

**Migration aspects from Legacy Centralized Version Control
System to Distributed Version Control System with Inherent
Resiliency & Auto Validation Features**

A thesis submitted to the

UPES

For the award of

DOCTOR OF PHILOSOPHY

In

COMPUTER SCIENCE & ENGINEERING

By

Vinay Singh

December 2024

Supervisor

Dr. Alok Aggarwal



**School of Computer Science (SoCS)
UPES
Dehradun- 248007: Uttarakhand, INDIA**

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DECLARATION

I declare that the thesis entitled "Migration Aspects from Legacy Centralized Version Control System to Distributed VCS with Inherent Resiliency & Auto Validation Features" has been prepared by me under the guidance of Prof. Alok Aggarwal, Professor, School of Computer Science, UPES, Dehradun. No part of this thesis has formed the basis for the award of any degree or fellowship previously.



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CERTIFICATE

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ABSTRACT

With the growing adoption of agile methodologies, there is a shift from centralized version control systems (VCSs), like SVN, to decentralized VCSs, like Git. Over the past six years, nearly 50,000 software projects have been migrated from SVN to Git, but none has succeeded on the first attempt. Issues such as missing project structure validation, weak SSH connectivity, and incorrect mapping between SVN users and Git authors have caused migration failures, prolonged timelines, resource inefficiencies, and delays in project delivery.

To overcome these challenges, an advanced auto-resilient, and modular version control migration model has been proposed in this work. The proposed model aims to pre-validate project structure compatibility, provide auto-correction during pre-migration, check remote server space, send alert notifications, enable restoration from the failure point during migration, and verify author mappings as part of post-migration activities. A comprehensive and proactive solution has been proposed through an advanced VCS migration model, which ensures validation at all three stages; pre-migration, during-migration, and post-migration; for a seamless transition from a legacy VCS to a modern distributed VCS. It integrates IoT devices to address the critical limitations of traditional migration methods.

It has been observed that the traditional migration model was only able to successfully migrate 3 out of 10 real-time projects, with the remaining 7 failing due to incompatible project structures of microservices. The proposed migration model successfully migrated all 10 projects by automatically correcting project structure issues and generating alert notifications when discrepancies were detected. During the migration process, it has been observed that several projects failed to migrate successfully due to insufficient disk space on the Git server and the capability to send email alerts or notifications when space limitations occurred. The proposed

migration model has been able to generate an alert whenever the space fell below 80% capacity, send timely alerts in response to network failures, and successfully restore the migration from the exact point of failure, proving its consistent restoration capability. Furthermore, the proposed model ensures that SVN authors are properly mapped to Git authors before migration, preventing any loss of revision histories.

The post-migration phase focuses on validating and verifying critical aspects such as accurate author mapping, preservation of revision histories, and ensuring the overall integrity of the migrated projects. The proposed model successfully addresses common post-migration issues, ensuring that all SVN authors are correctly mapped to Git authors, thus preventing any loss of revision history. Additionally, it ensures that the migrated repositories function smoothly within the new distributed VCS environment. The model's ability to automatically detect and resolve any discrepancies that may arise post-migration ensures a higher level of consistency and reliability compared to the traditional approaches. This comprehensive post-migration validation and monitoring process further enhances the migration's success rate, providing a more robust solution for the software companies moving from centralized to distributed VCSs.

The proposed model outperforms traditional migration tools by detecting project structure issues, sending timely alerts on disk space or network failures, and offering consistent restoration capabilities. With a success rate of 100% for author mapping, it efficiently migrates all users and revision histories. Additionally, the migration process is 22% faster than using traditional tools. The proposed model's auto-resilience, speed, and comprehensive features make it a superior solution to legacy methods. Through successful testing on real-time projects, it has been shown that the proposed migration model resolves critical migration challenges and guarantees a smooth, efficient, and error-free transition from legacy to advanced VCS systems.

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Table of Contents

DECLARATION	III
CERTIFICATE	IV
ABSTRACT	V
ACKNOWLEDGEMENT	VII
TABLE OF CONTENTS	VIII
LIST OF TABLES	XII
LIST OF FIGURES	XIII
ABBREVIATIONS	XIV
CHAPTER 1: INTRODUCTION	1
1.1 The Problems and Limitations of a Legacy Centralized Monolithic based System	6
1.2 An overview of microservices and their impact on the software industry	9
1.3 Fundamental Concepts of Version Control Systems	11
1.4 Classification of Version Control Systems and their architectural structures	15
1.5 Reasons for using Version Control: Its Advantages & Benefits	18
1.6 Difference between Legacy Centralized VCS & Advanced Distributed VCS	19
1.7 Centralized SVN versus Distributed Git: A Comprehensive Comparison of Version Control Systems	22
1.8 Common Terminologies in Version Control Systems	25
1.9 Some Useful Git Commands	25
1.10 Problem Statement	27
1.11 OBJECTIVE	39
1.11.1 Sub-Objectives	41

CHAPTER 2: REVIEW OF LITERATURE	43
CHAPTER 3: PRE-VCS MIGRATION PHASE: PROPOSED METHODOLOGY AND IMPLEMENTATION	52
3.1 Proposed advanced VCS migration model with capability of identification and validation of legacy project structure with auto resiliency capability as pre-VCS migration phase.....	52
3.2 Research problem and main contributions: Pre-VCS migration phase..	53
3.3 Identification of key features of traditional migration model	54
3.4 Challenges of the pre-VCS migration model	57
3.5 Data collection for appropriate parameters selections	598
3.6 Methodology and environment preparation for pre-VCS migration model	60
3.7 Results and Discussion	62
3.8 Conclusion.....	63
CHAPTER 4: DURING VCS MIGRATION PHASE: PROPOSED METHODOLOGY AND IMPLEMENTATION	65
4.1 Research problem and main contributions during VCS migration phase	66
4.2 Identification of key features of traditional migration model	66
4.3 Challenges of the during VCS migration model	66
4.4 Data collection for appropriate parameters selections	71
4.5 Methodology and environment preparation for during VCS migration model	71
4.6 Results and Discussion.....	74
4.7 Conclusion.....	75
CHAPTER 5: DURING VCS MIGRATION PHASE: PROPOSED METHODOLOGY AND IMPLEMENTATION	76
5.1 Research problem.....	76
5.2 Identification of key features of traditional migration model	76
5.3 Data collection for appropriate parameters selections:during VCS migration model	79

5.4	Methodology and environment preparation for during-VCS migration model	81
5.5	Results and discussion for during VCS migration model	84
5.6	Conclusion.....	84
CHAPTER 6: POST VCS MIGRATION PHASE: PROPOSED METHODOLOGY AND IMPLEMENTATION		85
6.1	Proposed VCS migration model for migration from a centralized VCS to a distributed VCS as a part of the post migration phase	85
6.2	Research problem and main contributions during post-VCS migration phase	87
6.3	Challenges of the post-VCS migration model.....	87
6.4	Identification of key features of traditional migration model during post VCS migration phase	93
6.5	Data collection for appropriate parameters selections during post-VCS migration phase	93
6.6	Methodology and environment preparation for post-VCS migration model	93
6.7	Results and discussion during post-VCS migration phase	96
6.8	Conclusion.....	102
CHAPTER 7: CI/CD AND DEVOPS EXCELLENCE PHASE.....		104
7.1	Proposed VCS migration model for migration from a centralized VCS to a distributed VCS: CI /CD and DevOps excellence phase.....	104
7.2	Data collection for CI/CD and DevOps excellence phase	105
7.3	Environment preparation for CI/CD and DevOps excellence phase....	105
7.4	Results and Discussion.....	106
7.4.1	Code Build and Deployment Time: Monolith versus Microservice Systems.....	106
7.4.2	Latency analysis: Monolith versus Microservice Systems.....	107
7.4.3	Scalability analysis: Monolith versus Microservice Systems.....	108
7.4.4	Fault tolerance analysis: Monolith versus Microservice Systems....	109
7.4.5	Time-to-market Analysis: Monolith versus Microservice Systems.	111
7.5	Conclusion.....	113

CHAPTER 8: CONCLUSION:	115
8.1 Pre-VCS migration model:.....	115
8.2 During-VCS migration model:.....	115
8.3 Post-VCS migration model:	116
8.4 CI/CD and DevOps Excellence:.....	119
REFERENCES	121
LIST OF PUBLICATIONS	136

LIST OF TABLES

Table Name	Page No
Table 3.1: A holistic comparison between the Traditional Migration tools and their features	53
Table 3.2: Total Number of Projects with Project Structure incompatibility and Auto Resiliency	62
Table 4.1: A holistic comparison between the Traditional Migration tools and their features	65
Table 4.2: Total Projects identified with Space issues with Alert Notification	73
Table 5.1: A holistic comparison between the Traditional Migration tools and their features	76
Table 6.1: A holistic comparison between the Traditional Migration tools and their features	92
Table 6.2: Total Number of SVN users before Migration and Total Git Authors as a result of Post Migration	97
Table 6.3: Final Report Generation by Post VCS Migration Model	99
Table 7.1: Different Software Required to setup CI/CD Pipelines for Better DevOps	104

LIST OF FIGURES

Title of Figures	Page No
Figure 1.1: Architecture of a version control system	2
Figure 1.2: Monolith versus Microservices system architecture	4
Figure 1.3: Various factors for adopting Microservices	5
Figure 1.4: A systematic flow of Microservices deployment	8
Figure 1.5: Process of fetching the code from local during offline commits in DVCS	15
Figure 1.6: Legacy Centralized Version Control System vs Distributed Version Control System	16
Figure 1.7: VCS Migration Rate: Legacy Centralized Version Control System to Distributed Version Control System and issues found over Last 10 years	17
Figure 1.8: A typical VCS workflow utilizing the intermediate staging area for offline VCS commits	23
Figure 1.9: Some useful VCS commands utilized in the software industry	25
Figure 2.1: A holistic statistics of legacy VCS to distributed VCS migration (2013-2019)	45
Figure 3.1: A workflow and preparation of VCS migration: pre-migration phase	60
Figure 3.2: SVN to Git migration: A scientific methodology	61
Figure 3.3: Project structure incompatibility and auto resiliency: pre-migration phase	62
Figure 4.1: A workflow and preparation of VCS migration: during migration phase	71
Figure 4.2: Integration of Node MCU IoT device with SVN & Git VCS servers	71
Figure 4.3: Total VCS projects with space-related issues and alert notifications triggered during migration phase	74
Figure 5.1: Network connection and health check validation, with automatic restoration from failure points during migration phase	80
Figure 5.2: System workflow of NodeMCU IoT device ESP8266 Wi-Fi SoC	81
Figure 5.3: Acknowledge the predefined messages sent by the NodeMCU IoT device	82
Figure 5.4: NodeMCU device flow chart to read the packets	83
Figure 6.1: A holistic workflow and preparation of VCS migration	93
Figure 6.2: A holistic visual representation of the SVN to Git VCS migration flow	94

Figure 6.3: A Python script for checking the author's mappings for SVN & Git systems	95
Figure 6.4: Algorithm for mapping the Git users with SVN users during post migration phase	96
Figure 6.5: Outcomes of configuring and deploying the SVN Mirror (SubGit) model	97
Figure 6.6: Total number of SVN users before migration and total Git authors: post VCS migration phase	98
Figure 6.7: A comparative analysis of time spent on projects with traditional migration tools and the proposed migration model	99
Figure 6.8: Total number of projects with proposed migration model (failure VCS projects versus successful VCS projects)	100
Figure 6.9: A final detailed VCS migration report: post-migration phase	100
Figure 6.10: A Python script for the final detailed VCS migration report: post-migration phase	101
Figure 7.1: A comparative analysis: Build and deployment time of microservices versus monolith application systems	106
Figure 7.2: Performance metrics: A latency graph between microservices and monolith application systems	107
Figure 7.3: Systematic scalability of monolith versus microservice systems	108
Figure 7.4: Fault Tolerance of Monolith versus microservice systems	109
Figure 7.5: A Python script to build and deploy for microservice systems: CI/CD and DevOps excellence	111
Figure 7.6: Total duration for infrastructure preparation of business production servers (time-to-market approach)	112

ABBREVIATIONS

CI:	CONTINUOUS INTEGRATION
CD:	CONTINUOUS DEPLOYMENT
DB:	DATABASE
DEVOPS:	DEVELOPMENT OPERATIONS
DVCS:	DISTRIBUTED VERSION CONTROL SYSTEM
IDE:	INTEGRATED DEVELOPMENT ENVIRONMENT
IOT:	INTERNET ON THINGS
IP:	INTERNET PROTOCOL
IT:	INFORMATION TECHNOLOGY
JDK:	JAVA DEVELOPMENT KIT
PROD:	PRODUCTION
QA:	QUALITY ANALYSIS
SIT:	SYSTEM INTEGRATION TESTING
SOA:	SERVICE ORIENTED ARCHITECTURE
SSL:	SECURE SERVICE LAYER
SSH:	SECURE SHELL
SVN:	SUB VERSION
TCP:	TRANSMISSION CONTROL PROTOCOL
TTM:	TIME TO MARKET
UAT:	USER ACCEPTANCE TEST
VCS:	VERSION CONTROL SYSTEM

CHAPTER 1

INTRODUCTION

In most software projects, the source code is considered a valuable asset that must be safeguarded. For many development teams, it represents essential knowledge and insights accumulated through hard work. Version control is crucial for protecting this source code from potential issues, human errors, and unforeseen consequences. In a collaborative setting, developers continuously add new code and improve existing code. Typically, the project, application, or software component's code is organized in a well-structured directory tree. One developer might be working on a new feature while another addresses a bug, often making changes to different parts of the directory. While it is technically possible to develop software without version control, doing so exposes the project to significant risks that no professional team would endorse [21-22].

The current trend in the software industry is focused on achieving new business goals faster, more efficiently, and with fewer errors by adopting advanced systems that reduce time to market [31-33],[40]. To achieve this, companies must carefully select and implement modern, sophisticated subsystems that can help meet their objectives. However, making changes to system architecture can be both costly and time-consuming, as frequent transitions to new systems often require substantial effort. Many industries face limitations with their existing processes, which can make adapting to changes difficult without significant resources and complications. Transitioning from an error-prone, slow, and high-volume legacy system, such as a monolithic architecture, to a faster, lighter, and error-free microservices-based system is not always straightforward. Maintaining the integrity of the software ecosystem during the shift from monolithic or other legacy systems can be challenging. Despite the complexity and high volume involved, many software architects, developers, and project managers are initially

reluctant to make the change. However, there is a clear motivation behind the adoption of microservices infrastructure by major players in the market, such as Netflix, Google, and Amazon [11-15].

There are many version control systems used, such as Subversion (SVN), Mercurial, CVS, and Git, etc. But Git is by far the most popular version control system available. Originally launched in 2005 by Linus Torvalds, the creator of the Linux kernel, Git has grown into a vital and powerful open-source project. A large number of both commercial and open-source software projects rely on Git for version control. Git offers a range of advanced features, such as its distributed architecture, the ability to commit offline, fast processing, and a staging area, among others. Figure 1.1 depicts the architectural diagram of a typical version control system. A substantial portion of the software development workforce is skilled in Git, which works seamlessly across various operating systems and integrated development environments (IDEs). In recent years, Git has become the preferred version control system for IT companies of all sizes due to its superior features [26-29].

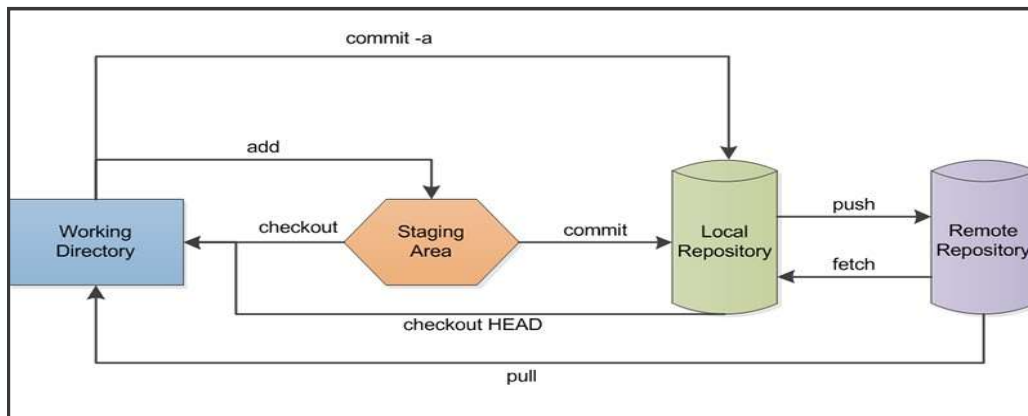


Figure 1.1: Architecture of a version control system

Git holds a commanding 77% share of the total version control systems (VCS), while Subversion captures only 13.5% [30]. As a result, many teams are migrating from Subversion to Git. Despite the availability of various migration tools, they often lack essential features, such as the ability to label empty directories before

migration, failover capabilities during network disruptions or server issues, and the ability to generate detailed reports after the transition. This work introduces a comprehensive, proactive, and innovative approach to support the entire migration process from Subversion to Git, addressing all stages—pre-migration, during the transition, and post-migration. Various scripts have been developed and executed in real-time across multiple projects to address the limitations of existing migration tools for transitioning from Subversion to Git.

Microservices are designed in a Service-Oriented Architecture (SOA) pattern and hosted in version control systems. This directly impacts the behavior of version control systems, especially advanced VCS like Git. Microservices is an architectural style that transforms applications into a dynamic collection of small, independent services known as microservices. This design philosophy emphasizes creating specialized modules with distinct interfaces that can function autonomously. Its growing popularity reflects organizations' efforts to improve agility and adopt DevOps practices, along with strategies for continuous integration and testing.

By leveraging microservices, companies can scale effortlessly, speed up deployment processes, and allow teams to work more autonomously on different components of the application. This paradigm promotes systems that are not only highly maintainable but also easily traceable, enabling efficient updates and enhancing overall performance. In essence, microservices signify a transformative shift in building and managing modern software applications. They offer several capabilities and inherent features, including:

- Focus on business capabilities
- High availability and scalability
- Managed by small, agile teams
- Loosely coupled
- More secure against vulnerabilities
- Faster time to market
- Quick deployment of products to meet business needs.

While beneficial, the microservices architecture has several drawbacks and obstacles. Additionally, developers often encounter various issues when adopting this design, requiring careful attention and resolution [96-97]. Figure 1.2 depicts the architectural difference between a Monolith System and a Microservice System. In Git, the working area consists of files that are not yet tracked, referred to as "untracked files." The staging area holds files that are set to be included in the next commit, helping Git understand which changes should be recorded. The repository itself contains all of a project's commits, which may also include untracked files. When deploying a large application, this typically involves running multiple identical instances of a single, often complex application. This usually requires provisioning N servers - whether physical or virtual - and launching M instances of the application on each. While deploying a large application can present its own set of challenges, it is generally less complicated than rolling out an application built using a microservices architecture [14].

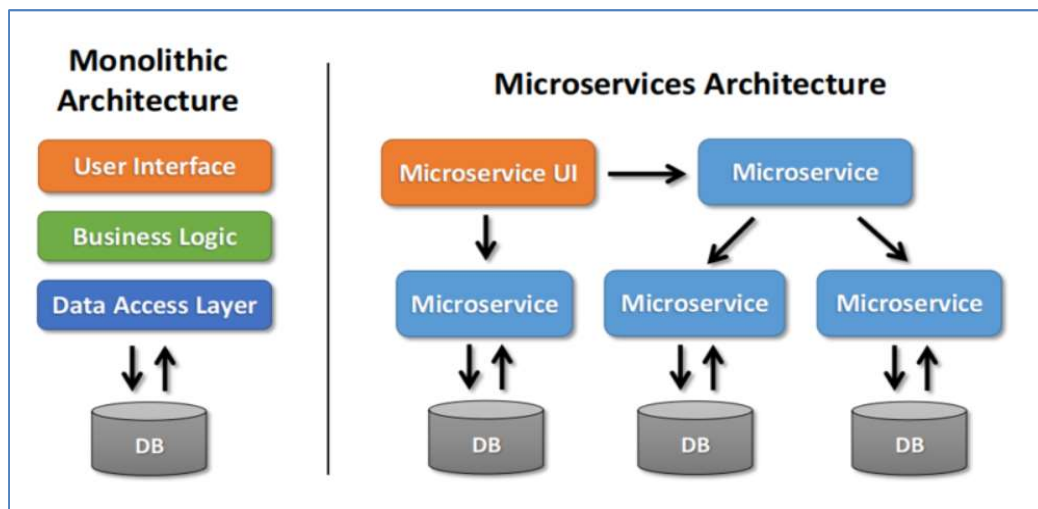


Figure 1.2: Monolith Versus Microservices system architecture

Figure 1.3 depicts the several factors that play a crucial role in adopting Microservices. A microservices application consists of several independent, small components in the form of services [16]. These services are built using various contemporary frameworks and programming languages, such as Java, Python, or

Spring Boot. Each service functions as an independent module with its specific design, framework, deployment, resource, scaling, and monitoring requirements. In a real-world example, a specific number of microservice instances for each service are created dynamically based on demand. Additionally, each instance of a processing service requires the appropriate allocation of CPU, memory, and I/O resources during deployment. To manage this complexity, the deployment process must be fast, reliable, and cost-effective.

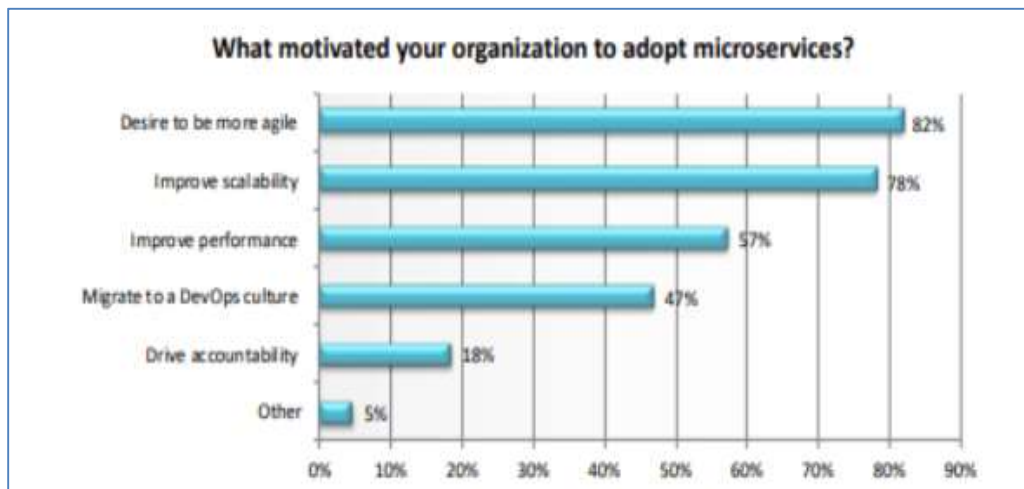


Figure 1.3: Various factors for adopting Microservices

1.1 The Problems and Limitations of a Legacy Centralized Monolithic based System

A conventional monolithic application consists of a large volume of programs, often spanning gigabytes, with all modules bundled together in a single program. This includes the database, a traditional client user interface, and server-side software. All components are tightly coupled and integrated, meaning the software is unified, and its various functions can only operate in a single environment. The complex components of monolithic software are highly interdependent and interconnected. While there are some advantages, such as enabling fast communication between software components through shared code and memory, the process of rewriting and debugging becomes cumbersome and inefficient,

especially in an agile ecosystem.

Monolithic applications, particularly the most effective ones, often require the use of marketing trade use cases driven by real-time or event-driven data exchange, such as application servers and databases [15]. A significant monolithic application can contain over 8,000 to 10,000 lines of code, making software maintenance more complicated and leading to higher deployment and management costs. Commercial software can be expensive and more difficult to deploy compared to open-source alternatives. Most businesses involve various software architects, product owners, and developers, all working to build, deploy, modernize, and review their code before release. Shared code in version control systems presents scaling challenges and contributes to a lack of agility, slow-release cycles, delayed innovation, difficult changes, and increased risks—all of which are well-known issues in monolithic architectures.

Many top-tier organizations have shifted from monolithic architectures to Service-Oriented Architecture or microservices over time, enabling them to scale, innovate, and improve operational efficiency. A prime example is Amazon, which has evolved its vast architecture to leverage microservices. The shift from a monolithic system to microservices allows Amazon to scale its various services independently, which is essential given the massive volume of transactions and the complexity of its global infrastructure. Each service, such as product search, order processing, and recommendation engines, can function autonomously and scale according to demand [12-14]. Similarly, major banking institutions like JPMorgan Chase and Bank of America have adopted microservices to handle their enormous transaction volumes. These organizations manage billions of API calls every day, with over 1,200 different types of devices connecting to their streaming video API. For instance, each API call to the video service generates approximately five additional requests to various backend services, including user authentication, data storage, and content delivery networks. By adopting microservices, these banks can process these requests in parallel, ensuring that each component is optimized for performance and scalability. Each service can be scaled individually, providing

flexibility and responsiveness in handling peak traffic, such as during financial market events or product launches [79-82].

The adoption of microservices in these scenarios addresses the critical need for high availability, scalability, and fault tolerance. For example, when one microservice (e.g., the payment processing service) experiences high traffic, it can be scaled independently without affecting other services like account management or transaction history. This approach enables faster deployment cycles, improved uptime, and easier maintenance, as developers can work on smaller, independent services without disrupting the entire system. This shift to microservices also allows for greater agility in development and innovation. As each microservice is a modular component, it can be updated, tested, and deployed independently, allowing organizations to release new features or fixes faster. In comparison, a monolithic system would require comprehensive testing and deployment cycles for any update, often leading to long delays and more potential risks.

In summary, large-scale organizations such as Amazon, JPMorgan Chase, and Bank of America have successfully transitioned to microservices to handle vast amounts of data, ensure reliability, and scale their operations efficiently. This evolution highlights the growing importance and effectiveness of microservices in modern software architectures, especially for companies dealing with high transaction volumes and complex systems [15-16], [79-82].

Figure 1.4 depicts a systematic flow of microservices deployment and talks how services are interconnected to each other using API Gateway. Approximately 40% of organizations are currently migrating to microservices or have already completed the transition. These systems manage a significant volume of requests from various applications, including those interacting with network service APIs and websites. This creates a demand for a robust, scalable, and resilient infrastructure; something that would have been nearly impossible to achieve with their legacy two-tier architecture.

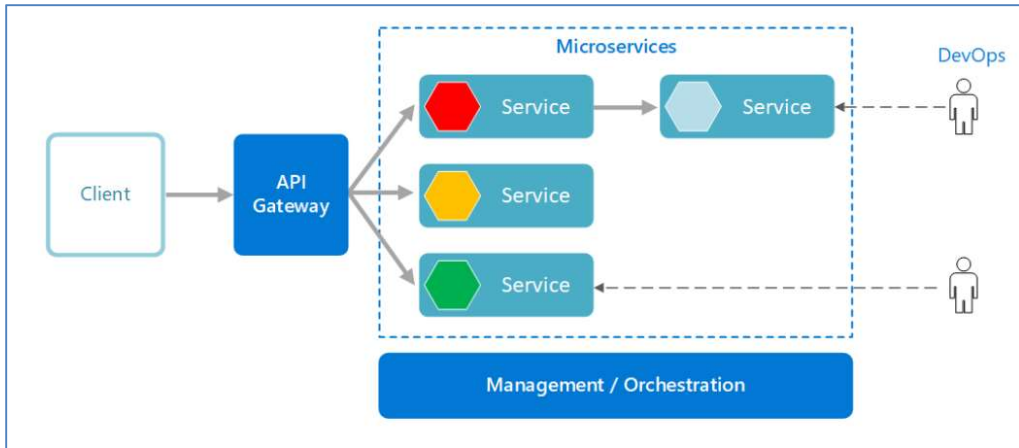


Figure 1.4: A systematic flow of Microservices deployment.

1.2 An overview of microservices and their impact on the software industry

A microservices architecture is particularly effective for continuous development and deployment. With DevOps prioritizing rapid deployment, flexibility, and scalability, microservices allow for the creation of dynamic systems that support continuous improvements with minimal user downtime. By breaking down a large set of features into smaller, independent services; which are decoupled from specific servers or dependencies; developers can construct a loosely coupled system where each microservice focuses on one or a few specific functions. In essence, microservices align with agile development methodologies and address the increasing need for a more streamlined and efficient flow of information [18-20]. Microservices architecture facilitates independent deployment, thereby empowering teams with greater autonomy. Each microservice can be updated in isolation, fostering continuous improvement and enabling more rapid application updates. This approach allows development teams to concentrate on specific microservices, working independently without the need for extensive coordination with the broader application ecosystem. Additionally, microservices inherently offer scalability on a granular level. As demand for the application grows, resources can be efficiently allocated to the most critical microservices, rather than scaling the entire application infrastructure. This enables faster, more cost-efficient scaling, optimizing both performance and resource usage. Microservices also enhance

system resilience through fault isolation - should a failure occur, it remains confined to the individual service, preventing cascading issues that could jeopardize the integrity of the entire application. This capacity ensures that mission-critical applications continue to function seamlessly, even in the face of localized disruptions.

Furthermore, the modular nature of microservices, with their smaller, more manageable codebases, simplifies both development and maintenance. Teams can easily comprehend and maintain the code, which not only streamlines deployment but also allows for improved code quality and enhanced ownership of individual services. This agility supports ongoing operational excellence, contributing to more efficient and effective software development practices.

Merits and Demerits of Microservices Architecture:

Microservices architecture offers developers the autonomy to write and deploy code independently, enabling them to work on distinct feature branches within the version control system and deploy services to containers. A microservice can be developed by a small, dedicated team, allowing different services to be coded in various programming languages (though maintaining consistency is generally recommended). This approach fosters seamless integration and automation through open-source continuous integration tools such as Jenkins and Hudson. Additionally, it offers a user-friendly experience for developers, allowing newcomers to quickly adapt and boost productivity. Engineers can leverage the latest technologies, while the code is organized around specific business capabilities, which accelerates web application launches and facilitates faster deployment cycles. Resilience is a key feature of microservices, with their inherent design enabling systems to recover more rapidly from failures.

Because each microservice is designed to perform specific functions independently, systems based on this architecture are more resilient to failures. Unlike monolithic systems, where issues in one component can affect the entire application, the failure of a single microservice typically has a more limited impact. When multiple

instances of microservices operate in an orchestrated environment, they can recover quickly from failures, significantly reducing the risk of prolonged downtime.

A further advantage of microservices lies in their support for Continuous Integration and Continuous Delivery (CI/CD). This enables specialized development teams to manage individual microservices, allowing them to make improvements without disrupting other services. Each team can operate autonomously, contributing to a larger integrated solution while minimizing conflicts between teams. Updates or changes to individual microservices can be deployed independently, streamlining the deployment process and enhancing overall efficiency.

Microservices also align well with agile development methodologies. Maintaining monolithic applications can be cumbersome and often does not support the rapid upgrades required by modern business demands. The limitations inherent in traditional monolithic systems have led to the adoption of microservices as a more scalable, flexible, and cost-effective approach. This architecture provides a solution that enhances time-to-market strategies, enabling organizations to deploy updates and scale operations quickly to meet evolving business needs [14].

1.3 Fundamental Concepts of Version Control Systems

Version control is an indispensable practice in modern software development, serving not only as a mechanism to manage the evolution of application code but also to oversee changes across various types of information—documents, website content, configuration files, and more. The importance of version control becomes particularly evident in the context of software development, where it governs the integrity and continuity of the core application. Source code, in particular, is rarely static; it is in a constant state of flux, with ongoing changes made to fix bugs, update features, or introduce new functionality to accommodate evolving business or user requirements.

This dynamic nature of source code makes version control vital, as it ensures that all changes are tracked, reversible, and transparent. When multiple developers are

working on a project simultaneously, version control becomes even more crucial to prevent conflicts, maintain synchronization, and ensure smooth collaboration. Without version control, developers risk overwriting each other's work, losing critical updates, or, worse, introducing bugs or inconsistencies into the codebase. Strict version control policies and best practices are therefore essential in creating a structured, efficient, and cohesive development environment, especially in agile and rapidly evolving projects.

Historically, version control systems like Subversion (SVN) have been the standard for managing code. SVN is a centralized version control system, meaning that all files and their associated history are stored in a central repository. While SVN can be effective for smaller projects or teams working in a single location, it presents significant challenges in distributed environments. A major limitation of SVN is that developers must be constantly connected to the central repository to commit their changes. This creates issues for teams located in different regions or working remotely, as network instability, latency, or server outages can disrupt the development workflow.

In practice, SVN requires that each developer interact with the central repository whenever they need to commit changes, access updates, or merge code. This reliance on a central repository can lead to delays, bottlenecks, and a reduction in team autonomy. For example, if a developer working remotely cannot access the central SVN repository due to network issues, they may be forced to pause their work until the connection is restored. This centralized model can also become a point of failure in large-scale projects, where the repository may be under heavy load, causing slowdowns or even downtime that hampers productivity [27].

Git, on the other hand, was designed to address these limitations with its distributed architecture. Unlike SVN, Git allows each developer to have their own local copy of the entire codebase, including the full version history. This means developers can work offline, committing changes and performing other version control tasks without requiring a continuous connection to a central server. Once they have access to the network, they can synchronize their local changes with the central

repository, making the entire development process more resilient and flexible. This distributed nature of Git is particularly advantageous for teams spread across multiple regions or time zones. Each developer or team member can work independently, push and pull changes to and from the remote repository at their convenience, and resolve any conflicts locally before committing their changes to the shared repository. Git enables continuous-integration and continuous-delivery workflows, allowing for faster iteration and smoother collaboration across geographically distributed teams.

Moreover, Git's speed and flexibility make it an excellent tool for large-scale open-source projects and organizations with complex development needs. Its branching and merging capabilities are robust, allowing teams to experiment with new features or fixes in isolated branches without affecting the main codebase. This capability is crucial for maintaining the stability of the production environment while encouraging innovation and experimentation. The adoption of Git has been on the rise in recent years, particularly with the growth of platforms like GitHub, which offers a centralized location for code hosting, collaboration, and version control. The recent developments around GitHub's acquisition by Microsoft have further amplified interest in Git, driving more organizations to transition from SVN or other older version control systems to Git. However, migrating from SVN to Git is not without challenges. The migration process can be time-consuming, requiring careful planning and execution to ensure that no data is lost, and the version history is accurately preserved. SVN and Git have fundamentally different workflows, with Git's distributed nature requiring a shift in how development teams manage their code and collaborate. As a result, organizations transitioning to Git often encounter issues such as incomplete migrations, extended transition periods, and the need for retraining developers on new workflows.

For instance, the mapping of SVN branches and tags to Git's more flexible branching model can be complicated, requiring tools or scripts to facilitate the process. Furthermore, Git's approach to merging and conflict resolution differs significantly from SVN, and developers accustomed to the latter's linear workflow

may face a steep learning curve when adopting Git's more decentralized structure. Despite these hurdles, the benefits of Git - such as increased flexibility, speed, scalability, and support for modern development practices like DevOps and CI/CD - often outweigh the initial migration challenges.

A branching strategy refers to the structured approach a software development team adopts to manage code development, merging and deployment within a version control system like Git. It defines how developers organize their workflow when working on the code locally, merging changes, and eventually checking out code for deployment. When multiple developers collaborate on the same codebase, efficient coordination becomes essential to prevent conflicts and overlapping changes. A well-structured branching strategy is designed to address this challenge, enabling teams to work in parallel on different aspects of the code without interfering with one another. The primary goal of any branching strategy is to ensure that multiple developers can contribute to the codebase simultaneously while minimizing the risk of errors and conflicts that can arise when changes are integrated. A branching strategy typically outlines the rules for creating and managing branches, specifying when to create new branches, how to merge them, and how to resolve conflicts if they arise. It ensures that each team member's work is isolated in their own branch, allowing them to make changes independently before merging into the main codebase. This isolation enables the team to collaborate efficiently while maintaining a stable and consistent version of the project.

Version control software, like Git, meticulously tracks every modification made to the code, recording these changes in a dedicated database. This allows developers to revert to previous versions of the code if necessary, providing a safety net in case mistakes are made. The ability to track and manage changes also helps developers quickly identify and correct errors, minimizing disruption to the team's workflow. With version control in place, mistakes can be addressed swiftly, allowing teams to maintain productivity and focus on delivering high-quality software.

In addition to facilitating collaboration and error resolution, branching strategies

also play a critical role in enabling continuous integration and deployment (CI/CD) practices. By using branching strategies effectively, development teams can automate the process of testing and deploying code changes, reducing the manual effort required and increasing the overall speed and efficiency of the software delivery process.

1.4 Classification of Version Control Systems and their Architectural structures

Version control systems are management tools that track changes made to a file or a group of files over time, with each change saved as a distinct version. Users can later revert to specific versions as needed. These systems are also known as revision control systems and operate as standalone applications. Programs such as spreadsheets and word processors typically include their own control mechanisms as well. The various types of version control systems are:

1. Local Version Control System (Deprecated)
2. Legacy Centralized Version Control System
3. Distributed Version Control System (Advanced)

The architecture of Centralized Version Control Systems (CVCS) is designed so that all developers check out from a central repository. Before committing their changes, they must ensure that their updates are both functional and stable. Various CVCS options exist, including CVS, Subversion, ClearCase, Perforce, and Visual SourceSafe. Each of these systems varies in terms of design, performance, and integration capabilities [11]. Figure 1.5 depicts a holistic systematic flow of microservices deployment and the role of “Working Repository”. Whereas Distributed VCS systems are designed with the objective that they support lightweight, Text, Binaries, BLOB, etc., and support the developer's code merges from one repository to another without any issue.

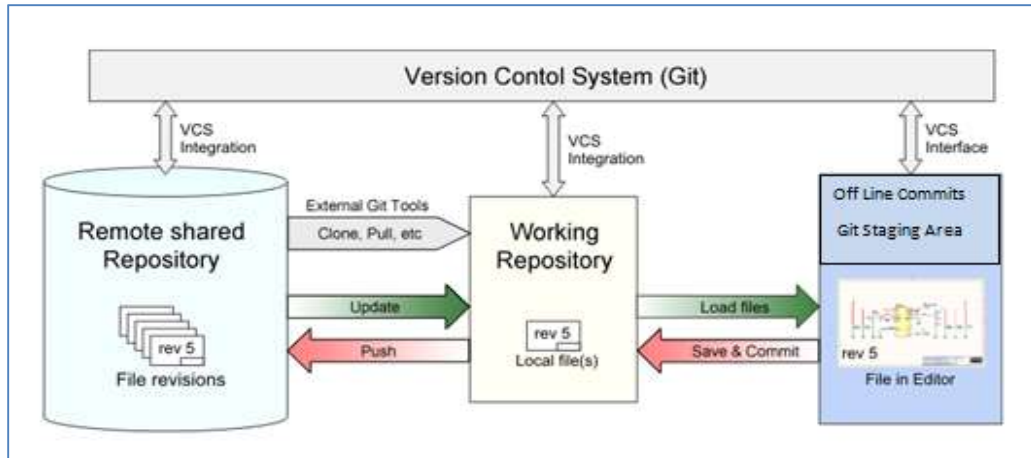


Figure 1.5: Process of fetching the code from local during offline commits in DVCS

The software industry has largely embraced Git, with many organizations either making the switch from SVN or actively in the process of doing so. Although there are various tools available for migrating from a legacy centralized version control systems to a distributed version control systems, these options often miss the mark in several key areas. Figure 1.6 demonstrates the clear difference between a legacy centralized version control system and distributed version control system and how they interact with individual repository. They frequently fall short in features like identifying empty directories during migration checks, lacking failover capabilities to manage network failures or disk space issues, and failing to generate detailed reports as part of the post-migration process. In short, while the tools are out there, they often don't quite hit the bullseye.

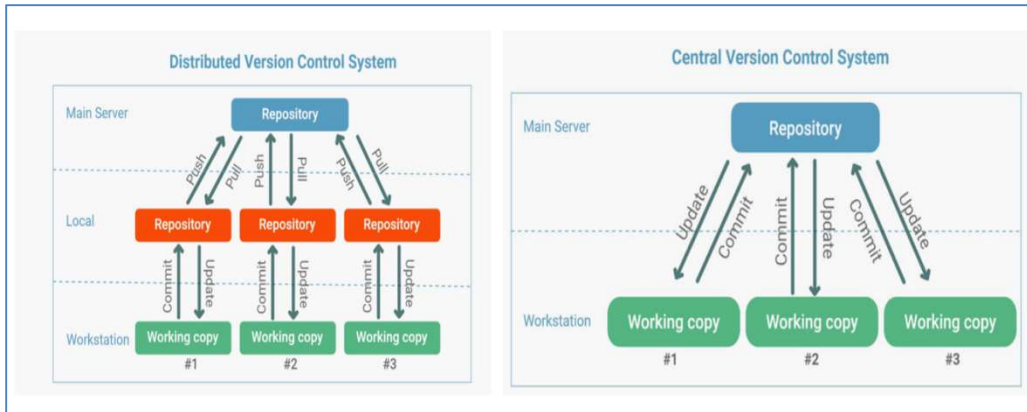


Figure 1.6: Legacy Centralized Version Control System vs Distributed Version Control System

Over the last six years, nearly 50,000 projects have been migrated from Subversion (SVN) to Git, driven by the need for more robust, scalable, and efficient version control systems. However, this migration process has not always been smooth, with many projects facing significant challenges during the initial attempts. Common issues such as missing project structure validation, weak SSH connectivity, and improper mapping between SVN users and Git authors have contributed to the failure of many migration efforts. These obstacles have led to extended migration times, resource wastage, and in some cases, delays in project deadlines and business delivery. Issues observed in SVN to Git migration for the last 10 years covering about 50,000 software projects migrated from 2013 to 2019 are shown in Figure 1.7.

The failure to validate the project structure early on is a critical issue, as it prevents the proper organization of files and repositories in Git, resulting in confusion and complications during the migration. SSH connectivity problems have also played a role, as inconsistent or insecure connections can cause disruptions in the migration process, leading to incomplete or corrupted repositories. Additionally, the improper mapping of SVN users to Git authors creates discrepancies in the project history, leading to inaccurate commit records and a lack of accountability, which complicates collaboration.

These challenges highlight the importance of thorough planning and preparation when migrating from SVN to Git. Ensuring proper project structure validation, addressing connectivity issues, and carefully mapping user identities are essential steps to ensure a smooth and successful migration. By addressing these issues early in the process, organizations can avoid wasting resources and minimize the impact on project timelines and business outcomes. Ultimately, a well-executed migration strategy can lead to significant long-term benefits, as Git offers enhanced functionality, flexibility, and collaboration features that better support modern development workflows.

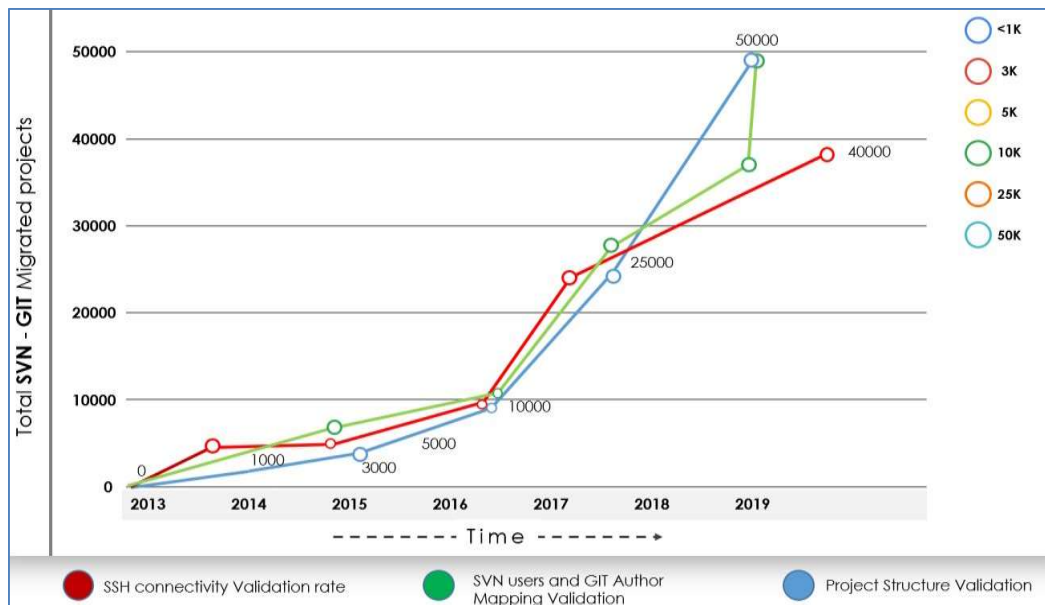


Figure 1.7: VCS Migration Rate: Legacy Centralized Version Control System to Distributed Version Control System and issues found over the last 10 years

1.5 Reasons for using Version Control: Its Advantages & Benefits

The most commonly used version control systems are categorized into two primary types: Centralized and Decentralized (or distributed). These systems enable multiple contributors to collaborate on the same codebase at the same time, avoiding overwriting or conflicts. They also allow developers to swiftly revert to

the last known stable version in the event of a failure or bug. By maintaining a complete history of all changes made to every file, version control systems simplify the process of identifying which changes caused bugs and which developer made those changes. Distributed version control systems, like Git, offer the capability to restore the entire codebase along with its history from a developer's local copy if the main repository is lost. This feature ensures that valuable work isn't permanently lost and allows teams to maintain continuity even in the face of unexpected setbacks [8].

Storing versioning of Code:

Version control plays a crucial role in managing the different versions of a project. It enables the tracking and maintenance of changes in files and code, keeping a comprehensive history of all activities within a codebase (repository). Modern version control systems like Git make it easy to revert to previous changes if problems arise. Branches and commits are key components that facilitate this change tracking, allowing developers to navigate through the project's evolution seamlessly.

Restoring or Generate backups:

One of the most significant advantages of using a version control system is that every time a developer clones a repository, they create a copy of that code. Having multiple backups across different machines is invaluable, as it helps safeguard the files against loss due to unforeseen issues or failures.

Collaboration with CI/CD in DevOps Model:

It integrates the Software efforts that are done simultaneously by different members of the team in a collaborative approach. It serves a pivotal role in simplifying the Software Development Life Cycle (SDLC). When a developer jumps into a project, they check out the code from the central repository at a designated branch. Once they've made their changes, they need to push the code

back to the remote repository using version control commands. This is where Continuous-Integration and Continuous-Deployment (CI/CD) come into play, enhancing the development workflow. Developers act as the vital link between coding and deployment, making version control systems essential components of CI/CD pipelines. The VCS lays the groundwork for the CI process, managing the original codebase and organizing it for deployment within the DevOps model.

Control and Access over Code:

A better control can be achieved over users and access (since it is served from one place) by using the Authorization and Authentication technique.

Traceability and troubleshooting the issues in Software code:

Another valuable aspect of version control is that when it comes to resolving an issue, comparison of different versions of files can be done effortlessly to spot inconsistencies. The latest file can be lined up against the problematic one, helping to get to the bottom of the issue and identify the root cause in no time.

Managing the code for multiple Teams, Branching and Merging:

While it's relatively easy to have team members work together, even individual contributors can gain from managing separate streams of changes across different branches. Creating a "branch" in a version control system allows various workflows to run independently, while still making it possible to merge them when the time is right. This setup enables developers to check that the changes in each branch don't clash with each other, fostering a smoother collaborative environment. It streamlines the process and helps keep everyone on the same page, reducing the likelihood of conflicts down the road.

1.6 Difference between Legacy Centralized VCS & Advanced Distributed VCS

The major advantage of Distributed Version Control Systems (DVCS) lies in their

ability to facilitate offline work and provide greater flexibility. With a complete history of the repository stored right on your machine, a developer can make changes to the local setup without needing an internet connection. This stands in stark contrast to Centralized Version Control Systems (CVCS), where working offline is often a cumbersome process. In DVCS, developers encounter fewer conflicts since each user has a full copy of the repository on their local device. On the other hand, CVCS lacks this same offline capability, making it a less nimble option.

Distributed VCS offers significant advantages, particularly the ability to work offline and greater flexibility. With the entire code history stored on your local hard drive, a developer can make changes to the repository without needing an internet connection, unlike with CVCS. Working on branches is easier in DVCS, resulting in fewer conflicts for developers. Since a client copies the entire repository to their local machine, DVCS allows for offline work, whereas CVS does not provide this capability.

DVCS is generally faster than CVCS because it eliminates the need to communicate with a remote server for every command. This local operation enhances speed and efficiency, especially when working on branches. In DVCS, developers have access to the complete history of the code, enabling them to share their changes before merging with the remote server. In contrast, working on branches in CVCS can be cumbersome and time-consuming due to the need for constant server communication. For projects accompanying a long past or many big files, downloading the entire warehouse in a DVCS may be behind and commence considerable room. In a CVCS, you only need to restore the distinguishing rule you're active on, saving two-together periods and depository. If the main server crashes in a DVCS setup, the full code history could be accessed from the local repository. In CVS, clients must obtain a local copy from the server, make changes, and then commit those changes back to the central source. This reliance on a single remote server for the entire code history makes CVS less robust than DVCS, where each client can have their own local branch with the

complete history [35].

Merge conflicts are less frequent in DVCS, as each developer works on their own segment of code. In comparison, CVCS tends to have more merge conflicts. However, developers in DVCS might become too isolated, taking advantage of the local history to work for extended periods without integrating their changes, which is less of an issue in CVCS. Overall, CVS is slower due to its constant communication with the server, while DVCS allows for quicker, local operations without frequent server interactions [41-42].

Committing new changes can be done locally, keeping them private until the developer is ready to share. Working on branches in CVS can be challenging, often resulting in merge conflicts for developers. With a DVCS, the set of changes are ready, these can be pushed all at once. Most tasks can be completed without an internet connection, allowing to work on a plane without needing to combine multiple bug fixes into one large change. Each developer has a full copy of the project repository, allowing them to share changes with a few teammates for feedback before submitting to the whole group. If the CVS server is down, developers can't work, but with a DVCS, they can keep going using their local copies.

Apart from delivering and inspecting changes, consumers can work offline accompanying DVCS. DVCS is notably faster than CVCS because there is no need to contact the principal attendant for each command. Merging and segregating changes in DVCS is smooth, and even though the central attendant crashes, the rule debris is dependable in local warehouses, guaranteeing better accomplishment overall.

1.7 Centralized SVN versus Distributed Git: A comprehensive comparison of version control systems

SVN stands for Apache Subversion, an open-source version and revision control system developed and maintained by the Apache Software Foundation. Its primary purpose is to manage files and folders stored in a repository, and it operates in a centralized manner, functioning like a standard file server that can be accessed by

users on different computers. On the other hand, Git is an open-source distributed version control system created by Linus Torvalds in 2005 as part of a research project. Git has evolved rapidly, emphasizing data integrity, fast processing, lightweight architecture, and support for microservices. It is robust and features a strong branching methodology with straightforward merging, allowing each developer to maintain their own repository with a local copy where they can modify history. In a conventional Git installation, the main directory is typically called the .git directory. This hidden folder contains various essential components, including:

Repository (Repo): A depository scope for the project, holding all files and the experiences of changes.

Commit: A photograph of changes fashioned to the files in the warehouse, in addition to a meaning defining the changes.

Branch: A parallel translation of the warehouse, admitting for unique happening of lineaments or fixes.

Merge: Combining changes from individual arm into another.

Clone: A copy of a warehouse that is to say built on your local gadget.

Pull: Fetching changes from a detached warehouse and combining the ruling class into the local arm.

Push: Sending the dedicated changes from the local warehouse to a detached warehouse.

HEAD: A remark to the current delivery or the tip of the current arm.

Checkout: Switching middle from two points arms or replacing active wood files.

Merge Conflict: A position that stands when changes indifferent arms contradict each one all along a consolidate.

Git includes a staging area that serves as a platform to hold files locally before they are committed to remote repositories. This allows to take, for example, 1,000 changes to the code and break them down into 10 or 20 commits, each with its own comments and detailed explanations. In addition to saving and staging the local

commits for others to view, a developer can also revert changes in the staging area as needed. This is a significant advantage of Git, developers can still build and deploy code even if the remote repository is unavailable due to network issues or disasters, enabling them to support real-time business operations during Git server failures. SVN lacks this capability. Figure 1.8 illustrates a typical VCS workflow of utilizing the intermediate staging area for off-line VCS commits.

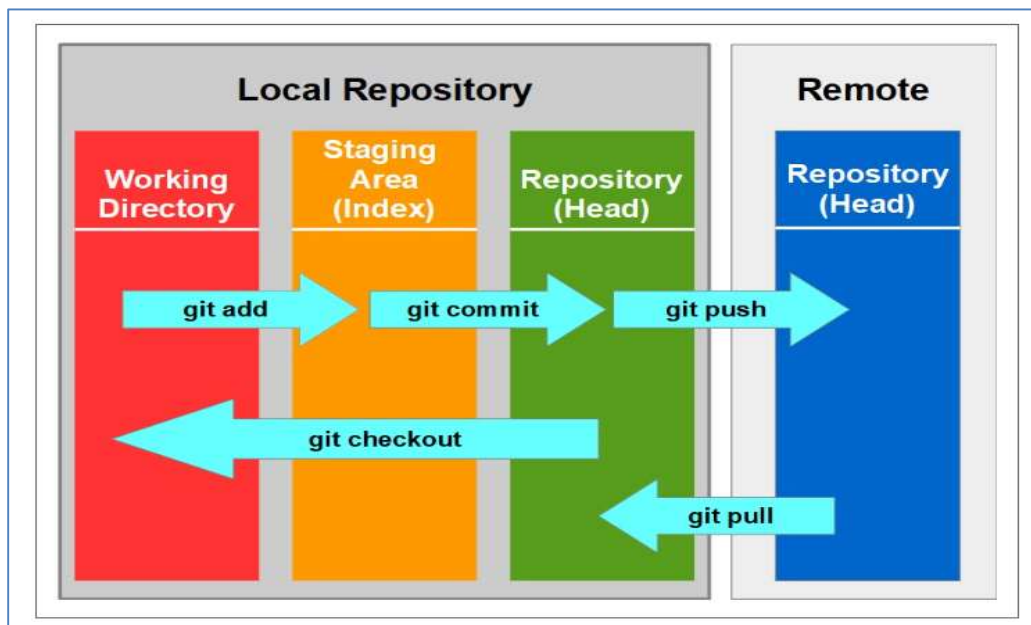


Figure 1.8: A typical VCS workflow of utilizing the intermediate staging area for off-line VCS commits

Beyond its eye-catching features, Git is engineered for speed and functionality in a distributed environment, enabling non-linear development paths. Users can fork and clone Git repositories, promoting collaborative growth. Platforms like Bitbucket, GitHub, and GitLab enhance this process, allowing contributors to send changes back upstream. This capability is a game-changer for many projects, encouraging input from a wide array of communities, which has driven the popular adoption of code management platforms like GitHub and GitLab in the open-source landscape.

1.8 Common Terminologies in Version Control Systems

Common terminologies in version control systems are discussed below:

Repository: A central location where all files and their histories are stored.

Commit: A record of changes made to the files, often accompanied by a message describing the update.

Branch: A separate line of development that allows for parallel work on features or fixes.

Merge: The process of combining changes from different branches into a single branch.

Checkout: Switching between branches or restoring files to a previous state.

Clone: Creating a copy of a repository to work on locally.

Pull: Fetching updates from a remote repository and merging them into the local branch.

Push: Sending committed changes from the local repository to a remote repository.

Conflict: A situation that arises when changes in different branches are incompatible during a merge.

Tag: A marker that points to a specific commit, often used to denote releases.

Staging Area: A space where changes are prepared before being committed.

Remote: A version of the repository hosted on a server, enabling collaboration with others.

1.9 Some Useful Git Commands

Figure 1.9 illustrates about some useful VCS commands utilized in the software industry.

Git Commands	
Command	Usage
\$ git init [project-name]	Creates a new local repository with the specified argument
\$ git status	Lists all new or modified files to be committed
\$ git config --global user.name "[user-name]"	Defines the name you want associated with your commit transactions
\$ git config --global user.Email "[user-email-address]"	Defines the email address you want associated with your commit transactions
\$ git config --global color.ui auto	Turns on colorization of command line output
\$ git add [file]	Prepares the file for commit by logically moving it to the staged area
\$ git ls-files --stage	Lists all the files in the staged area
\$ git commit -m "[commit message]"	Adds the staged files permanently in version history
\$ git diff	Shows unstaged file differences
\$ git diff --staged	Shows file differences between staging and the last file version

Figure 1.9: Some useful VCS commands utilized in the software industry

An example is given below.

GIT CLONE:

```
vsbui@GWTN156-1 MINGW64 /c/test
$ git clone https://github.com/githubtraining/hellogitworld.git
Cloning into 'hellogitworld'...
remote: Enumerating objects: 306, done.
Receiving objects: 48% (147/306) | 0 (delta 0), pack-reused 306 | 40% (123/306)
Receiving objects: 100% (306/306), 95.81 KiB | 1.23 MiB/s, done.
Resolving deltas: 100% (69/69), done.
```

GIT STATUS:

```
vsbui@GWTN156-1 MINGW64 /c/test/hellogitworld (master)
$ git status
On branch master
Your branch is up to date with 'origin/master'.

nothing to commit, working tree clean
```

GIT BRANCH:

```
vsbui@GWTN156-1 MINGW64 /c/test/hellogitworld (master)
$ git branch
* master
```

GIT ADD & GIT COMMIT

```
vsbui@GWTN156-1 MINGW64 /c/test/hellogitworld (master)
$ git add .

vsbui@GWTN156-1 MINGW64 /c/test/hellogitworld (master)
$ git commit -m "Adding a python script to do VCS Migration"
[master e837eca] Adding a python script to do VCS Migration
1 file changed, 0 insertions(+), 0 deletions(-)
create mode 100644 SVNtoGIT.py
```

GIT PUSH ORIGIN

```
vsbui@GWTN156-1 MINGW64 /c/test/hellogitworld (master)
$ git push origin
```

GIT BRANCH & GIT CHECKOUT

```
vsbui@GWTN156-1 MINGW64 /c/test/hellogitworld (master)
$ git branch develop

vsbui@GWTN156-1 MINGW64 /c/test/hellogitworld (master)
$ git checkout develop
Switched to branch 'develop'
```

1.10 Problem Statement

For decades, the software industry has been working towards migrating its software repositories from old, legacy centralized systems, such as SVN, to advanced, distributed, lightweight, and faster systems like Git. The need for this migration stems from the increasing demand for more efficient version control systems that can handle large-scale projects, support multiple contributors, and provide greater flexibility in modern software development. Git, with its distributed nature and high performance, offers many advantages over centralized systems like SVN. However, the process of migrating from SVN to Git is far from simple.

Several migration models have been developed to assist in transferring repositories from SVN to Git, each with its own approach to address the complexities involved in such a transition. While these models promise a smoother migration process, they often come with significant challenges. One of the key problems with legacy version control migration models is that they are typically designed to address only the basic migration needs, overlooking more advanced requirements. These models often fail to account for intricate issues like preserving commit history, managing large binary files, ensuring compatibility

with existing workflows, and maintaining user access control. As a result, legacy migration models frequently encounter obstacles during the initial attempt, leading to migration failures. These failures often necessitate rework and revisions to the migration strategy, which in turn results in wasted time, resources, and human efforts. The need for multiple attempts at migration introduces inefficiencies in the process, prolonging the transition and increasing the costs associated with it. Furthermore, the delays in completing the migration may lead to late delivery of the final product to end customers, causing dissatisfaction and a potential loss of business.

Another significant concern with these legacy migration models is the impact on the reliability of the final product in a real-time production environment. During the migration process, developers and operation teams may encounter compatibility issues, resulting in inconsistent behavior across environments. These inconsistencies can undermine the stability of the product, particularly when deploying to production systems, where reliability is critical. When migration issues are not adequately addressed, the risk of introducing bugs, inconsistencies, or disruptions in production increases, compromising the integrity of the final product.

In conclusion, while the migration from legacy centralized systems, like SVN, to distributed systems, like Git, is necessary to keep pace with modern software development practices, the existing migration models often fall short of ensuring a smooth and efficient transition. The intricacies and limitations of these models frequently result in failure during the initial attempt, requiring rework and leading to wasted resources, time, and human effort. Moreover, these challenges may cause delays in delivering the final product to customers and can negatively impact the reliability of the product in a real-time production environment. Therefore, a more robust, comprehensive approach to version control migration is essential to overcome these challenges and ensure a successful, timely transition to a distributed version control system like Git.

The transition from legacy centralized VCS to distributed VCS encounters significant challenges in the following capabilities:

- Lack of identification and validation of legacy project structure and auto resiliency capability for incompatible repositories in traditional VCS migration models which must be compatible with distributed architecture with pre-VCS migration requirement process.
- Lack of auto remote Git server space validation feature & alert notification in traditional VCS migration models as a part of pre-VCS migration requirement process.
- Lack of auto restoring feature due to network failure & auto alert notification in traditional VCS migration models as a part of during-VCS migration requirement process.
- Lack of SVN users & Git authors mapping validation capability & auto-correction and migration report generation in traditional VCS migration models as a part of post-VCS migration requirement process.

In a Gartner report, it has been experienced that almost 50,000+ projects were migrated from SVN to Git over the last six years, but they have never been successful in the first attempt due to missing project structure validation, weak SSH connectivity issues or sometimes improper mapping between SVN user and Git author which resulted in failure of migration, longer time, wastage of resources and missing the project deadlines & Business delivery.

We propose an advanced auto resilient, modular, and version control migration model that is capable of pre-identify the project structure compatibility and providing the auto correction feature as part of pre-migration, validate the remote server space and send alert notification, restore from failure point during VCS migration and validate the VCS authors mapping as part of post migration efforts. In this work, a holistic, proactive, and novel approach has been proposed to have an advanced VCS migration model that accomplishes the pre-migration, during-migration and post-migration validation from a legacy version control system to

an advanced distributed version control system using IoT devices and also covers all these four major limitations of the available in any traditional migration approaches. Software engineering approaches like agile methodology enforcing migrated from centralized version control systems like SVN to decentralized version control systems like Git due to focusing on microservices kind of lightweight coding techniques & lesser efficiency of former in terms of branching, fusion, time, space, merging, offline commits & builds and repository, etc.

Lack of identification and validation of legacy project structure and auto resiliency capability for incompatible repositories in traditional VCS migration models which must be compatible with distributed architecture as pre-VCS migration process

Migrating from traditional version control systems like Subversion to more modern systems like Git is often seen as a necessary step toward enhancing collaboration, scalability, and version management in software development. However, one of the most critical challenges in this migration process is the lack of proper identification and validation of the legacy project structure and the absence of auto-resiliency mechanisms for incompatible repositories. These gaps, particularly when dealing with the pre-migration phase, can significantly hinder the migration process and result in failed attempts, data inconsistency, and prolonged project timelines.

Traditional VCS, like SVN, often use centralized repositories with specific directory structures that may not align with Git's distributed architecture. In SVN, the repository structure can be rigid, with a focus on centralized branches and trunks, which might not be immediately compatible with Git's distributed nature that encourages local repositories and extensive branching. Without validating the legacy structure beforehand, organizations risk attempting to migrate repositories that are not organized in a way that Git expects, leading to potential errors during the migration. For instance, SVN projects might have nested directories or file

hierarchies that don't translate well to Git's flat repository structure, causing confusion or loss of important metadata during the migration process. If these structural mismatches are not identified in advance, it may result in incomplete migrations or a need for extensive manual corrections post-migration, which is resource-intensive and time-consuming.

Another key issue in traditional VCS migration models is the lack of built-in resiliency features to handle incompatible repositories. When migrating from centralized systems like SVN to distributed systems like Git, repositories often contain elements that cannot be automatically reconciled due to differences in how changes, branches, and histories are managed. In many cases, legacy repositories may have inconsistencies, conflicts, or corrupted files that traditional VCS migration tools are ill-equipped to detect or resolve. For example, SVN's centralized approach doesn't account for the flexibility of Git's branching model, which allows multiple developers to work in parallel on different features or bug fixes without interfering with each other's work. SVN's linear history and commit structure may not align with Git's branching and merging model, requiring manual intervention to realign history and merge code correctly. Without an automated resiliency mechanism that can identify and resolve these incompatibilities before migration, the process can be disrupted, leading to data loss, incomplete histories, and incorrect mappings of authors and commits.

To ensure a smooth migration from traditional VCS to a distributed architecture like Git, it is crucial to include comprehensive validation steps as part of the pre-migration process. Proper identification of the legacy project structure is necessary to assess whether it can be mapped directly to Git's distributed model, or whether adjustments are required. This includes reviewing directory structures, file history, and project dependencies. Automated tools that can scan and validate repository structures before migration can save significant time and effort, preventing the need for last-minute fixes. Additionally, introducing auto-resiliency capabilities in the migration process is vital for handling incompatible repositories. This could involve automated tools that detect issues in the legacy

repositories, such as broken branches, missing files, or inconsistent history, and resolve these before migration. For example, these tools could merge branches automatically or suggest ways to restructure files so that they are compatible with Git's branching model. Incorporating these resiliency features would allow the migration process to handle common pitfalls with minimal manual intervention, making the transition smoother and faster.

In conclusion, the lack of identification and validation of the legacy project structure, as well as the absence of auto-resiliency capabilities for handling incompatible repositories, poses a significant challenge in traditional VCS migration models. These issues often result in failed migration attempts, wasted resources, and extended project timelines. As organizations move from centralized version control systems, like SVN, to distributed systems, like Git, addressing these issues early in the migration process is essential. Pre-migration validation and the use of automated resiliency mechanisms can significantly reduce the risks and ensure a smoother, more efficient transition, ultimately helping organizations reap the full benefits of modern version control systems.

During SVN to Git migration, the Git revision counts get increased, Git logs get generated, Git authors meta-data is mapped from SVN. But in case of network failure, these revision counts are not accumulated and the whole migration is halted. In this situation traditionally, no migration tool measures if the total revision counts are really getting increased, if SVN users are properly being mapped to Git Authors. Even traditional migration tool never tracks the metadata. So, in case of a network disaster, the whole migration must be started over which results in a lack of proper resource utilization, and soaring costs associated with inadequately serving high-risk situations in business delivery.

Lack of auto remote Git server space validation feature & alert notification in traditional VCS migration models as a part of during VCS migration process

During the migration process from traditional version control systems like Subversion to more modern systems like Git, one significant challenge that often arises is the lack of auto remote Git server space validation and alert notification features. This issue becomes critical as organizations shift to Git-based systems, where remote repositories and distributed architecture play a central role. Without proper validation of available server space and the absence of timely alerts during migration, several issues can occur, such as failed migrations, resource wastage, and disruption in project timelines.

When migrating from SVN to Git, the migration process often involves transferring large amounts of historical data, including code, branches, tags, and commit histories, to a new Git repository. However, remote Git servers have limited storage capacity, and the data being migrated could exceed the available space. Traditional VCS migration models often overlook the importance of validating remote Git server space before and during the migration process. This oversight can lead to incomplete migrations, where the repository is not fully transferred due to insufficient server space, or the server might even crash during the migration due to sudden storage exhaustion. These issues can result in data loss, longer migration times, and potential downtime in development activities.

The absence of an automated validation feature means that developers or migration teams must manually check server space, which can be time-consuming and prone to human error. In some cases, the project team may not be aware of storage limitations until after the migration process has started, leading to unnecessary delays and extra work. Without an alert system to notify the team when the available space is nearing its limit, critical steps in the migration process, such as transferring large binary files or historical revisions, can fail without warning, jeopardizing the integrity of the migration.

Additionally, without real-time notifications about storage availability, the team may face challenges in proactively managing the migration process. A well-designed alert system could notify the team when the remote server is about to run out of space, allowing them to address the issue before it causes a migration

failure. Alerts could be set up to notify administrators about low disk space thresholds, enabling them to take corrective action—such as cleaning up old data or expanding the server capacity—before the migration process is disrupted. This would minimize the chances of project delays and resource wastage and ensure a more efficient migration.

Incorporating auto remote Git server space validation and alert notification as part of the migration process would significantly reduce these risks. By implementing automated checks for server space at various stages of the migration, organizations can ensure that the Git server has enough capacity to handle the repository transfer. Furthermore, integrating alert systems into the migration tools would give administrators timely feedback and visibility into the migration progress, allowing them to respond swiftly to potential space-related issues. This proactive approach would not only prevent server overloads but also improve the overall success rate of migrations, ensuring that repositories are fully transferred without interruptions or data inconsistencies.

In conclusion, the lack of auto remote Git server space validation and alert notification features in traditional VCS migration models is a critical issue during the migration from systems like SVN to Git. Without these features, organizations risk facing migration failures, data loss, and extended project timelines due to unexpected server space issues. By introducing automated server space validation and timely alerts during the migration process, organizations can ensure smoother migrations, reduce the risk of downtime, and optimize the use of resources, ultimately leading to more successful and efficient transitions to Git-based systems. During the migration process if the Git count is not increasing then most probably it is due to network failure. In this situation during migration, the migration process should get a restart from the last commit point but none of the existing Legacy Centralized Version Control System to Distributed Version Control System migration technical models have this capability.

Lack of auto restoring feature due to network failure & auto alert notification in traditional VCS migration models as a part of during-VCS migration process

During the migration process from traditional version control systems like Subversion to modern distributed systems like Git, one of the critical issues that often disrupts the migration is the lack of an auto-restoring feature in the event of network failures, coupled with the absence of real-time alert notifications. Network failures can be unpredictable and result in partial or failed migrations, which, if not addressed quickly, can lead to significant delays, data corruption, and additional resource consumption. Without an automated recovery mechanism and proper alerting system, these issues can cause severe disruptions, wasting both time and resources during the migration process.

In a traditional VCS migration, especially when moving large repositories with extensive commit histories, the process typically involves transferring substantial amounts of data between local machines and remote Git servers. This transfer can be interrupted by various network issues, such as bandwidth limitations, server disconnects, or temporary network outages. In the absence of an auto-restoring feature, when such network failures occur, the migration process might fail to resume from where it left off. This results in the need to restart the migration from the beginning, leading to prolonged downtime, wasted computing resources, and loss of productivity.

The lack of auto-restoring functionality means that migration teams often have to manually track and restart the migration process after a failure. This manual intervention is error-prone and inefficient, especially when dealing with large repositories. In some cases, the migration may fail multiple times due to recurrent network issues, consuming time and resources that could be better spent elsewhere. A lack of a built-in restoration feature also means that there is no mechanism to recover from partial migrations, where some commits or branches may not have been successfully transferred.

To mitigate these risks, the migration process should incorporate an auto-restoring feature that automatically resumes the migration process from the last successful point in case of a network failure. This feature ensures that the process can continue without human intervention, saving valuable time and effort. For instance, if the migration is interrupted, the system would recognize the point of failure, reconnect to the network, and proceed with the migration, ensuring that no data is lost in the process.

In addition to the auto-restoring feature, an integrated auto-alert notification system is essential to inform the migration team immediately when network failures occur, or when the migration process encounters issues. Alerts could be sent in real-time, notifying administrators about the nature of the failure, such as network timeouts, bandwidth issues, or server disconnections. These alerts would enable migration teams to quickly assess the situation and address the issue before it results in extended delays or data loss. For example, if the migration is interrupted due to a network error, an automatic notification would inform the team of the failure, allowing them to either take immediate corrective actions or let the system handle the recovery automatically.

The combination of auto-restoring capabilities and real-time alert notifications would not only ensure a more efficient and resilient migration process but also improve overall productivity and reduce the likelihood of costly setbacks. By automating the recovery process and providing immediate feedback on migration progress, organizations can avoid the need for constant manual oversight and ensure that the migration is completed successfully, even in the face of unexpected network issues.

In conclusion, the lack of an auto-restoring feature and real-time alert notifications in traditional VCS migration models significantly hampers the migration process, especially in the face of network failures. These issues can lead to prolonged migration times, wasted resources, and missed deadlines. By incorporating automated restoration mechanisms and timely alert systems, organizations can ensure that the migration process is both efficient and resilient, reducing the

impact of network failures and improving the chances of a successful transition to modern version control systems like Git.

Migration like this is not something we can do overnight, or even over a weekend. It needs to be managed for a sustained period of time and during this period if the network fails the migration tools must have the capability to generate SMS alerts. Traditionally, there is no migration tool that monitors the network traffic, network bandwidth, or network performance. Traditional tools do not have the capability to check the keep track of the last revision count so that in case of network disaster or any failure, migration could be restored from the failure point and not from scratch. But it has been over the past that legacy centralized version control system to distributed version control system migration failed and the whole migration had to start over which resulted in a lack of proper resource utilization, highly soaring costs associated with inadequately serving high-risk situations in business delivery at right time.

Lack of SVN users & Git authors mapping validation capability & auto-correction and migration report generation in traditional VCS migration models as a part of post-VCS migration process

In traditional version control system migration models, particularly when transitioning from systems like Subversion to Git, one of the critical challenges that often arise during the post-migration phase is the lack of effective mapping validation between SVN users and Git authors, coupled with the absence of automated correction mechanisms and comprehensive migration report generation. These issues can result in inconsistencies in commit histories, misattributions of work, and difficulties in tracking accountability, which significantly undermine the effectiveness and integrity of the migration process. SVN and Git manage user identities and commit histories differently. In SVN, user identity is typically tied to a global username that appears in the commit logs, while Git identifies authors based on an email address and a username associated

with each commit. This discrepancy becomes especially problematic during migration when the mapping between SVN users and Git authors is not correctly handled. In traditional migration models, without a proper validation mechanism in place, errors can occur where SVN users are mapped incorrectly to Git authors, leading to issues such as commits being attributed to the wrong individuals, or even the loss of author information altogether. This can complicate collaboration and lead to confusion about who is responsible for specific changes in the codebase.

Inadequate validation of this mapping often results in significant delays and requires manual intervention to correct these issues post-migration. In a scenario where a large number of commits need to be correctly attributed to the right author, this manual process can be both time-consuming and prone to errors. The absence of an auto-correction feature further exacerbates this problem, as developers or administrators are left with no automated means to fix these inconsistencies efficiently. For example, if an SVN user has multiple variations of their username or email in SVN and these are not mapped correctly to a Git author, there may be repeated errors across multiple commits, requiring extensive manual intervention to clean up the commit history.

Furthermore, the lack of comprehensive migration report generation significantly hinders the ability to track the progress of the migration and verify that the migration process has been executed properly. A detailed migration report that includes information on which users were mapped to which authors, the success or failure of the mapping process, and any corrections made during the migration would provide transparency and clarity. Without such a report, tracking the migration's success becomes challenging, and administrators may not even be aware of the issues until they cause bigger problems down the line, such as during audits or reviews of the project's version history.

The introduction of an automated SVN-to-Git user mapping validation feature would help identify discrepancies in the mapping process and highlight any users that were not correctly attributed. This capability could include an auto-correction

function that automatically fixes common mapping errors based on predefined rules (e.g., matching usernames or emails). Additionally, an automated tool could allow the migration process to run checks to verify if the users in SVN have been successfully mapped to corresponding Git authors, providing a clearer picture of the migration's accuracy. These tools would reduce the need for manual intervention and ensure that the commit history in Git is as accurate as possible. Alongside this, migration report generation would provide valuable insights into the migration process, documenting every step taken during the migration and summarizing any issues that were encountered, such as failed user mappings or other discrepancies. These reports would help teams and project managers understand the overall progress of the migration, assess the quality of the migration, and make necessary adjustments where required. Moreover, reports could be used as an auditing tool to confirm that no critical data was lost or misattributed during the migration process, offering reassurance to both developers and stakeholders that the migration was handled correctly.

In conclusion, the lack of SVN user and Git author mapping validation capabilities, coupled with the absence of auto-correction and migration report generation features, creates significant challenges during the post-VCS migration process. Incorrect user mappings and the inability to automatically correct these issues can result in misattributed commits and distorted project history, ultimately leading to confusion and potential loss of accountability. Implementing automated mapping validation, auto-correction, and comprehensive migration reporting will streamline the post-migration process, ensure accurate commit histories, and reduce the time and resources required to manually resolve issues. These features will contribute to a smoother, more efficient migration from SVN to Git and ensure the integrity of the version control system after migration.

Version control migration tools should have capabilities to check and monitor the total space left during migration and notify the users/administrator about statistics if space is left less than 20% during migration between source and destination. Due to a lack of pre-migration validation and a lack of identifying the total disk

space and file system, it has been observed while migration Git server space gets frequently filled up which severely resulted in legacy centralized version control system to distributed version control system migration failure. Almost over 50,00 projects were like that which faced these problems.

1.11 OBJECTIVE

The objective of this thesis is to design and implement an advanced auto-resilient version control migration model that addresses key challenges encountered in the VCS migration from traditional version control systems, like Subversion to modern distributed systems, like Git. The proposed model aims to enhance the migration process in three distinct phases: pre-migration, during migration, and post-migration.

Here we propose an advanced auto resilient and version control migration model that is capable of pre-identify and validating the project structure and providing the auto correction feature for incompatible repositories as part of pre-migration phase. The proposed model must validate the remote server space, send alert notification and capable to restore the migration from failure point as part of during migration phase and finally validate the VCS authors mapping with all migrated SVN users and generate a holistic report as part of post-migration phase. In the pre-migration phase, the model will be capable of pre-identifying and validating the legacy project structure to ensure compatibility with Git, as well as providing an auto-correction feature to handle incompatible repositories. This will streamline the initial setup, reducing errors related to file organization and repository structures. During the migration phase, the model will validate remote server space to ensure sufficient capacity for data transfer, send alert notifications in case of issues, and include an auto-restore feature that will allow the migration to resume from the failure point in case of network disruptions or other issues. Finally, in the post-migration phase, the model will validate the correct mapping of SVN users to Git authors, ensuring proper commit history attribution, and generate a comprehensive migration report that provides insights into the

migration process, identifies any issues, and ensures the integrity of the migrated repositories. This holistic approach will ensure a smoother, more efficient, and error-free migration to a Git-based system.

1.11.1 *Sub-Objectives*

To develop a comprehensive, efficient, and innovative version control system migration model that facilitates a seamless transition, we will focus on a full-stack transfer during all pre-migration, during-migration, and post-migration phases. This will involve proactive pre-labeling and pre-validation of project structures and space, accompanied by alert notifications, auto-restoration, and auto-mapping capabilities as we shift from a legacy centralized VCS to a distributed VCS. This should cover major limitations of the available SVN to Git migration approaches.

Sub Objectives are as follows:

- To propose an advanced VCS migration model with the capability of identification and validation of legacy project structure with auto resiliency capability as pre-VCS migration process.
- To propose an advanced VCS migration model which must have auto remote Git server space validation feature & alert notification as a part of during VCS migration requirement process.
- To propose an advanced VCS migration model with auto restoring feature due to network failure & auto alert notification as a part of during-VCS migration requirement process.
- To propose an advanced VCS migration model with the capability to do mapping validation between SVN users & Git authors with the auto correction feature and generate a complete migration report as a part of the post-VCS migration requirement process.
- To propose an advanced VCS migration model for migration from a centralized VCS to a distributed VCS: CI /CD DevOps improvement.

In the envisioned transition from a legacy centralized version control system to a distributed version control system, the model emphasizes comprehensive validation and preparedness throughout the pre, during, and post migration phases. This strategy effectively tackles the challenges associated with incomplete migrations.

CHAPTER 2

REVIEW OF LITERATURE

In SVN, past studies have predominantly explored how commit sizes are distributed, assessing the chances of a commit being of a particular size. The commit size, defined by the number of files included in a revision, can adhere to various statistical models such as power laws [10], the Pareto model [15], and Petro-distribution [16]. Commits have been classified based on several characteristics, primarily size and comments [17-18]. The dynamics of commit behavior among open-source software developers in SVN have been explored in [20]. Throughout the lifecycle of each project release, it is evident that the datasets at both the project and file levels exhibit complex delivery patterns that reflect a capacity distribution. This case study examined four open-source software projects from Apache.org. Additionally, an empirical analysis of inter-commit times in SVN was conducted in [10] on two Java projects, revealing that the distribution of commit intervals for both POI and Tomcat adheres to similar powerful patterns [35].

A study outlined in [27] examines how developers utilize branches in open-source software and how these practices influence the project's branch structure. It describes a system that reveals the origin stored in the version control system, which facilitates the publication of this information online and allows for integration with other systems using PROV. In [29], a mechanism is proposed for supporting file updates and version control through the use of error-correcting codes for a storage application. This approach is said to be applicable to standard data center systems (SDCS), new cloud storage solutions, and point-to-point distributed storage mechanisms aimed at managing files in different versions, thereby reducing storage costs and enhancing update efficiency while minimizing

the costs associated with downloading complete files in various formats. The mechanism is demonstrated to be a viable and effective solution applied to real data from a Git repository. Additionally, [26] presents an approach called Change Scribe, which generates automatic commit messages based on code changes within a set of modifications. This method extracts and analyzes the differences between two versions of the source code, providing an overview of the changes while classifying and describing each modification made by the developer [41-45].

A commit signing mechanism for centralized version control systems has been proposed in [21]. This mechanism supports various features, allowing clients to work on separate sets of files without accessing each other's changes, as well as enabling collaboration within a subset of the repository. Previous studies have focused on collaborative vocabulary development [23], with [22] investigating the applicability of Git for this purpose. Git4Voc has been introduced to provide guidelines on how Git can be utilized for vocabulary development. It exhibits that by harnessing terminology-distinguishing features, Git hooks can significantly enhance Git's fundamental capabilities. The migration of the LHC from SVN to Git is outlined in [27], addressing the specific needs of the LHC and providing valuable insights into the transition of large, non-standard SVN repositories. This journey is anticipated to have bolstered productivity by facilitating new projects, fostering contributions, and improving code quality through rigorous testing and reviews [28].

A mechanism for classifying and extracting changes is introduced in [32]. This includes a tool called Git Change Classifier (GCC), which utilizes text mining to identify the type of change and employs regular expressions for extracting the changes. GCC reports the annual number of changes for a file, categorizing them into: bug repair changes (BRC), feature introduction changes (FIC), and general changes (GC) [33]. Various challenges and confusions related to learning version control with Git have been discussed in [29], along with recommendations for addressing these issues [36]. Additionally, the general concepts of centralized and

distributed VCS are covered in [30], along with their implementation in SVN and Git VCS [39-40].

A comprehensive study was conducted on internet blogs and available documentation regarding the migration from legacy centralized version control systems to advanced distributed VCS. While git-svn offers the advantage of being integrated into recent versions of Git, several notable drawbacks during our initial migration attempts were encountered. Firstly, it struggled with non-standard SVN repository layouts [33]. Although the locations can be specified of the "trunk," "branches," and "tags" directories but issues arise if we lack a "trunk" directory or if your "branches" or "tags" contain subdirectories. In contrast, svn2git employs a pattern-matching schema that can be configured in a plain text file, allowing it to work effectively with complex and non-standard SVN layouts.

A unique authorized framework for a VCS migration model specifies how these objects are protected, while also emphasizing the significance of the relationships between the objects at two different points. Figure 2.1 illustrates a holistic statistic of legacy VCS to advanced distributed VCS migration (2013-2019).

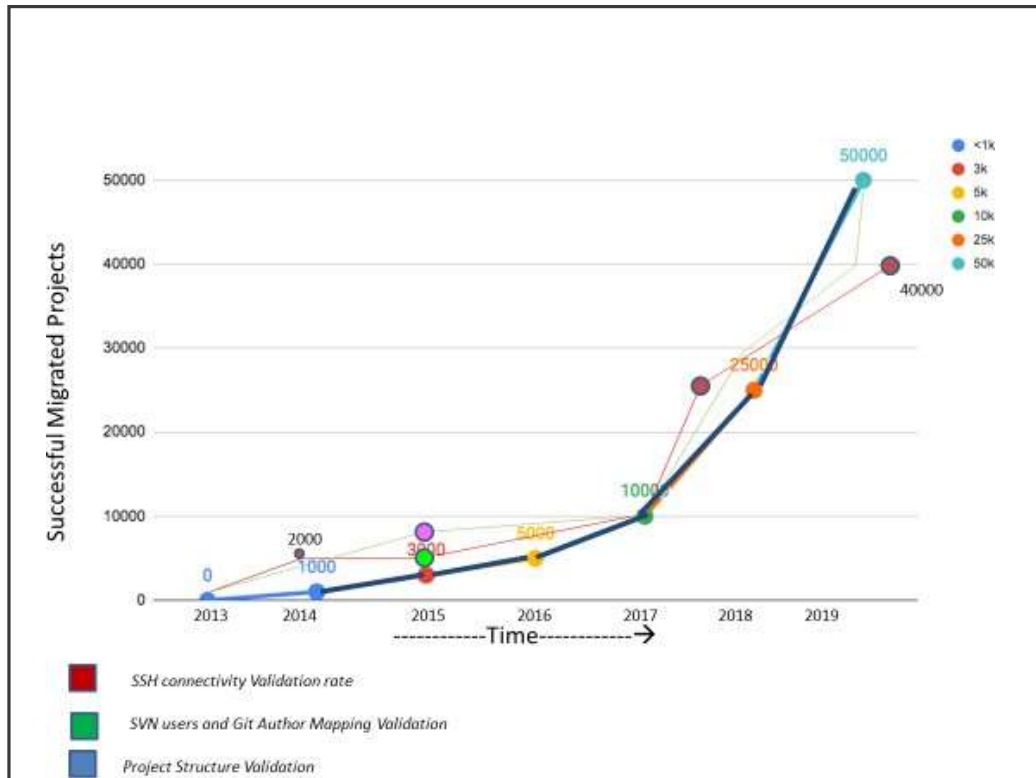


Figure 2.1: A holistic statistics of legacy VCS to advanced distributed VCS migration (2013-2019)

Very little published research work was found concerning the transition of Subversion VCS to Git VCS concerning time, space branching, merging, and repository aspects, there is much published research work on the other version control systems [51], work that uses Git as a file system [46-47]. In [49], the transition from CVCS to DVCS is analyzed through interviews and survey data, providing insights for individual developers, teams, and managers embarking on this shift. The study emphasizes key benefits, such as the capability to work offline, adopt an incremental approach, and navigate various contexts effectively - advantages made possible by commits and agile branches in user-friendly private DVCS setups. In [54], the authors delved into the transition process, identifying challenges and potential benefits associated with four open-source operating systems. The study also introduced a method for uncovering provenance within VCS, allowing for easy visibility of this information online and seamless

integration with other systems that utilize PROV.

Traditional legacy centralized version control systems to modernize distributed version control system conversion frameworks lack the following functionality:

1. Complete software project application identification and validation,
2. Validation of SVN & Git SSH & network connectivity,
3. Validation of SVN users & Git developer tracking, and
4. Validation of remote Git server space & file system.

The migration from SVN to Git has become a significant concern for many organizations, especially as Git's distributed nature offers numerous advantages over the centralized model of SVN. Version control systems are essential tools for managing software development, allowing teams to track code changes, collaborate on projects, and maintain the integrity of source code over time. SVN, being a centralized version control system, relies on a single server to manage repositories, while Git, a distributed version control system, allows every developer to have their own local copy of the entire project, complete with its history. This shift from centralized to distributed version control offers better flexibility, faster operations, and more powerful branching and merging capabilities, which is why many organizations are migrating from SVN to Git [19-21].

However, despite the technical advantages that Git provides, the migration process can be quite challenging. One of the main difficulties faced during SVN to Git migration is the shift in the development workflow. SVN's centralized model, where all developers work with a single server-based repository, contrasts significantly with Git's decentralized nature, where developers have their own local repositories. This fundamental difference requires teams to adopt new collaboration practices, including adopting new branching strategies and embracing a distributed workflow. Studies have shown that many organizations struggle with this change, particularly those that have been using SVN for many

years [101-106]. Additionally, there is a notable gap in research concerning the pre, during, and post-migration stages of SVN to Git migration. While several studies focus on the technical aspects of the migration process - such as tools to convert repositories and preserve historical data - there is less attention given to the comprehensive migration journey, including workflow adjustment, team training, and long-term integration.

Research related to SVN to Git migration has primarily addressed technical hurdles like repository conversion and data integrity. Popular tools such as `git-svn` and `svn2git` are commonly used to assist in the process of migrating SVN repositories to Git. These tools enable the conversion of SVN branches and tags to their corresponding Git structures, but they generally focus on the mechanics of migration rather than the broader challenges faced by teams [34], [38-39]. Studies have pointed out that although these tools can be useful for preserving the integrity of historical commits, they do not address the deeper issues related to workflow management or the human element of the migration process. The process of converting repositories from SVN to Git may appear straightforward technically, but it involves significant changes to how teams operate on a day-to-day basis [51-52].

There is also a significant gap in the literature concerning the pre-migration phase, which is crucial for preparing the organization for the changes ahead. For instance, understanding how to assess a team's readiness for the migration, mapping out potential challenges in workflows, and providing adequate training before the actual migration takes place are critical factors for a successful transition [99-100]. Similarly, the during-migration phase, which involves handling the migration tools, managing conflicts, and ensuring minimal disruption to ongoing development, is not extensively covered in most research. Furthermore, after the migration is complete, the post-migration phase - which includes optimizing workflows, ensuring that the team has fully adopted Git, and dealing with any remaining issues related to repository management - has also been largely overlooked in the literature [119-131].

In conclusion, while many studies have focused on individual aspects of the migration from SVN to Git, such as the technical aspects of repository conversion or the tools used for migration, there is a lack of comprehensive research that takes into account the entire migration lifecycle. Research has largely ignored the pre, during, and post-migration stages, which are essential for understanding the full scope of the migration process [43-50]. This gap presents an opportunity for further investigation into how organizations can manage migration effectively, taking into account not only the technical challenges but also the human and workflow-related factors that play a critical role in ensuring a smooth transition from SVN to Git [107-118].

The migration from SVN, a centralized version control system, to Git, a modern distributed VCS, presents significant challenges that are often underexplored in existing research. While numerous studies have focused on the technical aspects of repository conversion, tools such as `git-svn` and `svn2git`, and the conversion of historical commits, there is a notable gap in addressing the full migration lifecycle, particularly the pre, during, and post-migration stages. These phases are crucial for ensuring a smooth transition and optimal adoption of Git across the organization, yet they are often overlooked. The pre-migration phase, for instance, requires careful consideration of structural prerequisites and space validation, which are essential for preparing both the system and the team. SVN repositories typically have complex directory structures, and Git's flexible branching model requires a thoughtful approach to how branches, tags, and revisions from SVN will be mapped into Git. Without thorough planning for these structural differences, the migration can lead to confusion, data loss, or integrity issues. Furthermore, Git repositories are inherently larger due to their distributed nature, meaning that adequate storage space needs to be confirmed not just on the server but also on developer machines for local repositories. However, there is a lack of research addressing these critical preparatory steps, making it evident that a comprehensive migration model should include guidelines for ensuring that these structural and space requirements are met before migration [71], [83-84].

The during-migration phase is where the actual conversion of repositories takes place, but it presents its own set of challenges, particularly in terms of failure restoration and ensuring data integrity throughout the process. Migrating an SVN repository to Git often involves complex scenarios, such as handling sparse checkouts, external references, and custom SVN hooks that may not translate directly into Git. Failures in this phase, whether from data corruption, incomplete history, or issues with the tools themselves, can be disastrous. Current literature typically focuses on the technical capabilities of migration tools like `git-svn` and `svn2git`, but fails to address the operational concerns of handling failures during the migration, such as how to restore data if the migration fails or how to manage conflicts in the commit history. These are issues that need clear guidelines and solutions, yet they remain largely absent in existing research, which focuses predominantly on the mechanics of data conversion rather than on providing a reliable framework for managing the risks associated with the migration process [1-7].

Finally, the post-migration phase is critical for the long-term success of the transition to Git. After migration, organizations must optimize workflows, train teams to fully embrace Git, and ensure that the repository functions as expected in the new system. This phase also involves validating the correctness of the migrated data, ensuring no information has been lost or corrupted, and making necessary adjustments to the workflow to accommodate Git's distributed nature. Research on post-migration activities, such as performance tuning, Git workflow integration, and issue resolution, is notably absent. The post-migration phase is often glossed over in favor of focusing on immediate conversion results, yet it is essential for ensuring the sustainability and effectiveness of the Git system in the long run. As such, a post-migration report that outlines repository health, team adaptation, and workflow refinement is sorely needed but has been largely overlooked in migration research [9].

In conclusion, the absence of a comprehensive framework addressing the pre, during, and post-migration stages when migrating from legacy centralized VCS

systems, like SVN, to modern distributed systems, like Git, highlights a significant gap in the literature. This gap presents an opportunity for novel research, particularly focusing on the structural prerequisites, space validation, failure restoration during the migration, and post-migration evaluation. Such a model would not only address the technical conversion but also provide organizations with a roadmap to navigate the challenges of workflow adaptation, team re-training, and long-term repository optimization. This comprehensive approach to SVN to Git migration is vital for organizations to fully leverage the benefits of Git while minimizing the risks and disruptions associated with the migration process.

It has been experienced that almost 50,000 projects were migrated from SVN to Git over the last six years, but they have never been successful in the first attempt due to missing project structure validation, weak SSH connectivity issues, or sometimes improper mapping between SVN user and Git author which resulted in failure of migration from the scratch and resulted in longer migration time, wastage of resources and missing the project deadlines & business delivery [52]. This has motivated to propose an auto resilient migration model that covers all aspects of a successful VCS migration from a centralized legacy VCS to an advanced distributed VCS.

CHAPTER 3

PRE-VCS MIGRATION PHASE: PROPOSED METHODOLOGY AND IMPLEMENTATION

For the completion of the specified objectives discussed in Chapter 2. The research work was segregated into three sections; pre-migration efforts, during-migration efforts, and post-migration efforts. Identifying potential workflow challenges and offering training prior to migration are essential for a successful transition. Likewise, the during-migration phase, which includes managing migration tools, resolving conflicts, and minimizing disruption, is often insufficiently addressed. Additionally, the post-migration phase focused on optimizing workflows, ensuring full Git adoption, and resolving repository management issue that have been largely neglected in the literature. In this chapter focus is on VCS migration challenges that occurs during pre-migration phase and how to mitigate them using proposed model. Incompatibility of the project structure is discussed and a robust pre-VCS migration model is introduced which covers the project structure compatibility with auto resiliency capability.

3.1 Proposed advanced VCS migration model with capability of identification and validation of legacy project structure with auto resiliency capability as pre-VCS migration phase

An advanced distributed VCS migration model is presented inspired by the real world which overcomes all drawbacks and lacks in existing traditional migration model. As a focus on pre-migration efforts, this proposed model is designed to identify the compatibility of the project structure of microservices and can automatically correct the project structure. This project structure is different for legacy VCS to an advanced VCS. Translation in both directions is initiated

instantly and introduces minimal overhead. The evaluation parameter in terms of missing project directories, missing Pom.xml, missing Web.config must be identified by the system before actual migration starts.

It is asserted that the proposed model and simulation environment successfully represent real-world constraints, enabling the research community to explore and build upon it in future studies [67]. The proposal is to create a sophisticated advanced VCS migration model that focuses on missing pieces in the project structure of targeted migration code, for example if a project structure is missing an important package like LIBRARIES folder, DIST folder, TARGET, WEB-INF, SPRINGBOOT RESOURCES folder, it must identify it before migration starts so that these discrepancies can be accommodated beforehand as proactive approach otherwise VCS migration will fail. A Python script has been written and placed in the VCS migration model which has successfully identified and automatically corrected the project structure for those culprit projects that had such discrepancies [68].

3.2 Research problem and main contributions: Pre-VCS migration phase

Very minimal research efforts have been worked upon on VCS migration scope in the past. The existing research only focuses especially on how to migrate from legacy VCS to an advanced VCS systems by using various traditional migration software. They also focus on the pros and cons of different VCS systems but don't provide any thought on how to make this migration with auto resilient as a part of pre-migration essential efforts. In the proposed work, the focus has been given not only to how to migrate, but focus is specially given on how to mitigate the risk with a self-resilient and autonomous model so that it identifies and avoids all issues before migration starts. The verdicts of the projected framework have been used to authenticate preliminary setups, experiments, and validation of results. It is famous that many VCS migrations forsake when pre-migration readiness is lightly achieved or is likely minimal exertion. [53-61].

3.3 Identification of key features of traditional migration model

To achieve a solution for conducting a risk-free and systemic VCS migration, three stages of the code migration process were extensively analyzed: pre-migration, during-migration, and post-migration. For this purpose a detailed study was carried out which is given below.

Key Considerations During Pre-Migration

The key considerations during pre-migration are:

- License cost
- Capacity planning (JDK, File System, Disk Space)
- Security

Table 3.1 shows a holistic comparison between the traditional migration tools and their features.

Table 3.1: A holistic comparison between the traditional migration tools and their features

Features	SVN2Git	SVN Mirror	SUBGIT
Access Control	Limited users	Limited users	Up to 1000
Security	Weak	Weak	Strong
Speed	Slow and broken in low bandwidth	Poor	Better
Project Structure Identification	Absent	Absent	Absent

Manual and Disconnected Versioning:

Prior to the development of structured version control systems, software development teams often relied on manually tracking code versions and changes. Developers would save multiple copies of the code at various stages of development, often using local or physical repositories (e.g., folders or filing cabinets). This method led to disconnected workflows, and it became increasingly difficult to track and manage changes, especially in collaborative environments. There was no standardized process for handling versions, and each team or

developer would maintain their own versioning system, which resulted in a lack of consistency across projects.

Lack of Collaboration Support:

One of the critical features of pre-VCS migration was the absence of tools designed to support collaboration among developers. Teams would work on local versions of the code and later attempt to merge their changes manually, which often led to errors, duplication, or overwriting of code. Without any centralized repository, developers faced significant challenges in coordinating changes, tracking progress, or working simultaneously on different parts of the codebase. This disorganized collaboration meant that maintaining the integrity of the software became an arduous task, especially as team sizes increased.

Version Tracking via Physical Media:

Before automated version control systems, software developers would track changes on physical media, like floppy disks or tape drives. This was a rudimentary method, where developers would often rely on dated backups or manual log files to track which version of the code was on which disk or machine. This system of tracking could be inefficient, time-consuming, and prone to errors. Additionally, without centralized access, the management of various versions across multiple physical locations was both complex and resource-intensive.

Linear and Sequential Workflows:

The pre-VCS era was characterized by linear workflows, where development would occur sequentially, with minimal parallelization. The absence of version control systems meant that if two developers were working on the same part of a project, one might overwrite the other's changes, causing conflicts and a loss of work. As a result, teams generally worked in isolation or in strict sequences, which limited their ability to collaborate effectively on tasks or features that required concurrent development efforts.

Cumbersome Backups and Code Retrieval:

Without version control systems in place, developers often relied on manual backups of code and files to prevent data loss. This typically involved saving copies of the entire codebase in multiple locations. Retrieving the right version or tracking specific changes was often a matter of remembering which backup had been created at which time, adding to the potential for confusion or errors. Retrieving old versions of code from backups also often meant sifting through numerous copies and manually checking each one, a laborious and inefficient process.

Unreliable and Slow Recovery Process:

In pre-VCS migration, the ability to recover from errors or lost code was significantly hindered by the absence of an effective version control system. If developers encountered bugs or needed to revert to an earlier version of the code, this typically required restoring from backups, a process that could be slow and inefficient. The lack of a structured way to revert or merge changes meant that fixing errors could often result in further problems, making bug tracking and resolution a tedious process.

Limited Support for Distributed Development:

The development of software across multiple geographic locations was largely unfeasible without the support of version control systems. In the pre-VCS era, even if a development team existed in multiple locations, there were very few ways to ensure that everyone was working with the most up-to-date version of the code. This created synchronization issues, as different developers could work on isolated versions of the codebase, which would then need to be manually reconciled when they finally communicated or collaborated. This led to significant inefficiencies, especially when changes had to be integrated into a single, coherent software project.

3.4 Challenges of the pre-VCS migration model

Challenges of the pre-VCS migration model are discussed below.

High Risk of Code Conflicts:

A significant challenge of pre-VCS migration was the high risk of code conflicts. Since multiple developers would often be working on the same or related portions of the code without an effective way to track and merge changes, the likelihood of conflicts arising was high. If two developers made changes to the same lines of code or modules, it could lead to conflicts that were not easy to resolve. The process of reconciling these differences was done manually, which made the process error-prone and time-consuming.

Difficulty in Auditing and Traceability:

In the absence of version control, it was almost impossible to perform thorough audits or trace the history of changes to the code. Developers would be left without the ability to easily see who made changes, what changes were made, or why specific decisions were made in the codebase. This lack of traceability posed problems for troubleshooting, debugging, and understanding the evolution of the project over time. Without a history of changes, it was difficult to identify when a bug was introduced or to track down the cause of an issue.

Time-Consuming Code Integration:

In pre-VCS environments, when multiple developers worked on the same project, they would need to manually integrate their changes into a single version of the code. This integration process was both time-consuming and error-prone. Developers would often need to resolve differences manually, a process that could take hours or days, depending on the scope of the changes. The risk of introducing errors during the integration process was high, leading to further delays and potential failures.

Limited Support for Remote Development:

With pre-VCS migration, software development teams were often limited to a single physical location or were constrained by the technology available at the time. This severely limited the ability of distributed or remote teams to collaborate effectively. Without the tools to manage versions over the internet or synchronize code across different locations, developers working in separate offices or countries faced major obstacles. Any form of collaboration required manual intervention, whether it was through physical transportation of media (like floppy disks) or the use of basic communication tools.

No Backup or Redundancy Mechanism:

Backups and redundancies were often unreliable in the pre-VCS era. Without centralized or automated systems, there was a significant risk of data loss. Developers would create ad-hoc backup systems, but these were often inconsistent and unreliable. The absence of automated and regular backups meant that a simple hardware failure or mistake could result in the loss of critical code. This lack of proper redundancy posed a major risk to the success of a project and could lead to significant setbacks.

Inefficiency in Tracking and Managing Multiple Versions:

Without version control systems, developers faced significant inefficiencies in managing and maintaining multiple versions of the code. Every update, bug fix, or feature added to the project could be saved as a new copy of the entire codebase, creating confusion over which version was the most up-to-date. Additionally, it became more difficult to collaborate across different versions of the same codebase. Developers would have to manually compare versions, which was time-consuming and often resulted in mistakes.

No Parallel Development Capability:

Parallel development, where multiple teams or developers work on different

features simultaneously, was virtually impossible in the pre-VCS environment. Developers had to work sequentially, often waiting for others to finish their work before they could begin their own. This limited the pace of development and hindered the ability to release updates or new features quickly. The lack of parallel workflows slowed down progress and made the entire software development lifecycle much longer.

3.5 Data collection for appropriate parameters selections

A significant amount of data was gathered for the pre-migration phase, encompassing a total of 10 real-time projects. This data includes the total number of users, the required number of projects, user access levels, the administrator's role and access, the total revision histories, the number of tags, licensing costs, connectivity between source and target servers, and the current time taken for project migrations. This information helps in establishing a stable and effective benchmark model. The effective performance and high-level precision of the migration are intricately linked to the careful selection of these parameters. For instance, accurate references for both SVN and Git users must be meticulously recorded, encompassing the preservation of revision histories and Git metadata. The choice of parameters significantly influences the integrity of categorization. To pinpoint the ideal SVN and Git parameters, a range of factors is typically assessed to determine the most harmonious combination.

Operations

Operations applicable to each repository are defined as:

```
{isEmpty(k)} add Dir k d {isEmpty(k,d)} {isEmpty(k)} addFile k f {(k,f) 7→ ε }
{(k,f) 7→ c} modifyFile k f c c0 {(p,f) 7→ c 0 } {(k,f) 7→ ε }
deleteFile k f {isEmpty(k)} {isEmpty(k, d)} deleteDir k d {isEmpty(k)}
```

3.6 Methodology and environment preparation for pre-VCS migration model

The performance of the proposed model will be based upon the proper pre-configuration and environment preparation which also require submit software to be installed and configured with SVN Users and Git Authors credentials and a well-established SSH connectivity between two eco system.

A total of 10 real-time projects have been identified to evaluate the proposed migration model. The performance of this model will be compared against a benchmark model using similar datasets. This comparison will focus on the migration time from a legacy centralized version control system to a distributed version control system, the total number of failed projects, the number of users successfully migrated, and overall accuracy (efficiency).

This pioneering migration model investigates the shift from a legacy centralized monolithic system to a distributed microservices architecture, emphasizing critical factors such as decomposition, testing, security, performance, inter-service communication, persistence, and transaction management. Figure 3.1 depicts a workflow and preparation of VCS migration: pre-migration phase and its deep analysis which entails to propose a novel approach for migrating from a monolithic centralized system to a distributed microservices architecture, considering factors such as time, resource efficiency, time to market, and software quality, particularly in the context of large, complex software with a legacy spanning several decades. All experiments were conducted at the SRLC Software Research Lab in Pennsylvania, USA.

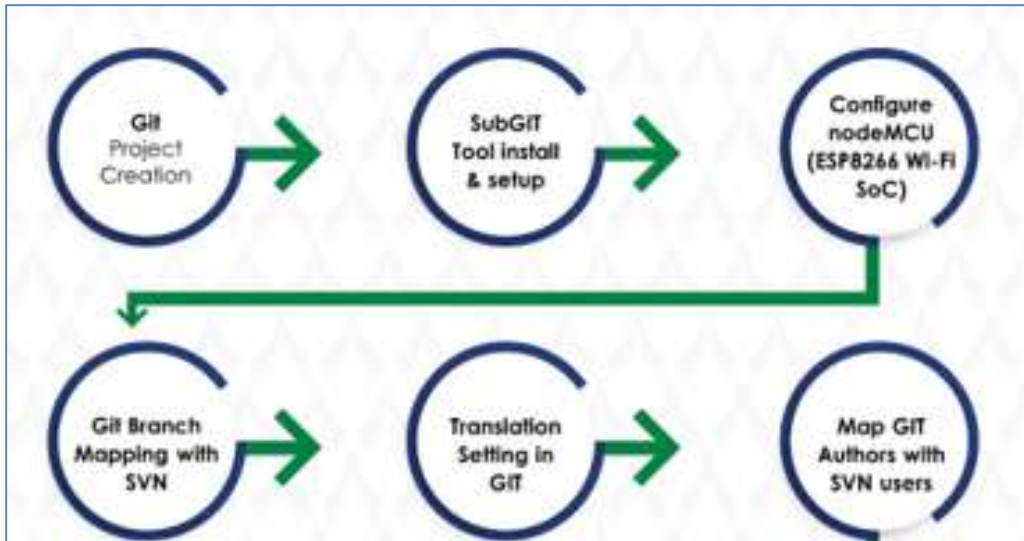


Figure 3.1: A workflow and preparation of VCS migration: pre-migration phase

The evaluation of the model can be done using qualitative and quantitative assessment approaches.

Qualitative Assessment: The performance of the proposed model will be compared against System performance.

Quantitative Assessment: The performance of the proposed model will be compared against a benchmark model with a similar test set.

To set up the environment for pre-migration work, some basic settings are needed, like JDK installation. The prerequisite is JDK 1.8 or higher version. The SVN server must have projects installed in separate repositories and needs to configure NodeMCU IoT device implementation and configuration setup at source and destination. NodeMCU device needs to be installed and properly configured to pre-validate the connection between SVN & Git servers to confirm the same to the root user. To achieve this, this work will utilize NodeMCU, a low-cost open-source IoT platform. The firmware operates on the ESP8266 Wi-Fi SoC from ESP Systems, and the hardware is built around the ESP-12 module. Figure 3.2 clearly illustrates a scientific methodology for successful migration for SVN to Git.

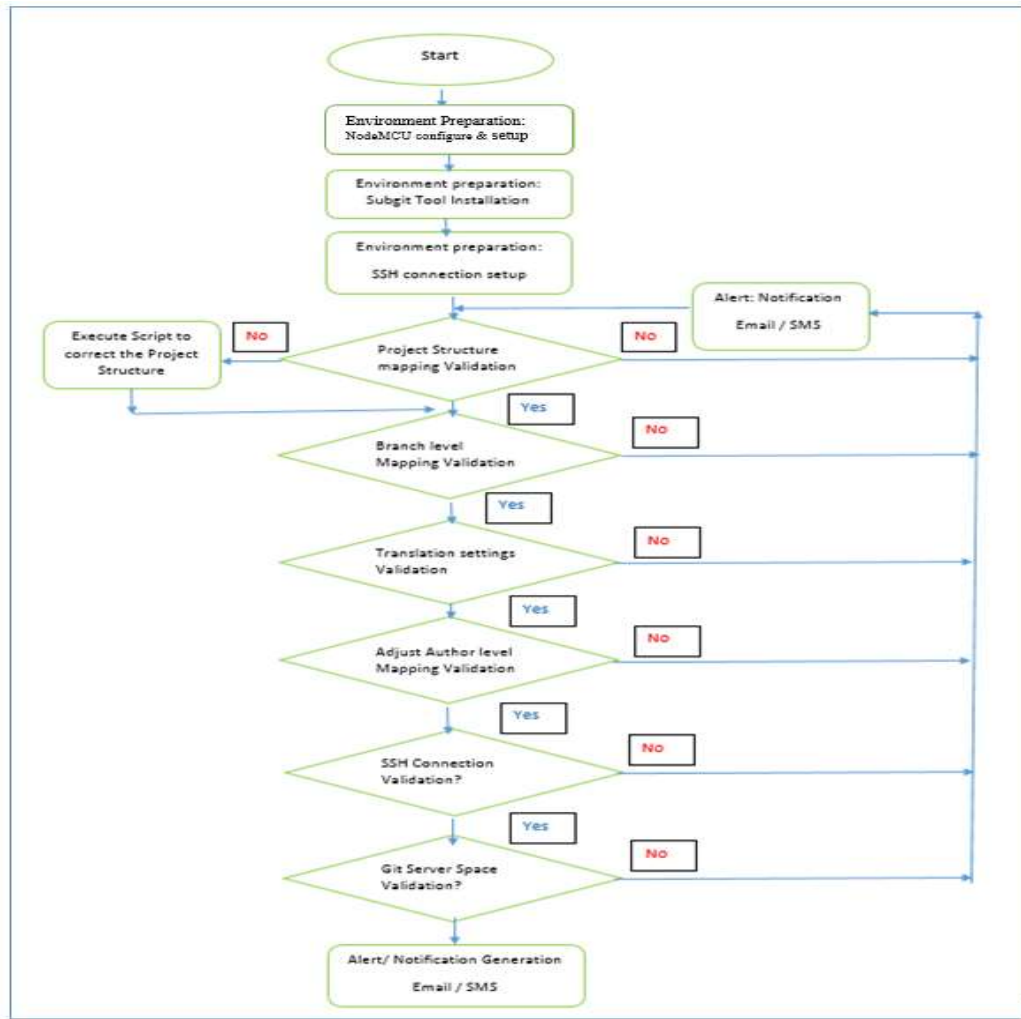


Figure 3.2: SVN to Git migration: A scientific methodology

3.7 Results and Discussion

Total number of projects with project structure incompatibility and auto resiliency are shown in Table 3.2. The traditional migration model could only migrate 3 projects and rest 7 were unsuccessful out of 10 real time projects because of the incompatible project structure of microservices. The proposed model smoothly migrated all 10 projects with no single issue by correcting the project structure and generating the alert notification on it. A related graph is depicted with a comparison between traditional and proposed model on successful migration of projects.

Table 3.2: Total number of projects with project structure incompatibility and auto resiliency

Projects	Using Traditional Migration Tool: Total No of identified Projects (With Improper Project structure)	Using Traditional Migration Tool: Total No of Projects Corrected	Success Ratio	Using Proposed Migration Tool: Total No of identified Projects (With Improper Project structure)	Using Proposed Migration Tool: Total No of Projects Corrected	Success Ratio
10	0	0	0%	10	10	100%

Figure 3.3 shows the project structure incompatibility and auto resiliency while in pre-migration phase.

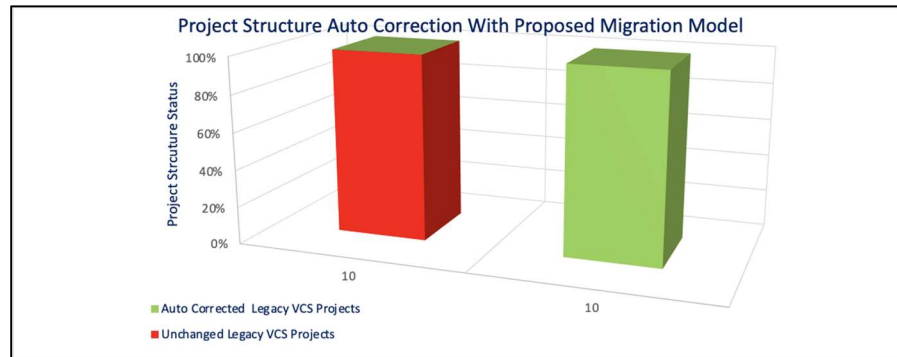


Figure 3.3: Project structure incompatibility and auto resiliency: pre-migration phase

3.8 Conclusion

It has been observed that the traditional migration model could only migrate 3 Projects and rest 7 were unsuccessful out of 10 real time projects because of incompatible project structure of microservices. The normal migration approach for Subversion to Git seems to make use of traditional tools. This tool however appears to be more of a live synchronization tool so that developers can use both Git and Subversion at the same time. For this reason and others, it cannot be considered an

ideal situation for a one-off migration. However the proposed pre-migration model successfully smoothly migrated all 10 projects by auto correcting the project structure and generating the alert notification on it. The whole migration was done smoothly without any single failure or hard halt. As a part of pre-migration, it also has been proven that traditional migration tool was not able to identify how many projects were having issues with the project structure. However, the proposed migration model can identify the issues in the project structure of microservices.

CHAPTER 4

DURING VCS MIGRATION PHASE:

PROPOSED METHODOLOGY AND IMPLEMENTATION

In the previous chapter we talked about the how the traditional migration model could migrate only a few projects due to incompatible microservices structures in pre-migration phase. The standard Subversion-to-Git approach, relying on live synchronization, is not ideal for one-time migrations. In this chapter, the intricacies and challenges observed in the during-VCS migration phase are covered. Issues and challenges faced during-VCS migration are discussed and a robust VCS migration model is proposed which entails the auto remote Git server space validation feature & alert notification capability so that VCS migration is successfully completed without any failure. The proposed VCS migration model for migration from a centralized VCS to a distributed VCS is based upon two main factors. The challenges, architectural flow, technical debt of traditional VCS migration model are discussed and how distributed VCS migration model covers all the aspects with sophisticated techniques and strategies.

There are two approaches for implementing during-VCS migration model. The first approach is to build a model that is self-efficient to check frequently on remote Git server space and do some basic validation by using IoT devices. Translation in both directions is initiated instantly and introduces minimal overhead. On an average, one revision translation takes 1 - 1.5 milliseconds. Of course, the bigger the number of revisions is, the longer the translation. If it runs much slower, though, there are a few things to consider. The second approach is that the proposed model must have the capability to execute consistent monitoring & generate alert notification with

restoration from the same network failure point where migration was halted and send alert notification.

4.1 Research problem and main contributions during-VCS migration phase

From the literature perspective, the earlier published work focused mainly on the migration of projects from a legacy VCS to a distributed VCS but never inclined on checking the remote server space during migration. The past research work doesn't focus on alert generation if disk space is lower than 20% i.e., below a certain limit. The proposed model covers all aspects by continuously checking the disk space and send alert notification in case of remote server space is low beyond to a certain defined limit. In general, an alert is sent if disk space is beyond 80% consumption.

4.2 Identification of key features of traditional migration model

Key considerations or challenges during-migration are as follows:

- SSH and TCP communications
- Network connectivity and ports (22,443,3609)
- Ping status and Netstat status

Table 4.1 shows the holistic comparison between the traditional migration tools and their features.

Table 4.1: A holistic comparison between the traditional migration tools and their features

Features	SVN2Git	SVN Mirror	SUBGIT
VCS Space Validation	Absent	Absent	Absent

4.3 Challenges of the during VCS-migration model

The during-VCS migration model refers to the phase of software development where organizations are transitioning from one version control system to another,

or from a manual, ad-hoc approach to a more structured, modern VCS. This period is often fraught with complexities and challenges because it involves significant changes to development workflows, practices, and infrastructure. The process of migrating between different VCS platforms (for example, moving from Subversion to Git) or from a traditional file-based system to a more modern distributed VCS can disrupt the development process and require careful planning to avoid costly errors and delays. This transition phase poses several challenges that can impact the productivity of development teams, the integrity of codebases, and the consistency of ongoing projects. Below are some of the main challenges encountered during the migration to a VCS, along with an explanation of the problems they present.

Data Integrity and Preservation of History:

One of the most significant challenges during the during-VCS migration model is ensuring that the integrity of the historical data, such as commits, branches, and tags, is preserved. When migrating from one VCS to another, particularly between different models (e.g., from centralized systems like SVN to distributed systems like Git), it is crucial to maintain a consistent history of changes made to the codebase. Different version control systems have different ways of structuring and managing data. For example, centralized VCSs store code in a single repository, while distributed systems store copies of the code on each developer's local machine. This discrepancy can lead to problems in retaining a complete history of changes during the migration process. If not handled carefully, developers might lose valuable information regarding when changes were made, why they were made, and who made them. The loss of historical context can severely hinder developers' ability to trace bugs, understand code evolution, or audit previous changes. Without this context, teams may face significant difficulties in debugging issues or understanding the rationale behind past decisions, making the migration less effective and causing disruptions to the software lifecycle.

Migration complexity and tool compatibility:

Migrating to a new VCS often involves tools, scripts, and processes that need to be adapted or reworked to fit the new system. This is especially challenging when the new VCS has different workflows or integrates differently with other tools in the development ecosystem. Some VCS tools may not have straightforward migration paths, and software companies must rely on third-party migration tools or develop custom scripts to move data from one system to another. However, even with these tools, compatibility issues can arise, particularly when migrating large repositories or legacy codebases. If the tools or scripts don't function as expected, it may lead to errors in migrating large repositories or result in data loss or corruption. This can significantly extend the timeline for the migration process, as teams may need to invest time in fixing issues with compatibility. Furthermore, manual intervention is often required to ensure that everything transitions smoothly, which adds to the risk of human error and further delays.

Workflow Disruptions:

Migration to a new VCS typically requires significant changes to the development workflow. A VCS migration is not just about changing the tools but also about adapting to new workflows and processes that come with the new system. For example, transitioning from a centralized system (e.g., SVN) to a distributed system (e.g., Git) requires a shift in how developers collaborate and manage their code. Developers who are used to specific workflows may face difficulties adjusting to new ones. A tool like Git, for instance, offers powerful branching and merging capabilities, but these features may not be intuitive for developers accustomed to a more linear process in centralized VCS systems. Training developers and ensuring they adopt the new workflows can be time-consuming and lead to short-term productivity losses. The temporary disruption of developer productivity during the transition period can slow down the project development cycle. The learning curve involved in understanding new commands, operations, and workflows can introduce inefficiencies in daily tasks. If not properly managed, workflow

disruptions can lead to delays, missed deadlines, and a decline in team morale.

Dependency management and integration challenges:

Version control systems play a critical role in managing code dependencies, ensuring that the right versions of libraries and modules are being used across different environments. Migrating to a new VCS can complicate dependency management, especially if the new system requires changes to the structure or handling of external dependencies. When migrating to a new VCS, developers may need to adjust how dependencies are tracked and integrated. For example, if the new VCS system uses a different approach to managing external dependencies, codebases that rely on particular versions of libraries may experience breakages. Additionally, integration with continuous integration/continuous deployment (CI/CD) pipelines, issue-tracking systems, and other development tools may be disrupted during the migration. The migration could lead to an integration breakdown, where tools that previously worked seamlessly with the old VCS no longer function correctly. Teams may need to spend additional time reconfiguring or replacing integration points. This disruption in the development environment can delay releases and testing cycles, as well as potentially introduce bugs or regressions if dependencies are not properly handled.

Training and knowledge transfer:

Adopting a new VCS often requires developers to learn new concepts, commands, and workflows. Even if the organization has already used version control in some form, migrating to a new system like Git or Mercurial may involve significant training. Developers may be resistant to change, particularly if they have been using a VCS system for many years. Migrating from a system like Subversion or CVS to a modern distributed version control system like Git means learning concepts such as branching, pull requests, and rebasing, which might be new to some team members. Additionally, the transition period often requires developers to understand the new system's best practices, including commit message

conventions, branching strategies (e.g., GitFlow), and merge policies. Resistance to change or a lack of proper training can lead to mistakes in the new system, potentially causing frustration among developers. Misunderstanding new commands or workflows could result in errors such as improper merges or failed commits. If the transition is not managed effectively, the organization might face morale issues, decreased productivity, and a higher number of bugs or mistakes in the codebase due to user errors.

Migration of Large Repositories:

For organizations with large codebases, migrating to a new VCS can be particularly challenging. Migrating large repositories with extensive commit histories can lead to performance bottlenecks, data corruption, or lengthy downtimes, depending on the tools and processes used. Migrating large repositories can put significant strain on the migration tools and infrastructure. Systems may become overloaded when trying to process and move huge amounts of data, and even after the migration, performance may be impacted due to the increased complexity of the repository's history. Large-scale migrations may cause substantial downtime, where development work is temporarily halted as the migration takes place. This delay can affect product timelines, especially if multiple teams are relying on the same codebase. Additionally, large repositories can present issues when migrating binary files or specific project structures that do not fit the new VCS model, leading to additional complexities and errors.

Risk of data loss or corruption:

Data loss is a major concern during the migration process, as developers transition from one version control system to another. It can happen during the migration itself or afterward, if the new VCS doesn't properly capture or store the entire repository's data. Errors in migration scripts, conflicts in version histories, or misconfigurations in repository setup can lead to the loss of critical data, such as code changes, commits, or branches. Data corruption might also occur if the

migration process is not fully validated or tested before the system goes live. Data loss can result in a permanent loss of valuable code, breaking the continuity of the project's history. This could potentially set the team back weeks or months in recreating the lost data, or worse, cause the project to fail entirely if the loss is severe enough.

4.4 Data collection for appropriate parameters selections

A vast amount of data was collected for during-migration including a total of 10 real-time projects as defined in pre-migration steps. These data had been collected to ensure that migration is successful without any failure. The parameters that were taken into consideration were revision history, ping status, total space in GB, port scanning, and TCP/IP connectivity between the two VCS systems. A working model has been prepared as a benchmark. The performance or accuracy of this migration directly depends upon the parameter selection. For example, the correct credentials of SVN and Git users are accepted in the system and also filter out the revision history and Git metadata [63-94]. The selection of these parameters affects the classification accuracy. To select the convolutional SVN and Git parameters, different variables are usually examined, and the best combination is selected.

4.5 Methodology and environment preparation for during-VCS migration model

A holistic workflow has been shown in the Figure 4.1 which covers all steps from pre-migration to during migration [71]. Project creation is required as an essential part of the migration and the Node MCU device needs to be installed and configured. In the case of a cloud environment, a Hosted VMS is needed. A smoke test is needed on SSH connectivity between the two systems. Figure 4.1 entails a complete workflow and preparation of VCS migration during-migration phase. This time python script written to validate the Git server space and restoration capability needs to be incorporated and finally integrated into the proposed model which has been shown in the Figure 4.2.

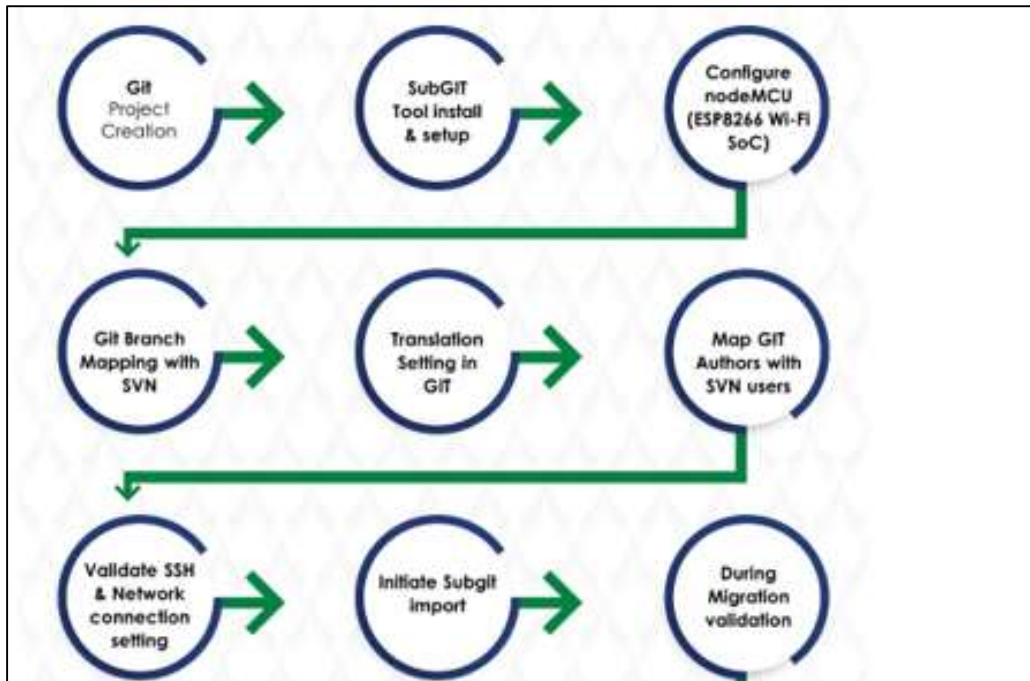


Figure 4.1: A workflow and preparation of VCS migration: during-migration phase

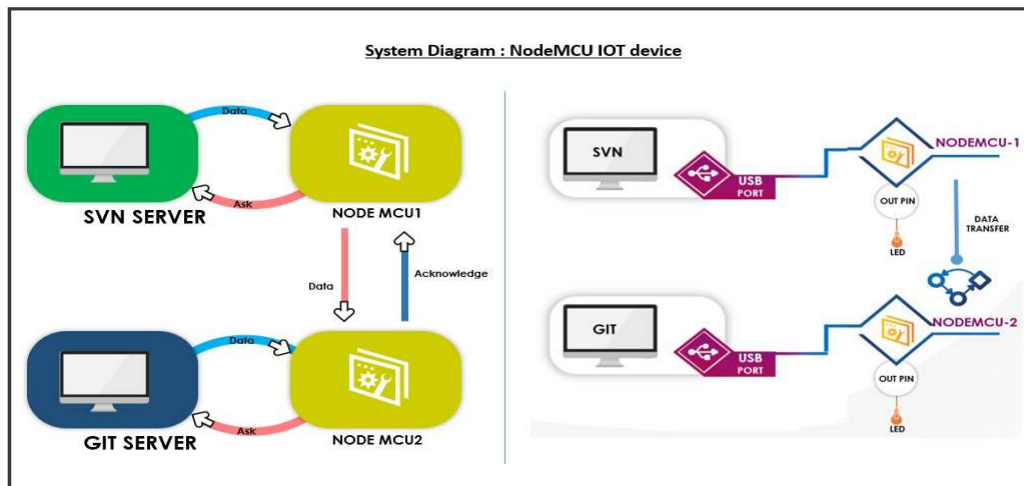


Figure 4.2: Integration of Node MCU IoT device with SVN & Git VCS servers

Steps to configure the IoT device Node MCU in the proposed model at both source and destination servers are given below.

- Step 1: NodeMCU2 connects to the Wi-Fi, starts the server, and waits for the client to connect.
- Step 2: NodeMCU1 connects to the Wi-Fi, starts, and waits for the setup message over the Serial port.
- Step 3: The SVN server starts migration and sends the setup block (message with type “setup”) with the server IP to connect.
- Step 4: NodeMCU1 at the SVN server opens the connection (as a client) to NodeMCU2 at the Git server.
- Step 5: SVN server sends 32K block of data (message with type “data”). NodeMCU has 64K memory so it can be experimented and waits for acknowledgment.
- Step 6: NodeMCU2 receives the data, checks it, and sends it to Git Server to store the revision history.
- Step 7: The Git server receives the data, checks and writes to the file, and stores the revision history in the AWS elastic cache. In case of success, ACK is sent back. If there is no space on the disk – write will fail and NACK will be sent back.
- Step 8: The SVN server constantly checks for the end of the file. In case of the end of the file – the remaining data is sent and then a message with type “End of file” is sent.
- Step 9: When Git Server receives the message “End of file” – It closes the file and reports back ACK.
- Step 10: In any case of failure – NACK is sent.
- Step 11: NodeMCU1 constantly checks for acknowledgment. If there is NACK received – LED can be lit with the help of Twilio or IFTTT SMS is sent. NACK is also sent to the PC1 for a file close and exit.

Step 12: Set up and configure SMTP in a hosted VM server having NodeMCU attached software and configure client IP by the web interface to facilitate Alert/Email notification.

4.6 Results and Discussion

Table 4.2 shows the total projects identified with space issues with alert notification.

Table 4.2: Total projects identified with space issues with alert notification

Using Traditional Migration Model				Using Proposed Model			
Total Projects	Using Traditional Migration Tool: Total Projects identified with Space issues	Using Traditional Migration Tool: Validation & Alerts Generation/Notification	Success Ratio	Using Proposed Migration Tool: Total Projects identified with Space issues	Using Proposed Migration Tool: Validation & Total No of Alerts Generation/Notification for Disk Space issue	Alert Generation	Success Ratio
10	0	0	0%	10	10	10	100%

The proposed mechanism during migration testing from SVN to Git addresses the main drawbacks of the available SVN to Git migration strategies. Most scripts were produced and performed for testing during migration and planning for migration, which overwhelms the issue of missing migration.

Total count of projects with having server space issues and alert notifications:

During migration it was observed that there were a few projects that got stuck and failed and could not be migrated successfully because of the Git server space was having crunch space issues and the traditional migration model could not facilitate to overcome this issue by sending the email/alert notification. However while using the proposed model where a Python script was written to identify the available space during migration helped to generate the alert if disk space was less than 80% limit. It has been depicted in Figure 4.3.

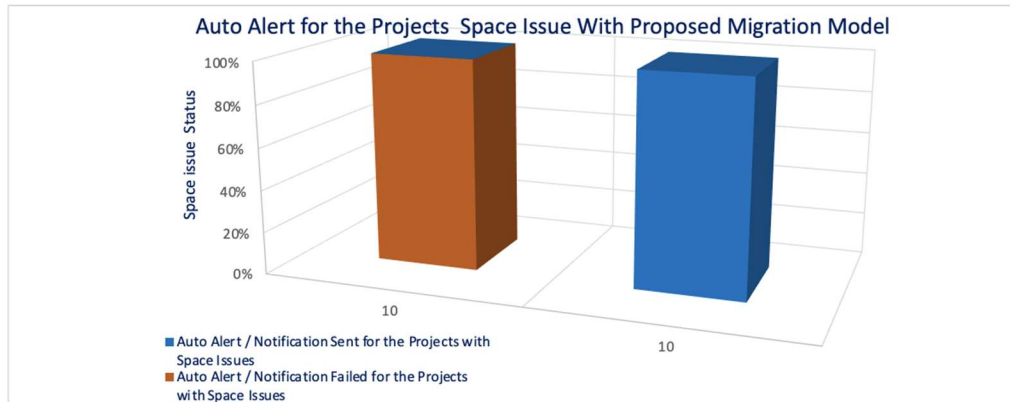


Figure 4.3: Total VCS projects with space-related issues and alert notifications triggered during-migration phase

4.7 Conclusion

During migration it was observed that there were a few projects that got stuck and failed and could not be migrated successfully because of the Git Server space was having a crunch of space issues and the traditional migration model could not facilitate to overcome this issue by sending the email/alert notification. However while using the proposed model where a Python script was written to identify the available space during migration helped to generate the alert if disk space was less than 80% limit. It has been observed that the proposed model has not only sent the alert notification on network failure but also restored the migration from exact same failure point. Hence proposed system has well proven consistent restoration capability to restore the migration from the failure point. For migration of revision histories as meta-data, SVN authors should be mapped with Git authors before migration takes place. The proposed work gives a mechanism by which SVN authors are mapped with Git authors before migration. In this way, revision histories are not lost.

CHAPTER 5

DURING VCS MIGRATION PHASE: PROPOSED METHODOLOGY AND IMPLEMENTATION

In the previous chapter the issues and strategies for during migration phase were discussed. Some projects failed due to Git server space issues, and the traditional migration model could not send alerts for this. In this chapter the issues and strategies during post-migration phase are discussed and finally a VCS migration model with auto restoring feature due to network failure & auto alert notification as a part of during VCS migration phase is proposed.

5.1 Research problem

It has also been observed that if migration fails due to network failure, the whole migration fails. In this case, migration must start from scratch, and the whole effort, time, and resources go in vain.

5.2 Identification of key features of the traditional migration model

Key considerations or challenges during migration are:

- SSH Connectivity and TCP communications
- Network connectivity and ports (22,443,3609)
- Ping status and Netstat status

Table 5.1 shows a holistic comparison between the traditional migration tools and their features.

Table 5.1: A holistic comparison between the Traditional Migration tools and their features

Features	SVN2Git	SVN Mirror	SUBGIT
Restoration from Network Failure	Absent	Absent	Absent

Migrating from SVN to Git involves significant changes, and careful consideration is required to address potential issues that can occur during the migration process. Below are the key considerations that focus on the technical challenges, data integrity, and system reliability during the migration from SVN to Git.

Server space and performance:

The storage requirements for a Git repository are typically higher than SVN due to its distributed nature. Every developer working with Git has a complete copy of the entire repository, including its history. If a large SVN repository is migrated, this could significantly increase the space required on the server. Git repositories can become quite large, particularly if the repository has a long history, many branches, or large binary files. Server capacity needs to be evaluated before starting the migration. Sufficient disk space needs to be ensured on both the server and the local machines where the repositories will be cloned. Git LFS (Large File Storage) is considered for managing large binary files.

Risk of data loss or corruption:

Data loss during migration can be a serious risk, especially if the conversion tools (e.g., git-svn) do not function properly or if there is a failure during the migration. If the SVN repository is not fully and correctly migrated to Git, valuable commit history, branches, tags, and other metadata could be lost. This can severely impact the team's ability to trace changes and manage the codebase. Perform the migration in stages, testing each step of the process with smaller repositories first. Always maintain backups of the original SVN repository and ensure that the migration is validated at each step to ensure that all data is properly transferred and preserved.

Missing alerts and monitoring for failures:

Migrating a repository can fail or cause errors during the process, and without proper alerts or monitoring, these failures may go unnoticed, leading to issues like incomplete or corrupted repositories. SVN to Git migration tools like git-svn may encounter errors related to permissions, repository structure, or large files. If there are no proactive alerts or logging mechanisms in place, the team may be unaware of these issues until it is too late. Set up monitoring for the migration process, with clear logging for errors or failures. Implement automated alerts for critical failures (e.g., if the migration script fails or if a repository is not fully migrated). These should be configured to notify administrators or the migration team immediately.

Difficulty in finding the failure point:

During migration, pinpointing the exact moment or step where a failure occurs can be challenging, especially if the migration process spans multiple stages or involves complex repositories. Errors may manifest in various forms, such as missing commits, incorrect branch structures, or failed merges. Without visibility into the migration process, the source of the failure can be difficult to trace and resolve. Break down the migration into smaller, manageable steps and test each step individually (e.g., migrating a single branch or directory). This makes it easier to identify where the failure occurs and provides a quicker path to resolution.

Syncing issues and delayed updates:

SVN repositories are centralized, meaning updates happen at a central location, and developers pull changes as needed. In contrast, Git's decentralized nature allows for local commits and pushes. Synchronizing the repositories during the transition can become problematic. Developers may continue working in SVN after the migration has begun, leading to discrepancies between the two systems and potential loss of updates if not managed correctly. This is particularly a concern if the transition is gradual or if there are parallel SVN and Git users during the migration phase. Plan for a cut-off date for SVN usage to avoid syncing issues. Ensure that all changes

made in SVN are migrated to Git before switching entirely to Git. A clear communication plan should be established so all developers are aware of the migration process and deadlines.

Workflow disruption and resistance:

Transitioning from SVN to Git may cause disruptions to existing workflows, as developers accustomed to SVN may struggle to adapt to Git's decentralized approach and new commands. Resistance to change can slow down the migration process, with developers continuing to use SVN practices in Git or misunderstanding Git's branching and merging processes. Provide proper training and documentation before and during the migration. Implement a gradual migration approach, with plenty of support for team members who need help transitioning. Encourage best practices for Git usage and introduce Git's advanced features (such as rebase, pull requests, and distributed workflows) after ensuring foundational knowledge is in place.

Dependency management and integration:

SVN may be integrated with other tools (e.g., Jenkins, CI/CD pipelines, ticketing systems) that rely on SVN's centralized workflow. Git's integration with these tools may require significant adjustments. The migration could break integrations with other systems, causing delays and issues with continuous integration/continuous delivery (CI/CD) or automated deployments. Audit all integrations and dependencies linked to the SVN repository before migration. Ensure that the new Git repository is properly integrated with these tools, and test each integration during the migration process to prevent disruptions in the development pipeline.

Migration downtime and its impact on development:

During migration, there may be downtime where developers cannot commit to the repository. If this downtime is not well-managed, it can impact the team's ability to deliver on projects. During the cut-over phase, developers will need to stop

committing to SVN, but if the migration isn't smooth, this could delay ongoing development work or cause confusion about which system should be used. Plan for migration during low-traffic periods (e.g., weekends or off-hours). Ensure that teams are aware of the timing and have contingency plans in case there are delays. Also, allow for an overlap period where both SVN and Git can be used in parallel before fully switching over.

Scalability issues during post-migration:

After migration, Git's distributed nature may put a strain on server resources, particularly when handling large teams or repositories with vast histories. Git can experience performance issues if the repository becomes too large, especially with numerous branches, tags, or large binary files. This can affect developers' ability to clone, fetch, or push changes efficiently. Consider implementing Git hosting solutions optimized for large-scale repositories (such as GitHub Enterprise, GitLab, or Bitbucket). Regularly monitor Git's performance and optimize the repository by periodically cleaning up old or unused branches and tags.

5.3 Data collection for appropriate parameters selections during VCS migration model

A vast amount of data was collected for migration including a total of 10 real-time projects as defined in pre-migration steps. These data were collected to ensure that migration is successful without any failure. The parameters that were taken into consideration were revision history, ping status, total space in GB, port scanning, and TCP/IP connectivity between the two VCS systems. A working model has been prepared as a benchmark. The performance or accuracy of this migration directly depends upon the parameter selection. For example, the correct credentials of SVN and Git users are accepted in the system and also filter out the revision history and Git metadata [86-87]. The selection of these parameters affects the classification accuracy. To select the convolutional SVN and Git parameters, different variables are usually examined, and the best combination is selected. Figure 5.1 shows an

algorithm for network connection and health check validation with automatic restoration from failure points while in during-migration phase.

```

1: gitCountFile ← Input Git count text file.
2: gitOldSize ← Input Git Old size text file.
3: svnCountFile ← Input SVN count text file.
4: svnOldSize ← Input SVN Old size text file.
5: gitdir ← Input Git directory.
6: email ← Input git migration Status.
7: svndir ← Input Svn directory.
8: lastGitCount ← Read gitCountFile.
9: lastSvnCount ← Read svnCountFile.
10: sizeoldGit ← Read gitOldSize.
11: sizeoldSvn ← Read svnOldSize.
12: stop ← 0
13: while stop = 0 do:
14:   if git ls -remote URL then:
15:     Print Git Connected.
16:     Change directory to gitdir
17:     Remove test directory using rm -r /test/
18:     get current working directory.
19:     Change directory to gitdir
20:     GitCommits ← List of commits from branches master
21:     if GitCommits > lastGitCount then:
22:       Print GitCommits > lastGitCount
23:       gitsize ← Get disk usage of gitdir
24:       Print gitsize
25:       if gitsize > sizeoldGit then:
26:         Print gitsize > sizeoldGit
27:       else:
28:         Print GitCommits > gitCountFile
29:         gitsize ← Get disk usage of gitdir
30:         Print gitsize
31:         if gitsize > sizeoldGit then:
32:           Print gitsize > sizeoldGit
33:         else:
34:           Pyhton3 email "Git size status" "Git size not in-
35: creased"
36:           stop = 1
37:           exit
38:         Pyhton3 email "Git commit count status", "Git commit
39: count not increased"
40:         stop = 1
41:         exit
42:       else:
43:         Print Git not able to connect.
44:         Pyhton3 email "Git cgnnection status" "Git not be able to
45: connect"
46:         stop = 1
47:         exit

```

Figure 5.1: Network connection and health check validation with automatic restoration from failure points during migration phase

5.4 Methodology and environment preparation for during-VCS migration model

A holistic workflow has been shown in the above figure which covers all steps from Pre-migration to during-migration. Projects creation is required as an essential part of the migration and the Node MCU device needs to be installed and configured. In the case of a cloud environment, a hosted VMS is needed. A smoke test is needed on SSH connectivity between the two systems. This time python script written to validate the Git server space and restoration capability needs to be incorporated into

the proposed model.

Working of NodeMCU IoT platform:

The connection between SVN & Git is achieved by the NodeMCU IoT connected to each PC's USB port (it is detected as a serial port and can be used as a serial port connection). Optionally, LED can be connected to the NodeMCU digital output as a failure indication. Figure 5.2 depicts a systematic workflow of NodeMCU IoT device ESP8266 Wi-Fi SoC.

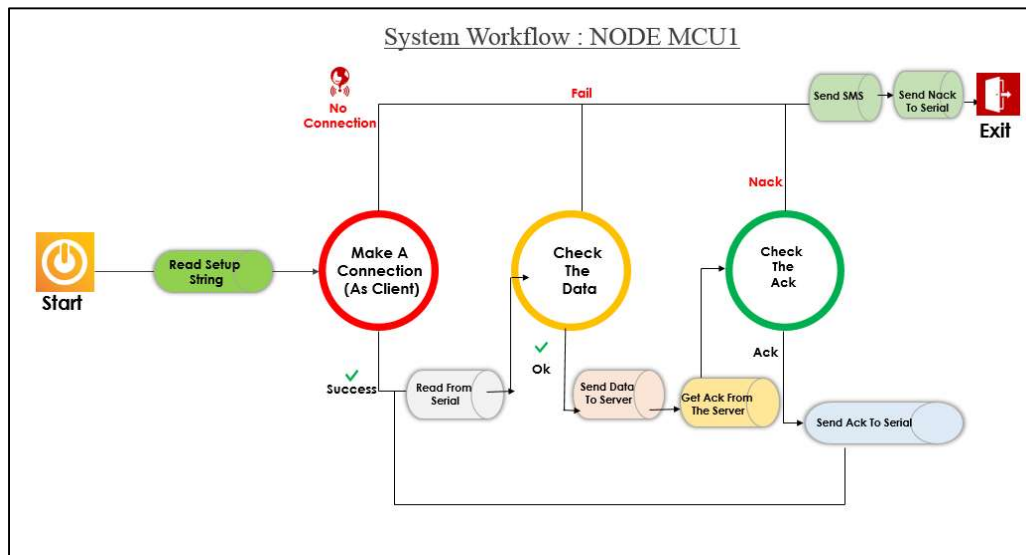


Figure 5.2: System workflow of NodeMCU IoT device ESP8266 Wi-Fi SoC

A few points to be considered are as follows:

- ACK is positive
- NACK is negative

It is assumed that Wi-Fi manager is part of the NodeMCU software. Wi-Fi manager allows web configuration of the Wi-Fi network. Alternatively, Wi-Fi parameters can be hardcoded in the software. For SMS sending additional hardware can be used, like GSM shield devices, Twilio or IFTTT, but an internet connection is the prerequisite for sending SMS alerts using these devices. It is mentioned in Figure 5.3.

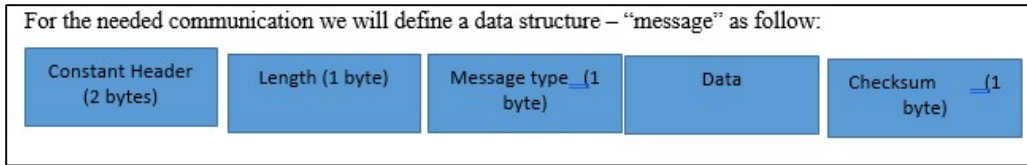


Figure 5.3: Acknowledge the predefined message sent by NodeMCU IoT device

The dataflow:

1. NodeMCU2 connects to the Wi-Fi, starts the server, and waits for the client to connect. It is mentioned in Figure 5.4.
2. NodeMCU1 connects to the Wi-Fi, starts, and waits for the setup message over the Serial port.
3. The SVN server starts migration and sends the setup block (message with type “setup”) with the server IP to connect.
4. NodeMCU1 at the SVN server opens the connection (as a client) to NodeMCU2 at the Git server.
5. SVN server sends 32K block of data (message with type “data”) (NodeMCU has 64K memory so it can be experimented) and waits for acknowledgment.
6. NodeMCU2 receives the data, checks it, and sends it to the Git server to store the revision history.
7. The Git server receives the data, checks and writes to the file, and stores the revision history in the AWS elastic cache. In case of success, ACK is sent back. If there is no space on the disk – write will fail and NACK will be sent back.
8. The SVN server constantly checks for the end of the file. In case of the end of the file – the remaining data is sent and then a message with type “End of file” is sent.
9. When the Git server receives the message “End of file” – It closes the file and reports back to ACK.
10. In any case of failure – NACK is sent.
11. NodeMCU1 constantly checks for acknowledgment. If there is NACK received – LED can be lit and with the help of Twilio or IFTTT SMS is

sent. NACK is also sent to the PC1 for proper file close and exit.

Setup messages can be avoided by including a web server in the NodeMCU software and configuring the client IP by the web interface.

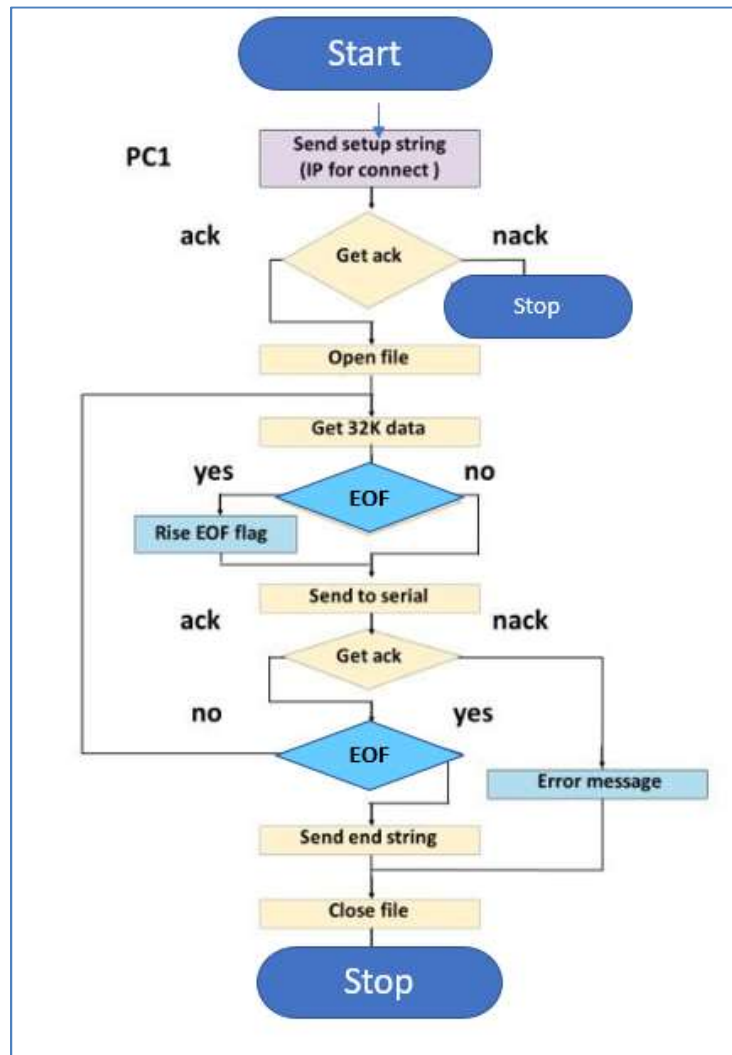


Figure 5.4: NodeMCU device flow chart to read the packets

5.5 Results and discussion for during-VCS migration model

During migration, it was observed that there were a few projects that got stuck and failed and could not be migrated successfully because of the network failure was having crunch of space issues and the traditional migration model could not

facilitate overcome this issue by auto restoration of migration failure from failure point and sending the email/alert notification. However using the proposed model where a Python script was written and implemented with NODE-MCU IoT to identify the available space during migration helped to generate the alert if there is any network failure.

5.6 Conclusion

After successful implementation of the during migration model especially keeping the capability of validating the auto remote Git server space and in case the space is consumed beyond a certain limit, it must send an alert notification as a part of during-VCS migration requirement process. With results, it was proven that Python scripts incorporated in the migration model were capable enough to work with Node-MCU IoT devices, which keep monitoring the server availability and space by sending continuous signals and receiving the ACK (acknowledgment). For this purpose, a total of 10 projects were identified. When migration started, the Node-MCU device started sending signals and kept monitoring the whole migration by checking the network health. We deliberately stopped the VCS migration from SVN to Git by stopping some SSH ports which artificially caused the migration halted. We can see that the traditional migration model did not have the capability to check the network health or send alert notifications. We could see that the proposed during-migration model was self-sufficient in sending alert notifications to several stakeholders.

CHAPTER 6

POST VCS MIGRATION PHASE: PROPOSED METHODOLOGY AND IMPLEMENTATION

In the previous chapter, during-migration model was discussed, which utilized Python scripts and Node-MCU IoT devices to successfully monitor Git server space and network health, sending alerts when space exceeded predefined limits. This model enhanced the migration process by ensuring continuous monitoring and real-time alerts. In this chapter, challenges and issues encountered in the post-migration phase are discussed. After migration, organizations often face difficulties in optimizing workflows, ensuring full system adoption, and addressing remaining repository management issues. These challenges include team adaptation to the new system, unresolved migration errors, and performance concerns in the new environment. To tackle these challenges, a post migration model is proposed in this chapter that includes alert notifications, VCS report generation, and ongoing support for post-migration issues. The proposed model will not only send alerts for any post-migration issues but also generate detailed VCS reports to track migration progress and document any problems. Additionally, it will offer continuous support to teams transitioning to Git, ensuring smooth operations after the migration. Through these strategies, the proposed post-migration model aims to provide a comprehensive solution for overcoming the challenges that arise after a VCS migration.

6.1 Proposed VCS migration model for migration from a centralized VCS to a distributed VCS as a part of the post-migration phase

Keeping the holistic end-to-end VCS migration approach in mind, a final model has been proposed and designed which is inspired by the software industry problems

which dealt with all shortcomings and missing features in the existing traditional migration model. These features are essential and imperative to provide a holistic version control migration. As a focus on post-migration efforts, the proposed model is designed to identify the total count of VCS users present in legacy VCS like SVN that have been properly mapped with advanced distributed VCS like Git. SVN users are called Users, but Git users are called authors. Translation with revision history and user metadata are required in both directions which must be initiated instantly with minimal overhead.

6.2 Research problem and main contributions during post-VCS migration phase

On reviewing the related works by different researchers, we found that there are no research efforts that worked upon on the VCS migration scope in the past. The existing research only focuses especially on straight migration from one legacy VCS to another advanced VCS system by using various traditional migration software. These traditional tools can not identify the total count of users finally migrated from source to destination. Traditional systems do not pay attention to how to generate detailed reports as a part of post-migration efforts. In the proposed work, the focus has been given not only to how to migrate but focus is specially given on how to mitigate the risk with a self-resilient and autonomous model so that it identifies and avoids all issues before migration starts [73-76]. The outcomes of the proposed approach have led to the establishment of several experimental setups and validations of results. It has been observed on multiple occasions that the overall VCS migration remains incomplete due to incorrect mappings, with no automated method available for counting mappings, necessitating a manual approach instead [85-88]. Hence proposed model especially focuses on providing a report on total SVN users mapped with Git Authors.

6.3 Challenges of the post-VCS migration model

After successfully migrating from Subversion to Git, several critical post-migration

considerations must be addressed to ensure smooth adoption, minimize disruptions, and optimize the newly implemented system. The key considerations include ensuring workflow consistency, team adoption, repository maintenance, and integrating new practices. These factors ensure that the new version control system effectively supports the development process, and teams can take full advantage of Git's features while minimizing any issues from the transition.

Adoption and training for Git Workflows:

After migration, one of the most crucial post-VCS migration steps is ensuring that the development team fully adopts Git and its workflows. SVN and Git operate differently, especially in areas like branching, merging, and committing, which require teams to shift from a centralized to a distributed version control mindset. SVN users are accustomed to working with a central repository and a linear version history, whereas Git uses local repositories and encourages frequent branching and merging. This shift can initially cause confusion and errors in workflows, such as improper use of git pull, merge, and rebase commands, leading to issues like merge conflicts or even loss of work. Organize training sessions for team members to familiarize them with Git's features, best practices, and workflows. Focus on Git-specific tasks such as:

- Branching strategies (e.g., feature branches, git flow)
- Merge conflicts and rebasing techniques
- Efficient commit management and proper use of pull requests

Offering practical, hands-on learning through paired programming or internal workshops can help team members quickly get up to speed.

Verifying the integrity of the migrated data:

Post-migration, verifying the accuracy and integrity of the migrated data is vital to ensure that no critical information is lost or corrupted during the transition. Even if the migration tools (like git-svn) are used, issues may still arise, such as missing

commits, incorrect branch structures, or improper tag mapping. Conduct a thorough comparison of the SVN and Git repositories to ensure that:

- All branches, tags, and commits were successfully transferred.
- Historical commit messages and author details are intact.
- Branch history and merges are properly represented in the Git repository.

Running automated checks and manual spot-checking of key historical points can help confirm that the migration was successful. If issues are discovered, additional adjustments may be needed.

Optimizing repository structure for Git:

Git offers more flexibility than SVN, allowing repositories to be structured in a way that best suits the team's needs. Post-migration, optimizing repository layout, file management, and branch structures are essential for improving workflow efficiency and ensuring scalability. The repository structure that worked well in SVN may not be ideal for Git. For instance, large repositories or large binary files may impact Git's performance due to its distributed nature. Large files can make clones or pulls slower, and many branches can lead to bloat in the repository. Review and adjust the repository structure to suit Git's distributed nature. Following need to be considered:

- Splitting large repositories into smaller, more manageable submodules or separate repositories, particularly for unrelated components.
- Using Git LFS (Large File Storage) to handle large binary files and keep the repository size manageable.
- Regularly cleaning up unused branches, tags, and old history to maintain performance.

This restructuring can make the repository more scalable and ensure smoother day-to-day operations for developers.

Ensuring smooth integration with CI/CD pipelines:

Migrating to Git often involves changes to the continuous integration/continuous deployment (CI/CD) pipeline that was previously integrated with SVN. Post-migration, it's crucial to ensure that Git works seamlessly with your build, test, and deployment systems. SVN and Git handle operations like commits, updates, and checkouts differently. CI/CD tools configured for SVN need to be adapted for Git repositories. Issues like broken pipelines or misconfigured Git hooks could arise. Update the configuration of CI/CD tools, such as Jenkins, CircleCI, or GitLab CI, to integrate with Git repositories instead of SVN. This includes:

- Updating webhooks or triggers to work with Git's push events.
- Ensuring the build system works with Git branches and tags.
- Verifying the pipeline's ability to handle Git features such as pull requests, rebase, and merge events.

Conducting test runs after integration will ensure that the entire development process, from code commit to deployment, works seamlessly with Git.

Adjusting to Git's distributed model:

One of the significant differences between SVN and Git is the transition from a centralized model (SVN) to a distributed model (Git). In SVN, the repository is centralized, and developers work with a local working copy of the files, which they commit to the central repository. In contrast, Git allows each developer to maintain a full copy of the repository locally, which they can commit to and later synchronize with remote repositories. Git's distributed nature provides developers with the ability to work offline and commit locally before syncing with others. However, this can lead to challenges such as issues with local repositories diverging or duplicate commits when multiple developers push conflicting changes. After migration, establish best practices around syncing local repositories with the main remote repository regularly and resolving conflicts early. Teams need to be trained for:

- Fetch and merge changes from the remote repository before committing.
- Use pull requests to review changes and resolve conflicts before pushing.
- Regularly sync branches to avoid long-lived divergences and potential conflicts.

By instilling these habits, the team will maintain a consistent and smooth workflow.

Revisiting access control and permissions:

In SVN, access control is typically managed at the repository level, with specific permissions assigned to users for read/write access. In Git, permissions are often managed at the remote hosting level (e.g., GitHub, GitLab, or Bitbucket), and access can be more granular at the level of branches or repositories. Post-migration, the team may face issues with ensuring proper permissions for different users or groups, especially if different teams have different levels of access in the SVN repository. Review and configure repository access controls on the Git hosting platform:

- Set up branch protection rules to control who can push, merge, or delete branches.
- Implement access levels for different repositories or parts of a project.
- Ensure that sensitive data or proprietary code is restricted to authorized users only.

This will prevent unauthorized access or accidental changes to critical parts of the project.

Monitoring and maintaining the new Git workflow:

Post-migration, monitoring the usage and performance of Git is essential to identify any issues early and optimize the workflow. Git's flexibility offers many benefits, but it also introduces new complexities that need to be managed actively. The transition may introduce inefficiencies or errors in how the team uses Git,

particularly with its branching model, commit structure, and collaboration features like pull requests. Implement tools and processes to monitor Git repository health and usage:

- Set up Git hooks to enforce best practices like commit message formats, branch naming conventions, and code quality checks.
- Use repository analytics and monitoring tools to track performance, activity, and growth (e.g., GitHub Insights, GitLab Analytics).
- Continuously collect feedback from the development team to address issues as they arise and refine Git workflows.

This ongoing evaluation helps ensure that the team is using Git efficiently and that potential issues are addressed before they become significant problems.

Documenting new processes and best practices:

After migrating to Git, documenting the new workflows, guidelines, and best practices is essential for maintaining consistency across the team. This includes detailing the processes for common Git tasks, troubleshooting, and resolving issues. Without clear documentation, teams may revert to old SVN habits or make mistakes when using Git, leading to inefficiencies or confusion. Create comprehensive Git documentation that includes:

- Branching strategies (e.g., Git flow or trunk-based development)
- Commit message conventions
- Merge conflict resolution strategies
- Git-specific troubleshooting (e.g., how to undo changes, reset branches)

Make this documentation easily accessible and ensure it is regularly updated as the team refines its use of Git.

6.4 Identification of key features of traditional migration model during post-VCS migration phase

Key considerations during post-migration are as follows:

- Authors Checking
- SVN Decommissioned
- Revision Histories
- Branches and Repositories
- Meta Data at project level

Table 6.1 shows a holistic comparison between the traditional migration tools and their features.

Table 6.1: A holistic comparison between the traditional migration tools and their features

Features	SVN2Git	SVN Mirror	SUBGIT
Post Migration Report Generation	Absent	Absent	Absent

6.5 Data collection for appropriate parameters selections during post-VCS migration phase

A vast amount of data was collected for post migration including a total of 10 real-time projects. Data would be collected for the total number of users, their individual emails, usernames, and the overall number of repositories and tags to serve as a benchmark, as the performance and accuracy of this migration directly hinge on the selection of parameters. The choice of these parameters impacts the accuracy of categorization. To determine the optimal SVN and Git parameters, various factors are typically assessed, and the most effective configuration is selected.

6.6 Methodology and environment preparation for post-VCS migration model

As proposed that total of 10 real-time projects have been identified to implement

the proposed model. Figure 6.1 illustrates such kind of workflow and what factors to keep in considerations. Several Python scripts have been developed and implemented as a Git extension, enabling the inspection of a Subversion repository and facilitating the migration to a local Git repository. These scripts also allow for pushing changes from the local Git repository back to the Subversion repository. These steps provide a detailed overview of the process for transitioning from SVN to Git in various environments while synchronizing back to the original SVN repository.

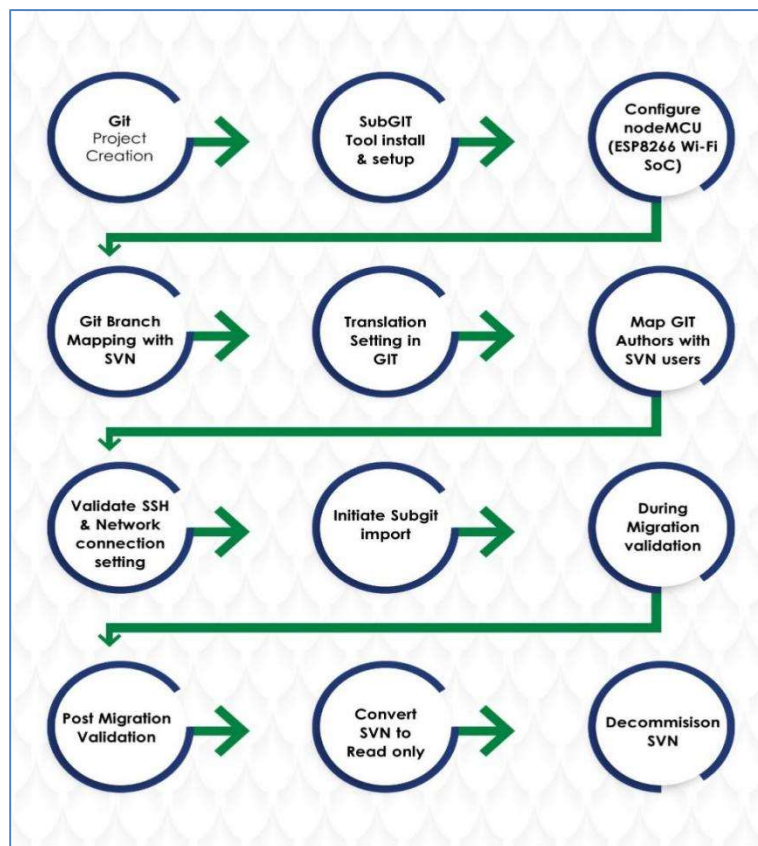


Figure 6.1: A holistic workflow and preparation of VCS migration

Figure 6.2 shows a holistic view of all the major steps considered in pre, during, and post-migration. Node MCU device was configured and set up to support the post-validation effort. Migrations from SVN to Git can differ significantly in

complexity, influenced by the structure of the repository and the number of branches that have been created and merged. Furthermore, whether one is using traditional SVN or a related variant like SVK can also impact the intricacies of the migration process.

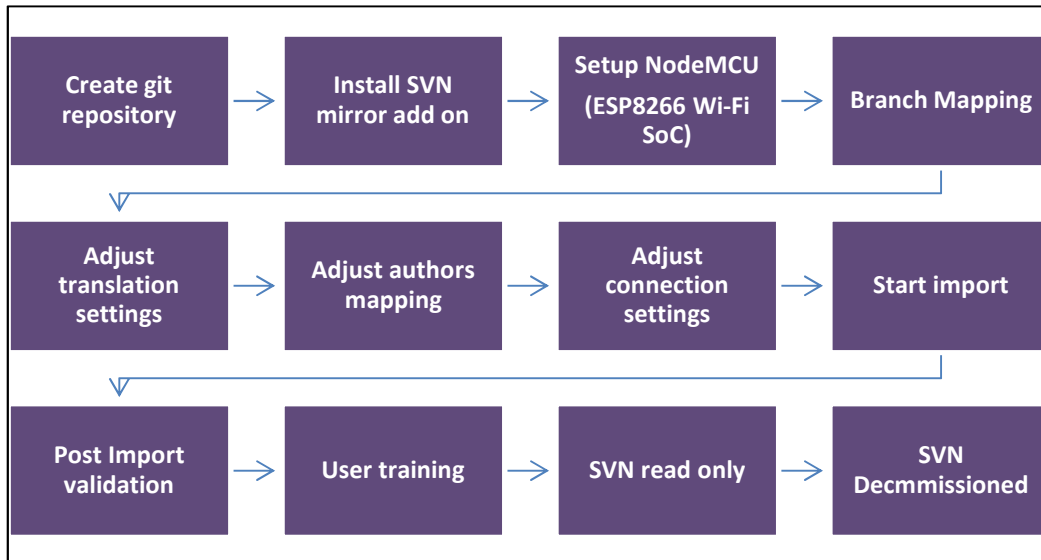


Figure 6.2: A holistic visual representation of the SVN to Git migration flow

A Python script in Figure 6.3 was written to check the author mapping and validate the author's mapping.

```

#This script would do following
#   Get project name as an argument and navigate to respective SVN and GIT locations
#   Get list of authors.
#   Compare list of authors and send an email.

#!/bin/bash

svn_repo_url = "/Users/shashibisht/svn_tutorial/$1"
git_repo_url = "/Users/shashibisht/git_tutorial/$1"
echo "Removing files from previous runs." > logfile
if [ -f SvnAuthors ]
then rm SvnAuthors
fi

if [ -f GitAuthors ]
then rm GitAuthors
fi

cd svn_repo_url
svn log --quiet | grep "^r" | awk '{print $3}' | sort | uniq > SvnAuthors
echo "Added list of SVN authors to SvnAuthors file" > logfile
cd git_repo_url
git log --all --format='%aN' | sort -u > GitAuthors
echo "Added list of GIT authors to GitAuthors file" > logfile
diff -q SvnAuthors GitAuthors >/dev/null
comp_value=$?

if [ $comp_value -eq 1 ]
then
echo "SVN and GIT Authors list do not match" > logfile
mailx -s "SVN Author list not same as GIT Author list" abc@gmail.com
else
echo "SVN and GIT Authors list match!!!" > logfile
mailx -s "SVN Author list is same as GIT Author list!!!" abc@gmail.com
fi

```

Figure 6.3: A Python script for checking the author's mappings for SVN & Git systems

A script was written to compare the Git users with SVN users. This script saves the information of Git authors in a log file which can be later used to identified and compared with total no of SVN users. It is shown in Figure 6.4.

```

1. Begin
2.   Define svn_repo_url
3.   Define git_repo_url
4.   Set svn_repo_url
5.   Set git_repo_url
6.   If svnAuthors File is present
7.     Delete svnAuthors File
8.   End the construct
9.   If GitAuthors File is present
10.    Delete GitAuthors File
11.  End the construct
12.  Print: Removing files previous runs
13.  Change Directory svn_repo_url
14.  Find the unique Svn Authors
15.  Print: Added list of svn authors to svnAuthors file >logfile
16.  Change Directory git_repo_url
17.  Find the unique Git Authors
18.  Print Added list of GIT authors to GitAuthors file
19.  If SVNAuthors Not Equal GitAuthors)
20.    Print SVN and GIT Authors lists do not match
21.    Email “ Users Don’t Match”
22.  Else
23.    Print SVN and GIT Authors list match
24.    Email “ Users Match”
25.  End the construct
26. End

```

Figure 6.4: Algorithm for mapping the Git users with SVN users during post migration phase

6.7 Results and discussion during post-VCS migration phase

Figure 6.5 shows the running logs of post migration Task. Table 6.2 shows the total number of SVN users before migration and total Git authors as a result of post migration.

```

> subgit.bat configure --layout auto --trunk trunk http://example.com/svn/repository/project C:\repo.git

SubGit version 3.2.4 ('Bobique') build #3670

Configuring writable Git mirror of remote Subversion repository:
  Subversion repository URL : http://example.com/svn/repository/project
  Git repository location   : C:\repo.git

Detecting peg location...
Authentication realm: <http://example.com:80> Subversion Repository
Username [user]: user
Password for 'user':
Peg location detected: r10248 project/trunk
Fetching SVN history... Done.
Growing trees... Done.
Project origin detected: r1 project/trunk
Building branches layouts... Done.
Combing beards... Done.
Generating SVN to Git mapping... Done.

CONFIGURATION SUCCESSFUL

To complete SubGit installation do the following:

1) Adjust Subversion to Git branches mapping if necessary:
   C:\repo.git\subgit\config
2) Define at least one Subversion credentials in default SubGit passwd file at:
   C:\repo.git\subgit\passwd
   OR configure SSH or SSL credentials in the [auth] section of:
   C:\repo.git\subgit\config
3) Optionally, add custom authors mapping to the authors.txt file(s) at:
   C:\repo.git\subgit\authors.txt
4) Run SubGit 'install' command:
   subgit install "C:\repo.git"

```

Figure 6.5: Outcomes of configuring and deploying the SVN Mirror (SubGit) Model

Table 6.2: Total number of SVN users before migration and total Git authors as a result of post migration

Projects	Total No of SVN users (Before Migration)	Total No of Git Authors (After Migration)	Success Ratio	Total No of SVN users (Before Migration)	Total No of Git Authors (After Migration)	Success Ratio
10	100	30	30% (Because only 3 Projects were successful)	100	100	100%

Figure 6.6 shows the total number of SVN users before migration and total Git authors during post VCS migration phase. It has been observed that out of 100 users for a total of 10 projects were targeted to migrate with the help of traditional migration tools like SVN2Git but only 30 users could be migrated due to inconsistency of project structure and tools themselves were not capable enough with auto resilient feature but the proposed advanced migration model successfully

migrated all 100 users from a legacy VCS to an advanced distributed VCS with their revision histories.

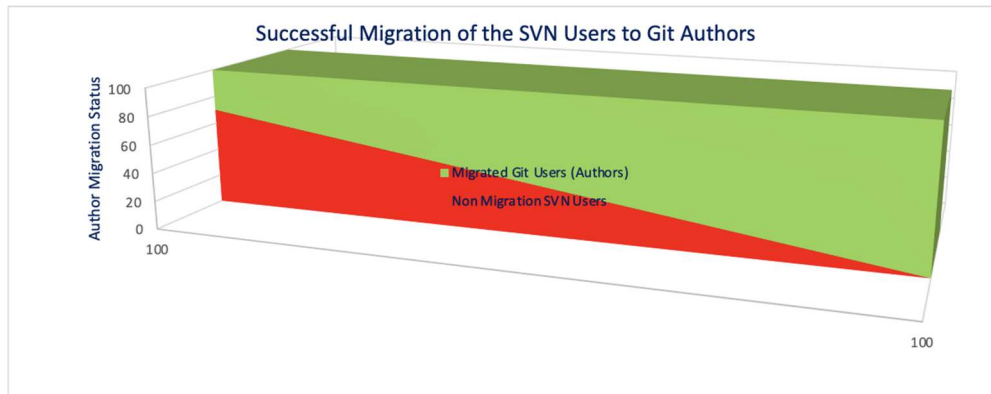


Figure 6.6: Total number of SVN users before migration and total Git authors: post VCS migration phase

Ten real-time software projects have been taken for analysis for legacy VCS to advanced VCS migration. Figure 6.7 shows the time consumed before and after missing project structure validation. The blue colored bar shows the migration time of ten projects totaling 228 hours without applying the proposed approach. This longer migration time is due to Git space issues, SSH connectivity issues, missing project structure, or other reasons. The green colored bar shows the migration time of ten projects totaling 36 hours by applying the proposed approach. The proposed approach covers the issues related to Git space issues, SSH connectivity issues, missing project structure, or other reasons. The results indicate that with the proposed approach, the migration from SVN to Git took approximately six times longer, based on a sample of ten projects. Table 6.3 shows the final report generation by post-VCS migration model.

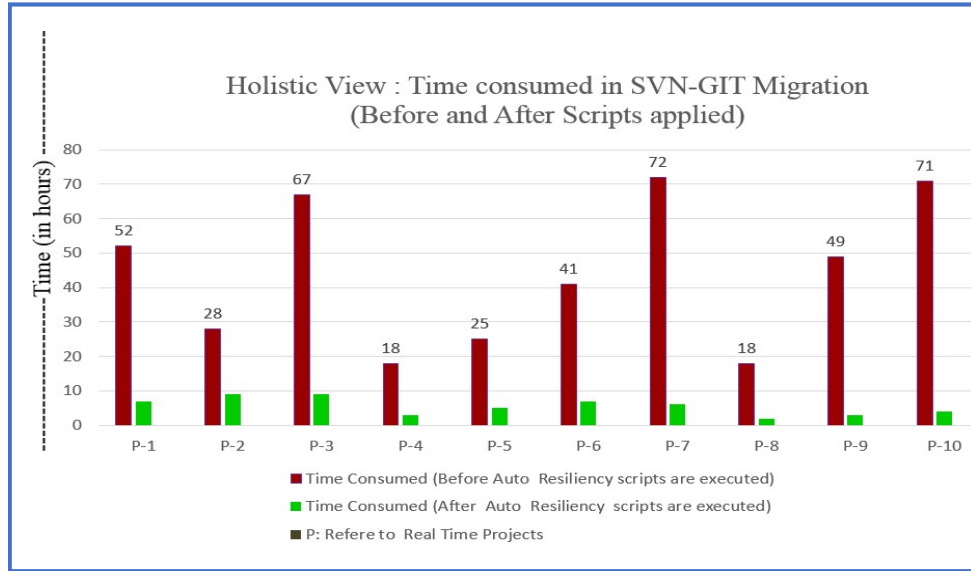


Figure 6.7: A comparative analysis of time spent on projects with traditional migration tools and the proposed migration model

Table 6.3: Final report generation by post-VCS migration model

Project Counts	Total No of Failure Migration	Total No of Successful Migration	Reason of Failure	Success ratio	Total No of Projects	Total No of Failure Migration	Total No of Successful Migration	Success Ratio
10	7	3	Incompatible Project Structure & Improper Author Mapping	30%	10	0	10	100%

These ten real time software projects have been taken for analysis for legacy VCS to advanced VCS migration. The figure 6.8 above shows the time consumed before and after missing project structure validation. The blue colored bar shows the migration time of ten projects totaling 228 hours without applying the proposed approach. This longer migration time is due to Git space issues, SSH connectivity issues, missing project structure, or other reasons. Figure 6.9 shows a final detailed VCS migration report during post migration phase and Figure 6.10 shows a Python script for final detailed VCS migration report during post migration phase.

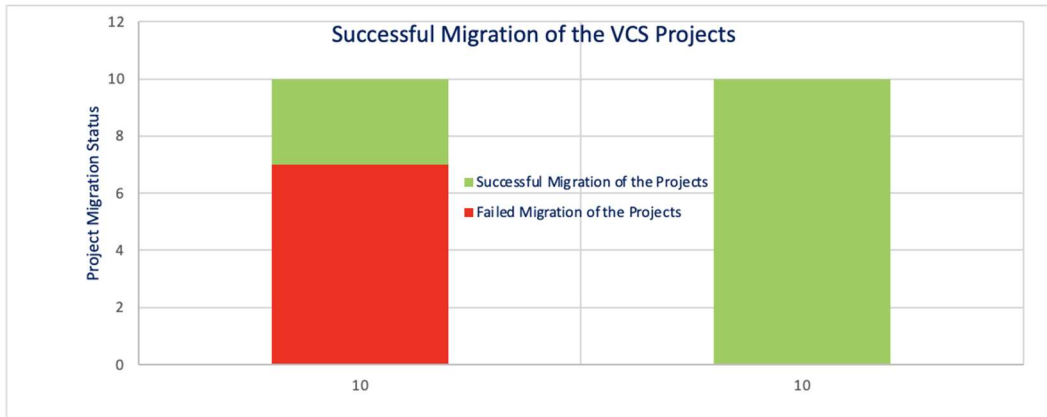


Figure 6.8: Total number of projects with proposed migration model (failure VCS projects versus successful VCS projects)

Project Report before Version Control Migration		Project Report after Version Control Migration		Success Ratio
Total No. of Version Control Projects	10		10	100%
Total No. of Repositories	10		10	100%
Total No of users(Authors)	100		100	100%
Total No of code commits by each author	3500		3500	100%
Total no of branches in each repository	6		6	100%
Total no of folders in all branches	450		450	100%
Total No. of folders with git place holder	60		60	100%
Total No of tags in all repositories	80		80	100%

Figure 6.9: A final detailed VCS migration report: post migration phase

```

vsinghxz@PTS-LDR-SINGV9 MINGW64 /c/svn_git_repoistories
$ ./git_svn.sh
***** Comprehensive Report of on SVN to Git Migration*****
*****Authors*****
Total Authors in Git= 54
Total Authors in SVN= 10
All Authors name in Git=
Author: Chinmaya Sahoo <chinmaya.sahoo@walgreens.com>
Author: salia4f <syedazam.ali@walgreens.com>
Author: Vinay Singh <vinay.x.singh@walgreens.com>
All Authors name in SVN=
VisualSVN Server
Created folder 'develop'.
Created folder 'master'.
Deleted folder '/branches/master'.
Initial structure.
*****First and Last commits in Develop Branch*****
First commit in Git=
commit e2d93442905afala808a8728ad99872cc1675293
First commit date in Git=
Date: Mon Apr 22 20:03:33 2019 +0000
Last commit in Git=
e2d93442905afala808a8728ad99872cc1675293 Initial Commit
Last commit date in Git=
Date: Sat May 25 12:53:13 2019 -0500
First commit in SVN=
r1 | VisualSVN Server | 2019-06-22 23:03:20 -0500 (Sat, 22 Jun 2019) | 1 line
First commit date in SVN=
2019-06-22 23:03:20 -0500 (Sat, 22 Jun 2019)
Last commit in SVN=
-----
r5 | VisualSVN Server | 2019-06-22 23:06:41 -0500 (Sat, 22 Jun 2019) | 1 line
Changed paths:
A /branches/master
Created folder 'master'.
-----
r6 | vsinghxz | 2019-06-22 23:07:54 -0500 (Sat, 22 Jun 2019) | 1 line
Changed paths:
A /branches/develop/.classpath
A /branches/develop/.project
A /branches/develop/.settings
A /branches/develop/.settings/org.eclipse.core.resources.prefs
A /branches/develop/.settings/org.eclipse.jdt.core.prefs
A /branches/develop/.settings/org.eclipse.m2e.core.prefs
A /branches/develop/.settings/org.eclipse.wst.common.project.facet.core.xml
A /branches/develop/.springBeans
A /branches/develop/README.md
A /branches/develop/pom.xml
A /branches/develop/src
A /branches/develop/src/main
A /branches/develop/src/main/java
A /branches/develop/src/main/java/poc

```

Figure 6.10: A Python script for final detailed VCS migration report: post migration phase

6.8 Conclusion

Figure 6.9 depicts the detailed VCS migration report for the post migration phase and Figure 6.10 depicts about a python script developed and leveraged for generating those data reports. The traditional migration model could only migrate 3 projects and rest 7 were unsuccessful out of 10 real time projects. This happened because of the incompatible project structure of microservices and due to that, only those VCS users who were part of the successfully migrated projects and repositories could be properly mapped by traditional migration tools which resulted in only a 30% success ratio. But the proposed model has successfully migrated all 10 real-time projects which resulted in 100% migration of all authors belong 10 projects. The normal migration approach for Subversion to Git seems to make use of traditional tools. These tools, however, appear to be more of a live synchronization tool so that developers can use both Git and Subversion at the same

time. For this reason and others, it cannot be considered an ideal situation for a one-off migration. However the proposed model smoothly migrated all 10 projects by auto correcting the project structure and generating the alert notification on it. The whole migration was done smoothly without any single failure or hard halt.

CHAPTER 7

CI/CD AND DEVOPS EXCELLENCE PHASE

Following the proposal of the pre, during, and post migration models, we aimed to extend our research by enhancing the CI/CD pipelines to accelerate the VCS migration process while optimizing the "time-to-market" factor. To achieve this, we introduced a CI/CD DevOps Model for VCS migration as an extension of our research, which facilitated faster, more efficient migration with minimal errors, significantly improving the overall migration performance.

7.1 Proposed VCS migration model for migration from a centralized VCS to a distributed VCS: CI/CD and DevOps excellence phase

A very minimal volume of published research work was found concerning migration from monolithic based systems to microservices based systems concerning time, space, decomposition, testing, security, performance, inter service communication, and persistence aspects. Though there is some published research work on migration [11], work which uses microservices based migration approach [16]. Authors in [21] discusses the concept of architectural decomposing and subsequently compares 10 various refactoring methodologies recently proposed in the academic literature.

The methods and techniques are organized and implanted using a core decomposition process. The review details various strategies for dismantling a large application into distinct, manageable components. Many of these approaches are suited only for specific scenarios. In [2], the authors examine practical research.

Prominently, the various design patterns and research on various practices always focus on targeting practitioners involved in the process of migrating their applications and they shed light on (i) the diverse migration activities carried out

and (ii) the real challenges faced during the transition. In [37], they tackle the hurdles and strategies involved in shifting legacy systems from a monolithic setup to a cloud-based architecture. Various migration tactics are scrutinized, weighing their pros and cons. In [38], the authors unveil a set of transfer and rearchitecting design patterns they have gleaned from large-scale software migration projects.

Key features of the traditional migration model for CI/CD and DevOps excellence phase are as follows:

- Cloud and version control agnosticism
- Pipeline creation with standardized definitions
- Reusable pipelines for microservices
- Improve build and deployment in a containerized environment

7.2 Data collection for CI/CD and DevOps excellence phase

Table 7.1 shows the different software required to setup CI/CD pipelines for better DevOps.

Table 7.1: Different software required to setup CI/CD pipelines for better DevOps

Software Installation	Version
JDK Version	1.8 or higher
Git Version	2.34.1
Jenkins Version	2.303.1
Release Tag Version	17.05
Docker Version (https://www.docker.com/)	20.05.0
Maven Version	3.6.1

7.3 Environment preparation for CI /CD and DevOps excellence phase

JDK was installed in a Docker container. After JDK installation, Docker registry was setup properly. A Jenkins server was spun up with the JDK 1.8 version installed on it. After that Git hooks were initiated to call Jenkins pipelines. All standards

DevOps CICD stages were also created as part of Jenkins Script [82-85]. To make a well-informed judgment, it is important that the findings are based on the reasoning derived from the Docker spreadsheet, which is a widely used open-source tool - a completely clean Java application designed for load testing and performance measurement. Initially intended for testing web applications, it has since broadened its scope to include various testing functions. Furthermore, the reasoning is backed by advanced insights from the new Relic platform, which helps capture and validate the potential results.

7.4 Results and Discussion

Various obtained results during CI/CD and DecOps excellence phase are discussed below.

7.4.1 Code Build and Deployment Time: Monolith versus Microservice Systems

Speed and agility are crucial elements in any version control system. It is clear that coding locally often outpaces sharing resources on a public server. The considerable size and numerous dependencies of monolithic architectures complicate and prolong build and deployment processes. In contrast, microservices are designed to be lighter on resources and built for scalability. With modules decoupled, the building and deployment processes become more manageable. Each commit to a microservice should result in a tested build, and once the tests pass and the build system is satisfied, the next step is either a manual or automated deployment to production. Optimizing the deployment process paves the way for quicker iterations and fosters a variety of effective coding practices.

With the above graph depicted in Figure 7.1, it is observed that it took almost 300 seconds to build 10 monolith applications and almost 800 seconds to build 30 monolith applications contrast to 2 seconds and 5 seconds respectively for a microservices, which depicts a huge amount of time difference and clearly proves that a microservice based system takes a very less amount of time to be built by

Jenkins and maven and finally deployed on Docker container hence increased system performance.

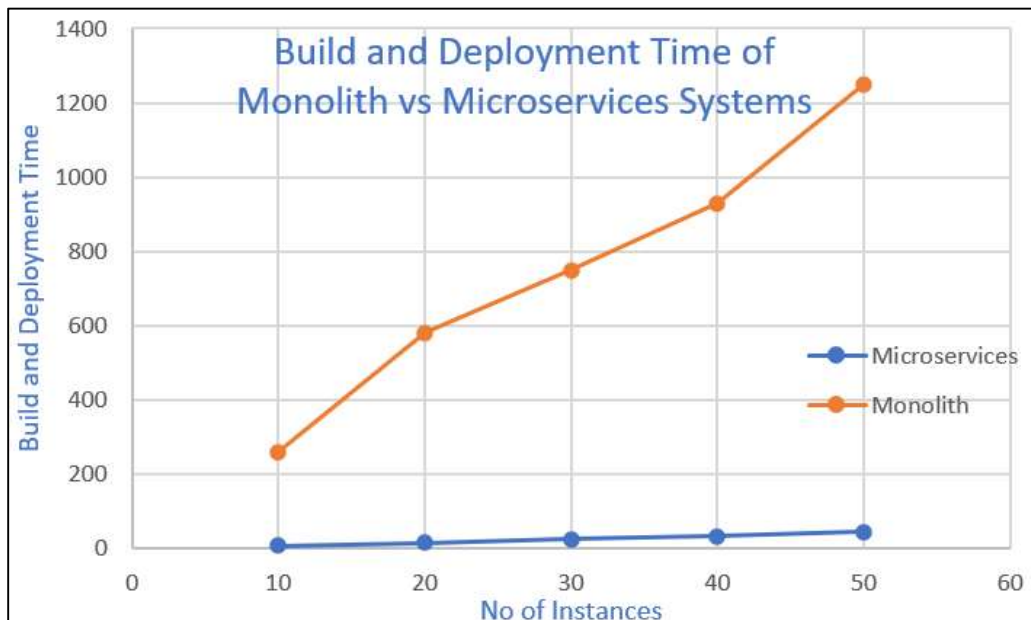


Figure 7.1: A comparative analysis: Build and Deployment time of microservices versus monolith application systems

7.4.2 Latency analysis: Monolith versus Microservice systems

The digital transformation or modernization of legacy applications from a monolith architecture to a microservice architecture is getting increasingly popular in recent times. However, to gauge the real benefits of this migration needs to be evaluated on certain parameters like performance which is shown in Figure 7.2. The objective of this evaluation is to benchmark one of the critical factors latency of the services in two target environments.

The accomplishment of the request is contingent upon several detracting tasks, containing the judgment of test of system functions results, pursuing the number of create requests, and timing the event necessary to deal with the ruling class. When these tasks are favorably achieved, a response from the attendant is incited. In Case 1, a total of 2,500 requests per second were efficiently treated by two together setups. In Case 2, 4,000 requests per second were created by JMeter, with all

requests being controlled seamlessly for one microservices construction, while 300 requests were not treated as apiece monolithic request.

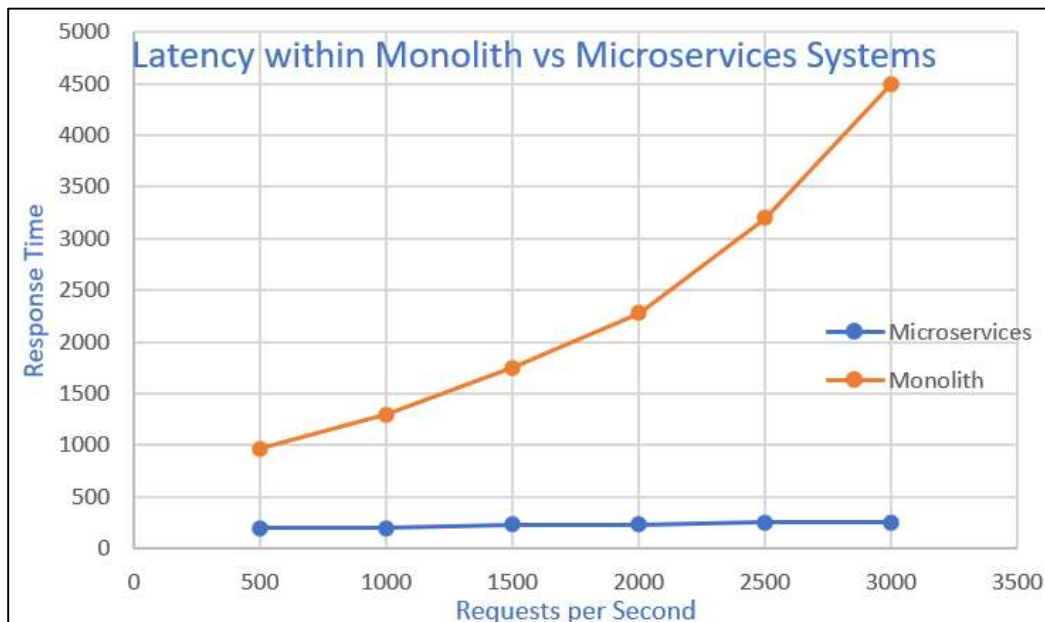


Figure 7.2: Performance metrics: A latency graph between microservices and monolith application systems

The killing occasions of the tests are emphasized, an appearance that delays were known by the massive structure, that accepted 00:01:50, while the microservices construction achieved its tasks outside wrongs in just 00:01:29, happening in a benefit of 00:00:21. Furthermore, a bettering in processing speed was noticed accompanying the microservices request. In Case 1, 2.5 seconds were captured for one massive setup distinguished to 3.1 seconds for the microservices (a dissimilarity of 0.6 seconds), while for fear that 2, 1.2 seconds were written apiece massive system and 1.4 seconds apiece microservices, flexible a 0.2-second benefit for the massive use system.

7.4.3 Scalability analysis: Monolith versus Microservice systems

It is imperative to design the monolith carefully as it gets more complicated over time as business demands increase and it needs new modules to be added. But

strategies for a microservices-based application from an unexpected failure, make real-time application fault tolerant, and resilient and highly scalable [86-89].

Scaling a vast request is considered somewhat straightforward - what is necessary is the addition of more money as the workload progresses over occasion. To scale a severe request, load compare methods are achieved to assign extra money. A solid request is usually treated as a distinct system behind a load balancer that is to say used to direct traffic across individual or more comparable servers.

After conducting experiments on various real-time projects, it has become evident that monoliths are a tough nut to crack when it comes to scaling, as changes to individual modules necessitate a complete redeployment of the entire application. In contrast, microservices allow teams to build systems in a more scalable fashion without stepping on each other's toes or disrupting other functionalities which is shown in Figure 7.3.

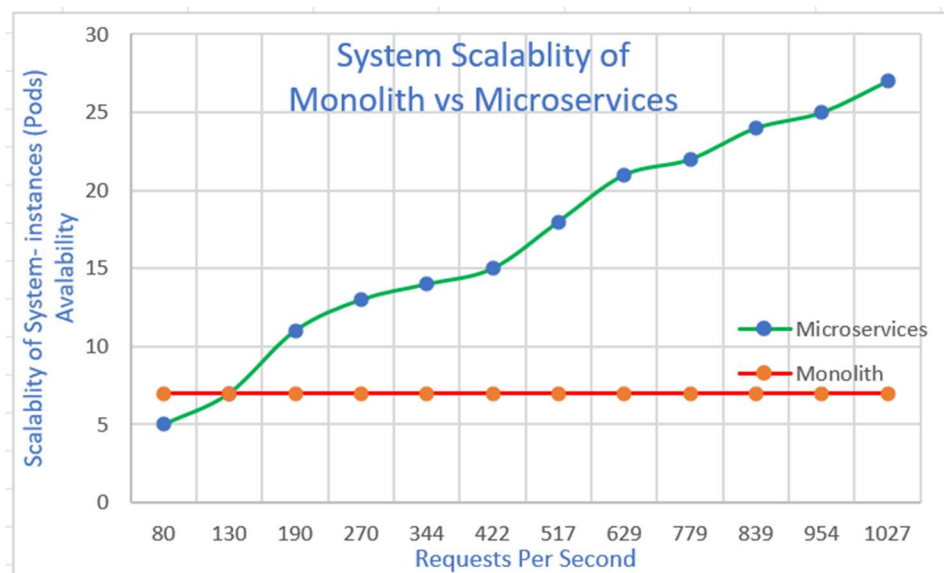


Figure 7.3: Systematic scalability of monolith versus microservice systems

7.4.4 Fault tolerance analysis: Monolith versus Microservice Systems

The biggest advantage of monolithic architecture is inherent fault tolerance. In fault tolerance, if any portion or subsystem does not work or fails in a monolith system,

then the entire system may drastically go down. Microservices are more fault-tolerant than monoliths because a single instance or a service can continue working even if another service or instance fails [90-95].

A monolithic system is complicated and very large in volume. A monolith system works as an entire single unit and if there is an exception or fault in any subunit then the entire application will stop working because the application is always deployed as a single unit. Usually, monolith systems are very large in volume, and sometimes they are deployed as 1-5 terabytes as a whole. Sometimes monolith becomes so large and big, it becomes complex and difficult to maintain in the monolithic architecture, as a single change can make us test the complete application and it is always time-consuming.

With the above experiment, it has been proven that monolith systems are not fault-tolerant and they fail if any single exception occurs in the system. Whereas microservices are fault tolerant and if any exception happens or any sub system fails then still rest part of the microservices system continues to respond. Monolithic architectures are not agile in nature, because a minor change in any feature development entails a complete, complex, and time-consuming deployment. It is depicted in Figure 7.4.

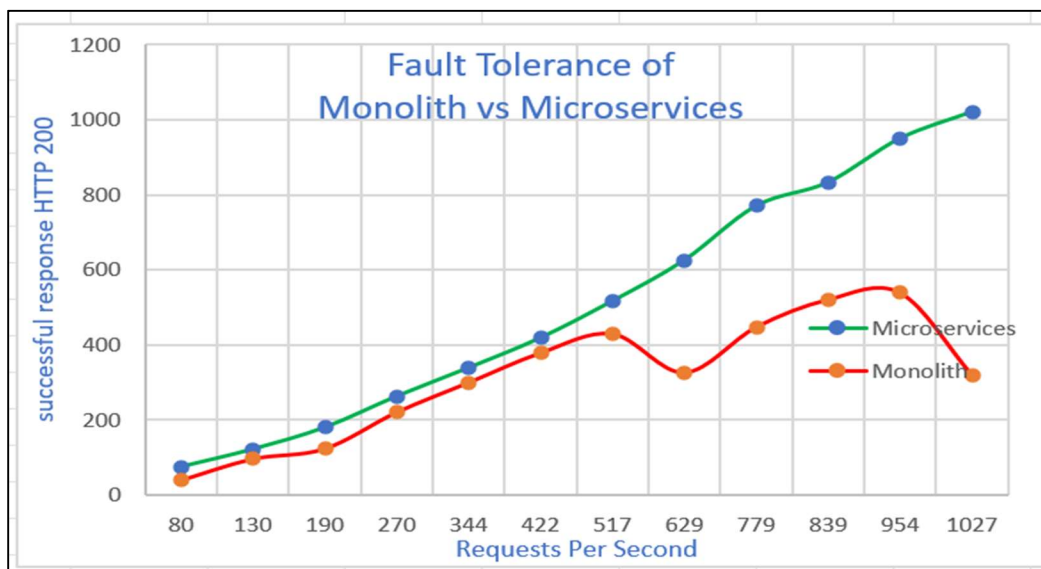


Figure 7.4: Fault tolerance of monolith versus microservice systems

7.4.5 Time-to-market analysis: Monolith versus Microservice systems.

One of the reasons industries adopt microservice architectures is time-to-market. Monolithic systems are often a tough cookie to deploy due to their hefty size and a tangled web of dependencies. They take time to be built and delivered to end customers and hence do not meet the criteria for “time-to-market”. It is depicted in Figure 7.5.

It has shown in the Figure 7.6 that microservices can start action when they meet expectations for deployment and period to retail. In contrast, monolithic plans are an evident headache, as their complicatedness makes them inflexible - some wanted changes can require a complete redo. Microservices stress designing subsystems and their mixed narrow atheneums without seizing became stuck in implementation analyses. This approach allows any Devops and production engineer to adjust the behavior of subsystems and their implementations outside bearing to overhaul the whole design or related services. Furthermore, microservices are easier to deploy and ready to be tested in a real-time production environment. With fewer dependencies, tests can be composed and executed in a flash. Additionally, microservices are seen as less resource-hungry and are designed for scalability, paving the way for seamless rollouts. Microservices can be deployed on a subset of cluster nodes, allowing for a gradual migration of users to the new version. The fine-grained architecture of microservices sets the stage for quicker and more flexible rollouts, cutting down the time from concept to production deployment.

```

deploy:
  needs: [test]
  runs-on: ubuntu-latest

  steps:
    - name: Checkout source code
      uses: actions/checkout@v2

    - name: Generate deployment package
      run: zip -r deploy.zip . -x '*.git*'

    - name: Deploy to EB
      uses: einaregilsson/beanstalk-deploy@v20
      with:

        // Remember the secrets we embedded? this is how we access them
        aws_access_key: ${ secrets.AWS_ACCESS_KEY_ID }
        aws_secret_key: ${ secrets.AWS_SECRET_ACCESS_KEY }

        // Replace the values here with your names you submitted in one of
        // The previous sections
        application_name: django-github-actions-aws
        environment_name: django-github-actions-aws

        // The version number could be anything. You can find a dynamic way
        // Of doing this.
        version_label: 12348
        region: "us-east-2"

```

Figure 7.5: A Python script to build and deploy for microservice systems: CI/CD and DevOps excellence

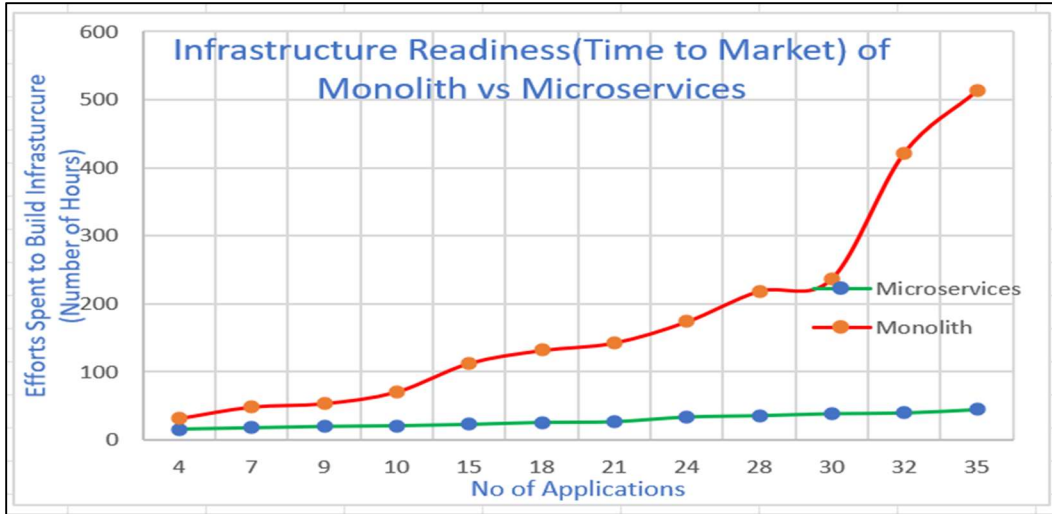


Figure 7.6: Total duration for infrastructure preparation for business production servers (time-to-market approach)

7.5 Conclusion

After the microservices had been fully migrated from a centralized legacy version control system to an advanced distributed version control system, we extended our research work by implementing and enhancing the DevOps CI/CD framework to improve DevOps CI/CD build and deployment work and find out the latency difference between microservices and monolith application. We strived to increase the instances of microservices and performed a test to see the behavior of build and deployment time as part of the CI/CD approach. We observed that microservices build time does not affect even if we increase the of microservices at build time, but the monolith application takes much higher time by consuming high DevOps resources. It proves that a microservice-based system takes a very substantial amount of time to be built by Jenkins and Maven and finally deployed on a Docker container. A comparative analysis between microservices and monolith application was performed by sending multiple requests per second with the help of JMeter. Results show that microservices have been performing and responding consistently with an increase of requests whereas monolith application throttled down on performance and started behaving badly with degraded performance as the number of requests increased. The microservice construction is not of the highest quality-

breadth-fits-all resolution; it has allure own set of challenges. Although the appeal of this approach is powerful, skilled are many issues that need to be discussed. While the potential of microservices is alluring, it is owned by requesting the right questions before attempting the significant change from a massive makeup to microservices. Employing a healthy pattern word authorizes developers to evaluate whether microservices are appropriate for the application and specifies the finishes inevitable to survive this design efficiently.

CHAPTER 8

CONCLUSION

8.1 Pre-VCS migration model

After implementing the pre-migration model and executing several scripts, we found some results that depict the statistics of the total number of projects with project structure incompatibility and auto resiliency. Results are very positive and expected. Results show that the pre-migration model was capable enough not only to identify the total number of projects with improper project structure but also, they were corrected by other scripts placed in the model to correct the project structure exactly in the same way as expected to build and deploy by CI/CD pipeline. This proves that the proposed pre-migration model is capable enough to identify the project structure, auto correct them as an auto resiliency capability feature, and validate them after correction.

8.2 During-VCS migration model

After successful Implementation of the during migration model especially keeping the capability of validating the auto remote Git server space and in case the space is consumed beyond a certain limit, it must send alert notification as a part of during VCS migration requirement process. With results, it was proven that Python scripts incorporated in the migration model were capable enough to work with Node-MCU IoT devices, which keep monitoring the server availability and space by sending continuous signals and receiving the ACK (acknowledgment). For this purpose, a total of 10 projects were identified. When migration started, the Node-MCU device started sending signals and kept monitoring the whole migration by checking the network health. We deliberately stopped the VCS migration from SVN to Git by

stopping some SSH ports which artificially caused the Migration halted. We can see that the traditional migration model did not have the capability to check the network health or send alert notifications. We could see that the proposed during migration model was self-sufficient in sending alert notifications to several stakeholders.

8.3 Post-VCS migration model

After the successful implementation of the post VCS migration model, we executed the Python Scripts on 10 real-time projects and found that the total numbers of 100 SVN users were present and found that only 30 SVN users got successfully migrated, but the traditional VCS model was incapable to identify the final count of SVN users which got converted into Git authors. But our proposed post-VCS model was capable enough not only to identify the total number of SVN users migrated from SVN to Git but also could generate a holistic report that depicts the total number of SVN projects, Git authors, total count of code commits, total number of repositories, total number of branches inside Git repositories and their proper mapping with SVN repositories.

Apart from the above four proposed migration models, we tried to improve the DevOps process by implementing the Continuous-Integration and Continuous-Delivery pipeline using Jenkins, Git, and Groovy scripts which resulted in faster code build of microservices, improvement in latency, systematic scalability, improvement in fault tolerant and reducing the time-to-market factor by delivering the faster and sustainable error-free software product to real-time production system.

Given the intricacies of VCS migration testing, it is essential to keep all migration facets front and center. A minor slip in verification and validation during the migration can lead to significant issues in production, which makes it imperative to conduct a thorough and meticulous study of the system before, during, and after the transition. We've rolled up our sleeves and crafted an innovative and effective VCS migration strategy, complete with robust scripts, NodeMCU equipped with IoT

features, and state-of-the-art software, all backed by a skilled and prepared team of testers ready to tackle any challenges that may arise.

As we know pre, during and post migration has a huge impact on the quality of the projects that we use hence a good amount of effort was taken into consideration to put up to verify the entire system in all aspects like project structure, remote VCS space, alert generation, functionality, total number of VCS authors finally migrated and CI/CD improvement to evaluate the performance, which in turn ensured a holistic successful migration. With the successful testing and results, it is observed that this proposed migration model covers all aspects of potential migration issues and bottlenecks which might occurs as part of pre-migration, during-migration and post-migration efforts for ex. project structure in compatibility, auto resiliency on project structure, checking network connectivity and send alert notification in case of network failure during migration, restoration capability from the point of failure. As a part of pre-migration, it also has been observed that traditional migration tools were not able to identify how many projects were having issues in project structure. But the proposed migration model could easily identify the issues in project structure of microservices. It has successfully corrected the project structure of microservices with success ratio of 100% project structure compatibility capability. Over time, various attempts have been made to transition monolithic legacy systems to a microservices architecture. Through often challenging experiences, many risks and obstacles have been identified. One particular effort resulted in significant costs, along with considerable time and resource consumption. However, after a successful migration, it became evident that the advantages of microservices allow projects to be delivered more efficiently and swiftly. This shift also addresses and alleviates numerous business-related concerns and future planning challenges.

Microservices provide several advantages over complex monolithic structures, including simpler builds, more straightforward deployments, shorter timelines, and improved scalability. They also require considerably less space when deployed on production servers. The streamlined configuration facilitates easier management

and helps control software ownership costs internally, rather than incurring hefty maintenance fees. Further research is needed to refine the methods particularly by exploring various domains to enhance the results.

As a part of during migration, the proposed model successfully checked the disk space and network connectivity. During migration it was observed that there were a few projects that got stuck and failed and could not be migrated successfully because of the Git server space was having a crunch of space issues and the traditional migration model could not facilitate to overcome this issue by sending the email/alert notification. But while using the proposed model where a Python script was written to identify the available space during migration helped to generate the alert if disk space was less than 80% limit. Hence proposed model successfully sent alerts notifications on disk space issues and proved the capability of sending alert notification on network failure and consistent restoration capability to restore the migration from the failure point.

As a result generated with post-migration, it has been observed that out of 100 users for a total of 10 projects were targeted to migrated with the help of traditional migration tools like SVN2Git but only 30 users could be migrated due to inconsistency of project structure and tools itself were not capable enough with auto resilient feature, but proposed advanced migration model successfully migrated all 100 users from legacy VCS to advanced distributed VCS with their revision histories. Hence the proposed model can map legacy VCS users with advanced distributed VCS with 100% author mapping efficiency. It was also proven that the total time taken for the migration of projects (total of 10) by the proposed migration model was 22% faster than projects migrated by traditional migration tools.

The proposed model is designed and implemented with several Python scripts which makes it compatible and self-sufficient to not only migrate the projects with faster speed but also to auto correct the project structure. The proposed model is capable enough to overcome a situation by identifying and sending alert notification the Git server space is going to have the crunch of space issue, but the traditional migration model could not facilitate to overcome this issue by sending the

email/alert notification. But while using the proposed model where a Python script was written to identify the available space during migration helped to generate the alert if disk space was less than 80%.

With the above results it has been proved that the proposed model can auto correct the project structure of microservices by adding a Git placeholder, but traditional migration tools are incapable enough with this Auto resilient feature. The proposed model is capable enough to map between the two different VCS systems like SVN and Git. It has all the features mentioned in the research objectives and it is auto resilient and highly capable than the traditional migration model in terms of auto resiliency, velocity, and inherent features.

With the successful several testing on the VCS migration model and real time projects, we received various results on the data provided, it is well proved that this proposed migration model covers all aspects of potential migration issues and bottlenecks that might occur as part of pre-migration, during-migration and post-migration efforts for ex. project structure in compatibility, auto resiliency on project structure, checking network connectivity and sending alert notification in case of network failure during migration, and restoration capability from the point of failure.

8.4 CI/CD and DevOps excellence

After the microservices had been fully migrated from a centralized legacy version control system to an advanced distributed version control system, we extended our research work by implementing and enhancing the DevOps CI/CD framework to improve DevOps CI/CD build and deployment work and find out the latency difference between microservices and monolith application. We strived to increase the instances of microservices and performed a test to see the behavior of build and deployment time as part of the CI/CD approach. We found that microservices build time does not affect even if we increase the of microservices at build time, but monolith application takes much higher time by consuming high DevOps resources. It proves that a microservice based system takes a very substantial

amount of time to be built by Jenkins and Maven and finally deployed on a Docker container. A comparative analysis between microservices and monolith application was performed by sending multiple requests per second with the help of JMeter. Results show that microservices have been performing and responding consistently with an increase of requests whereas monolith application throttled down on performance and started behaving badly with degraded performance as the number of requests increased.

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2. “Noise Reduction System and Method” by Alok Aggarwal, Deepak Chandra Bijalwan, Vinay Singh, Patent Application no. 202011022847, The Patent Office Journal No. 25/2020, Date of Publication: 26th June 2020, Date of Grant: 12th Sep. 2024.

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