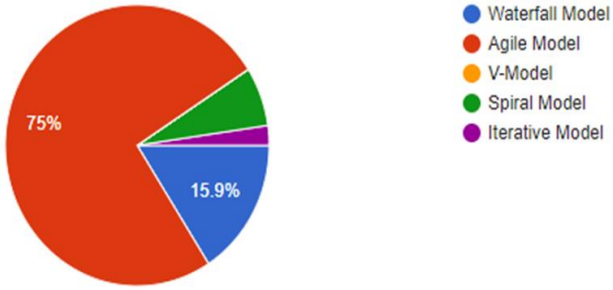


Fig 4.5: Ensuring for more security in healthcare system

Agile Model ensures more security in healthcare system and 75% of engineers agreed with it.

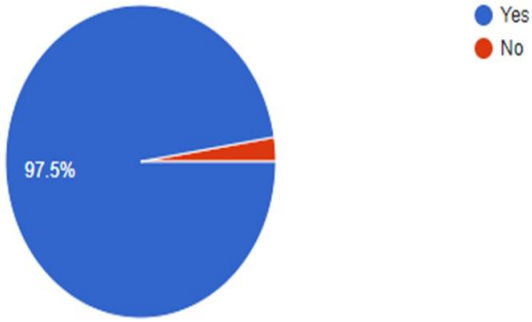


Fig 4.6: Security enhance design phase

"Security will enhance from the creation of a primary product prototype during the design phase of the SDLC" 97.5% of engineers agreed with it.

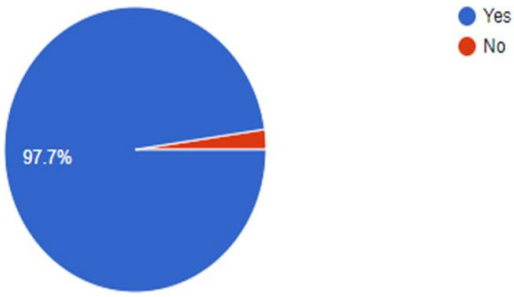


Fig 4.7: Detecting Error save time

97.7% Engineers are agreed that detecting errors in the early stage can save time, energy and cost in the software development process.

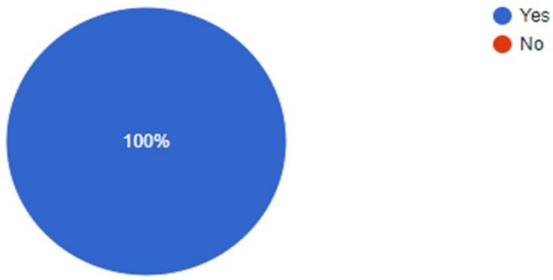


Fig 4.8: Development of Secure Software

100% of engineers agreed that detecting errors in the early stage of software development could be a significant turning point in the development of secure software.

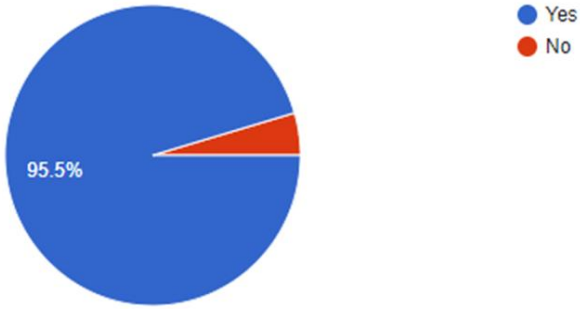


Fig 4.9: Hybrid Model ensures system's security

95.5% of engineers agreed to use a hybrid model in the business if it ensures your system's security.

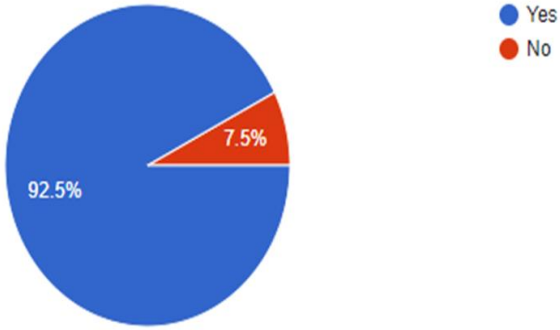


Fig 4.10: PACS Service improve healthcare sector of Bangladesh

92.5 % of engineers agreed that PACS (Picture Archiving and Communication System) service can improve healthcare sector of Bangladesh.

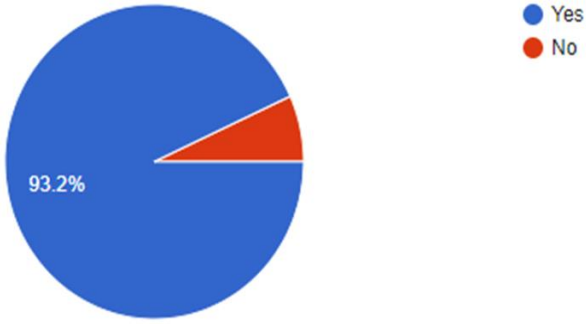


Fig 4.11: Electronic Prescription software's effectiveness in the Healthcare sector in Bangladesh

93.2% of engineers agreed that third-party integration with electronic prescription software will offer effective security for the healthcare sector of Bangladesh.

4.1 Proposed SDLC Model:

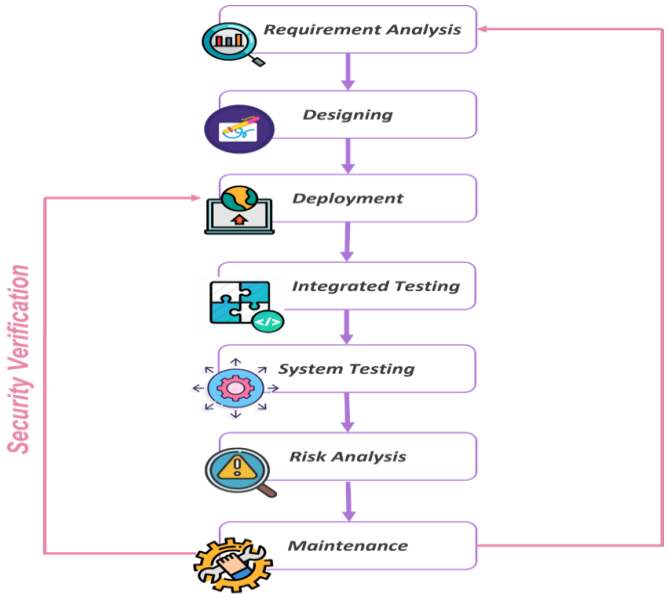


Fig 4.12: Proposed SDLC Model Architecture

Project managers and developers can make sure that security protocols are applied consistently throughout the development process in line with the set of rules by using systematic techniques like frameworks and procedures in Healthcare Applications in Bangladesh. Proposed SDLC Model Architecture there is a flowchart. All the programs work in a systemically way. By using this Model, software engineering methodology in the healthcare system in Bangladesh is properly secured and all the development processes in line.

In Healthcare security and its application in Bangladesh, there must be a security issue for all users, so that the proposed model is used here properly. Another thing is for the telemedicine issue it is important for all patient to give their medical prescription to the system.

The idea of tackling security vulnerabilities and security early in the software development life cycle is now stressed by the majority of studies. The design phase entails distilling all of the analysis and requirement knowledge necessary for software design. For designing, a variety of tools can be used, including data dictionaries, entity-relationship diagrams, and flow diagrams. There are numerous designs available, including functional and object-oriented designs. Software design guidelines exist that can be applied to creating secure frameworks, enhancing the security of programming frameworks, and dealing with problems that impede the development and security . In the healthcare security and its application in Bangladesh the most important issue is security. Because the data of patients, physicians and hospitals are here. So that the hacker or others tries to break the security of the system. Therefore, the recognition of different security risks at the design phase will help avoid the loopholes that may pose a threat to the security of the system in the future. Our system is not only having security issue another part of our system is telemedicine and other types of healthcare related issue solving. But the main thing is the security of healthcare system is the main design phase of our proposed Model.

In Healthcare security and its Application in Bangladesh, now-a-days, software maintenance is a generally accepted component of the SDLC. It refers to all updates and adjustments made after a software product is delivered. Deployment and maintenance of software are the final stages

of the software development lifecycle process. The actual installation of the software product, along with all of its components and database, in the production environment, may also fall under this phase. This typically leads to a variety of complications that are associated with this type of integration. According to Payer, an update and patching strategy establish how to address security problems, create patches, and provide users with updated software. In order to often check for new updates while taking into account the demand on the update servers, the component in charge of security updates must be created. We can go back and look at previous requirements studies or system testing stages if necessary. The Healthcare Application in Bangladesh is further enhanced and new features and functionalities are gradually added during the operation and maintenance period.

5. DISCUSSION:

A new Secured Agile Software Engineering Methodology has been proposed in this paper. As the data of the Healthcare Industry is considered the most valuable asset on planet earth, the security of Healthcare Software Solutions should be more secure and interactive. To ensure the integrity of data and source, extra security layers have been introduced into the proposed agile method. The main focus of the newly proposed Agile method was on design and preventive threat modeling. In the design phase of the proposed Secured Agile Model, four sequential subphases have been introduced and those are Security Requirements Analysis, Forming Secure Coding Structure, Threat Modeling, and Developing Security Architecture. The reason behind the sequential approach is to ensure effectiveness in providing protection in each and every phase from cyber criminals, attackers, phishing, threats, and malware.

For implementing or upgradation using sprint system of Agile model, a whole new Maintenance system has been introduced in the proposed agile methodology. The maintenance system will work as a pathway of creating a re-engineered and a better Healthcare System than before. It is believed that, the freshly proposed Agile Method for Healthcare System will bring an evolutionary change on Healthcare Industry that will be more flexible, reliable and secure.

Almost all software system has some limitations. Building a secure Healthcare Software Solution is a challenging task since it has to be reliable, user-friendly, stable, and safe for its users. Since the proposed agile-based healthcare system emphasizes security and data integrity, poor implementation may bring a great hamper. As mentioned earlier in this paper that, the system will be an interactive approach among the patients, physicians, and hospitals. So, miscommunication between the user and the system site may break down the entire system, as it relies on a network that is compact. Additionally, the mis interaction of patients with technology instead of face-to-face customer care might cause a misleading treatment or service. Also, poor data collection and misleading data analysis can create a disaster to the patient care process in the proposed Secure Agile Method. Since agile cares about building a better product in a short period of time, a lack of proper documentation may hamper the structure of the system.

6. CONCLUSION AND PERSPECTIVES:

Since the Agile method heavily depends on user interaction, maintenance of that system can be critical and may be driven in the wrong direction due to a lack of interaction and communication between the system and the user. A poor testing strategy may lead the system at risk of data breach and can cause a great catastrophe as Healthcare System holds the confidential data of patients, hospitals, and physicians. In conclusion, the proposed Healthcare Agile Method should be handled carefully with professional hands and advanced technology.

This paper discussed what helped improve the modern healthcare system. The models used here help to improve the various sectors of healthcare. These models can be developed in the future and used to help develop other fields, including healthcare. These models can be developed depending on the uses and product. Here the algorithm can be implemented so that it can be used in large complex systems. As a result, many complex systems can be used very easily. This model can be improved in such a way that everyone can use the model perfectly in business and enterprise software also. Automation of software models can be done to ease future development by developers. AI systems can also be used as a result whole software system will be improved which can be very useful in every business. In the healthcare system, huge data should be stored in different sectors and all the information of a patient is stored. Sometimes it is difficult to maintain all the data by humans. So, it will be better if the AI system is used in healthcare. So, in the future AI system can be improved for developing the healthcare system. So that it may be easier to use in every sector and it will also be helpful to reduce maintaining the big data of the healthcare system. This system can be improved in such a way that every class of people can use it easily and receive modern health care.

REFERENCES

1. Neelu Lalband, D.Kavita, “Software Engineering For smart healthcare applications”,International Journal Of Innovative Technology and Exploring Engineering(IJITEE),April 2019
2. S.L.R. Vrhovec*,** MIPRO 2016,May 30- June 3,2016,Opatija,Croatia.
3. Richard J Holden, Malaz A Boustani , Jose Azar,2021. Agile Innovation to transform healthcare : innovation in complex adaptive system is an everyday process,not a light bulb even.
4. Nosheen, N. and Muhammad, K., 2018. A Review of Security Issues in SDLC.
5. Unuakhalu, M., 2014. Integrating Risk Management in System Development Life Cycle.
6. Mamdoh Alenezi*,Sadiq Almuairfi,’’Security Risks in the software Development Lifecycle’’,International Journal of Recent Technology and engineering (IJRTE),2019
7. J. Hellström and A. Moberg, "A Lightweight Secure Development Process for Developers", Diva-portal, 2019.
8. Mateehew Roberts, “Successful Public Health Information System Database integration projects : A qualitative study, Online journal of public health informatics * ISSN 1947-2579* http://ojphi.org*10(2):e207,2018
9. Samir El-Masri,A new proposed software engineering methodology for healthcare application in Bangladesh,https: //www.researchgate.net/publication/258206008 .
10. Tutorialspoint.com. 2022. SDLC - Useful Resources. [online] Available at:
    a. <https://www.tutorialspoint.com/sdlc/sdlc_useful_resources.htm> [Accessed 18 November 2022].
11. Y. -H. Tung, S. -C. Lo, J. -F. Shih and H. -F. Lin, "An integrated security testing framework for Secure Software Development Life Cycle," 2016 18th Asia-Pacific Network Operations and Management Symposium (APNOMS), 2016, pp. 1-4, doi: 10.1109/APNOMS.2016.7737238.
12. T. F. Bissyandé et al., "Static Analysis of Android Apps: A Systematic Literature Review", 2017. Information and Software Technology, vol. 8, pp. 67-95. DOI: 10.1016/j.infsof.2017.04.001.
13. Guru99. 2022. Spiral Model: When to Use? Advantages and Disadvantages. [online]
    a. Available at: <https://www.guru99.com/what-is-spiral-model-when-to-use-advantages-disadvantages.html> [Accessed 02 December 2022].
14. Radek Fujdiak, Petr Mlynek, Pavel Mrnustik, Maros Barabas, Petr Blazek, Filip Borcik, and Jiri Misurec.

Managing the secure software development. In 2019 10th IFIP International Conference on New Technologies, Mobility and Security (NTMS), pages1–4. IEEE, 2019.

15. Mathias Payer. Software Security: Principles, Policies, and Protection. HexHive Books, 0.35 edition, April 2019
16. Nouman, M., Pervez, U., Hasan, O. and Saghar, K., 2016, May. Software testing: A survey and tutorial on white and black-box testing of C/C++ programs. In 2016 ieee region 10 symposium (tensymp) (pp. 225-230). IEEE.
17. Mendelev, K., Ragoler, I., Chess, B.V., Firestone, S.J. and Kfir, Y., Hewlett Packard Development Co LP, 2013. Application security testing. U.S. Patent Application 13/331,777.
18. Guru99. 2022. White Box Testing – What is, Techniques, Example & Types. [online] Available at: <https://www.guru99.com/white-box-testing.html.> [Accessed 13 November 2022].
19. Kamal, A., Yi Yen, C. and Hui, G., 2020. Risk Assessment, Threat Modeling and
    a. Security Testing in SDLC. [online] Researchgate. Available at: <https://www.researchgate.net/publication/347125346_Risk_Assessment_Threat_Modeling_and_Security_Testing_in_SDLC#fullTextFileContent> [Accessed 15 November 2022].
20. Sahu, K., Pandey, R. and Kumar, R., 2014. Risk Management Perspective in SDLC.
    a. [online] Available at: <https://www.researchgate.net/publication/273063901_Risk_Management_Perspective_in_SDLC> [Accessed 10 November 2022].
21. 2022. [online] Available at: <https://en.wikipedia.org/wiki/Pair-programming.> [Accessed 25 November 2022].
22. 2022. [online] Available at: <http://www.sei.cmu.edu/reengineering> [Accessed 13 November 2022].
23. M. R. Garey and D. S. Johnson. Computers and Intractability: A Guide to the Theory of NP-Completeness. Freeman, San Francisco, CA, 1979.
24. Alshamrani, A., 2022. A Comparison Between Three SDLC Models Waterfall Model, Spiral Model, and Incremental/Iterative Model. [online] Academia.edu. Available at: <https://www.academia.edu/10793943/A_Comparison_Between_Three_SDLC_Models_Waterfall_Model_Spiral_Model_and_Incremental_Iterative_Model> [Accessed 15 November 2022].
25. "Secure Code Review: A Practical Approach - InfoSec Resources", InfoSec Resources,
    a. 2013. [Online]. Available at: https://resources.infosecinstitute.com/topic/secure-code-review-practical-approach/#:~:text=In%20the%20SDLC%20. [Accessed: 16- November-2022].
26. "Secure Code Review", The MITRE Corporation. [Online]. Available at: https://www.mitre.org/publications/systems-engineering-guide/enterprise-engineering/systems-engineering-for-mission-assurance/secure-code-review. [Accessed: 16- November- 2022].
27. "Professional Independent Security Code Review | Bit Sentinel", Bit Sentinel. [Online]. Available at: https://bit-sentinel.com/security-code-review/. [Accessed: 16- June-2022].
28. J. Frankle, “Iterative and Adaptive Slack Allocation for Performance-driven Layout and FPGA Routing,” Proceedings of the 29th ACM/IEEE conference on Design automation conference, 1992, Page 536.
29. T. F. Bissyandé et al., "Static Analysis of Android Apps: A Systematic Literature Review", 2017. Information and Software Technology, vol. 8, pp. 67-95. DOI: 10.1016/j.infsof.2017.04.001.
30. Tutorialspoint.com. 2022. SDLC - Useful Resources. [online] Available at:
    a. <https://www.tutorialspoint.com/sdlc/sdlc_useful_resources.htm> [Accessed 12 November 2022].
31. G. Stoneburner, A. Goguen and A. Feringa, "Risk Management Guide for Information Technology Systems", Hhs.gov, 2020.
32. Risk Assessment and Threat Modeling", Developer.apple.com, 2016. [Online].
    a. Available at: https://developer.apple.com/library/archive/documentation/Security/Conceptual/Security_Overview/ThreatModeling/ThreatModeling.html. [Accessed: 09- November- 2022].
33. Jalote, P. (2012). An integrated approach to software engineering. Springer Science & Business Media.
34. Weber-Jahnke, J. H., Price, M., & Williams, J. (2013, May).Software engineering in health care: Is it really different? And how to gain impact. In Proceedings of the 5th International
35. Workshop on Software Engineering in Health Care (pp. 1-4). IEEE Press.
36. SEBoK, "IEEE Computer Society," 2017. [Online]. Available: http://sebokwiki.org/wiki/Healthcare_Systems_Engineering. [Accessed 27 10 2022].
37. Aitken, A., & Ilango, V. (2013, January). A comparative analysis of traditional software engineering and agile software development. In System Sciences (HICSS), 2013 46th Hawaii International Conference on (pp. 4751-4760). IEEE.
38. Petersen, K., & Wohlin, C. (2009). A comparison of issues and advantages in agile and incremental development between state of the art and an industrial case. Journal of systems and software, 82(9), 1479-1490.
39. https://www.researchgate.net/publication/346819120_Software_Development_Life_Cycle_Models-A_Comparative_Study