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Aim & Scope

AIM

International Journal of Innovative Technology and Exploring Engineering (IJITEE) is having ISSN 2278-3075 (online), monthly international journal, being published in the months of January, February, March, April, May, June, July, August, September, October November, December by Blue Eyes Intelligence Engineering & Sciences Publication (BEIESP) Bhopal (M.P.), India since year 2012 and processed papers will be forwarded for inclusion in the Scopus database. It is academic, online, open access (abstract), peer reviewed international journal. The aim of the journal is to:

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- dispense a platform for publishing results and research with a strong empirical component.
- aqueduct the significant gap between research and practice by promoting the publication of original, novel, industry-relevant research.
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- create a bridge for significant gap between research and practice by promoting the publication of original, novel, industry-relevant research.
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SCOPE

International Journal of Innovative Technology and Exploring Engineering (IJITEE) covers all topics of all engineering branches. Some of them are Computer Science & Engineering, Information Technology, Electronics & Communication, Electrical and Electronics, Electronics and Telecommunication, Civil Engineering, Mechanical Engineering, Textile Engineering and all interdisciplinary streams of Engineering Sciences. The main topic includes but not limited to:

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- •Image Processing and Pattern Recognition
- •WSN
- •Artificial Intelligence and machine learning
- •Data mining and warehousing
- •Data Analytics
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Analyzing the Effect of Temperature on DO andBOD of the Tapi River using QUAL2Kw Model

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ABSTRACT

Environmental pollution and climate change is theultimate result of rapid urbanization. The change inenvironmental conditions due to undesirable human activitiesincreases local ambient temperature hence it is leading to a rise inthe river water temperature. Tapi river is the main source ofdrinking water for Surat city, Gujarat, India. A stretch of riverTapi has been studied from Kamrej to Causeway which has astretch of about 22.39 km. The river water quality was found to bedegraded due to the excessive discharge of pollutants from variouspoints and non-point sources. Extreme discharge of pollutantsinto the river decreases the dissolved oxygen (DO) concentration.At the same time due to the increase in temperature, the process oftransformation of atmospheric O2 gas into dissolved form alsobecomes very slow. In this study, the QUAL2Kw one - dimensionwater quality model was applied to assess the DO and BOD atvarious locations. The QUAL2Kw model was calibrated andvalidated with observed data. The calibrated model was applied toevaluate the effects of temperature on the DO and BOD of theTapi river. The conditions of maximum, minimum, and averagetemperature for March, April, and May from the year 1991 to2021 were considered. The result revealed that the full stretch of22.39 km was not able to maintain minimum dissolved oxygen(DO) concentration, hence biochemical oxygen demand (BOD)has subsequently increased downstream of the river stretch. It wasalso observed that DO and BOD levels tremendously fluctuateambient temperature.

Keywords: BOD, Dissolved Oxygen, QUAL2Kw, Tapi River,Water Quality

I. INTRODUCTION

The temperature of steam water is one of the mostsignificant parameters as it influences many chemical processes in the river [1]. The availability of dissolved oxygen (DO) and biological oxygen demand (BOD) in wateris influenced by temperature and pollutants present in theriver water. Due to various activities, significant pollutantsenter into rivers and streams which lower dissolved oxygenbelow a critical point which results in adversely affecting the ecosystem, odor problems, and aesthetic nuisances [2,3].

The deterioration in water quality can be assessed bymeasuring DO and BOD [4,5] Hence, BOD becomes anessential factor in determining organic substances present in a river [6,7]. The analysis of the effects of temperature on pollutants in river systems is a very challenging task [8, 9,10].

Expanding water scarcity coupled with declining quality is pressuring developing countries to explore river water quality restoration options. As an outcome, it has become essential to consider river water quality and forecast future changes in water quality [11]. Mathematical modeling is an effective tool for load estimation in aquatic environments, establishing cause-and-effect relationships between water quality and pollution sources. It also evaluates how the aquatic environment will respond to various circumstances. The simulation results are an effective management tool that canhelp decision-makers to develop realistic strategies. It considers the unique conditions of the river

and forecasts the impact of accidental discharges or additional pollutant loads[1]. The QUAL2Kw model is effectively used to simulatevarious pollutants regarding varying climatic conditions. High stream water temperatures can harm the aquatic system by restricting fish habitation and in some cases causing fish mortality. It has been reported that a higher river water temperature of 23°C to 25°C can be responsible for trout mortality [12]. The significant differences in stream water temperature increase during the summer season also affect other factors like solar radiation, low flows, depth of water, cloud cover, etc. Generally, the higher difference is observed in the summer season whereas minor differences have been noticed in the winter [12]. The main aim of this research work is to assess the effects of temperature on the concentration level of DO and BOD in the stretch of the Tapi river using the QUAL2Kw model.

II. METHODOLOGY

A. About The Qual2kew Model

The QUAL2Kw is a one-dimensional stream water quality model developed in 2006 by Pelletier and Chapra [5] which considers the river to be divided into several segments [13]. It can simulate water quality parameters like pH, temperature, electrical conductivity, DO, carbonaceous biochemical oxygen demand, inorganic suspended solids, organic Nitrogen, NH4-N, NO3-N, organic and inorganic phosphorus, alkalinity, phytoplankton, and bottom algae [14]. It facilitates an automatic genetic algorithm for the calibration process. The QUAL2Kw considers the various climatic conditions as it can influence the heat balance which influences the water quality conditions.

The following equation (1) shows heat equilibrium in elements [15,16].

$$\frac{dT_i}{dt} = \frac{Q_{i-1}}{Vi}T_{i-1} - \frac{Qi}{Vi}Ti - \frac{Q_{ab,i}}{Vi}Ti + \frac{E'_{i-1}}{Vi}(T_{i-1} - Ti) + \frac{E'_i}{V_i}(T_{i+1} - T_i) + \frac{W_{h,i}}{\rho_\omega C_{p\omega V_i}} \left(\frac{m^3}{10^6\ cm^3}\right) + \frac{J_{h,i}}{\rho_\omega C_{p\omega H_i}}\left(\frac{m}{100cm}\right) + \frac{J_{s,i}}{\rho_\omega C_{p\omega H_i}}\left(\frac{m}{100cm}\right) \quad (1)$$

where Ti = temperature in reach I (oC)
t = time in days
E´i = the bulk dispersion coefficient between reaches I and i + 1 (m3/d)
Wh, i = the net heat load into reach from point and non-point sources I (cal/d)
ρω water density (g/cm3)
Cpw = the specific heat of water [cal/(g oC)]
Jh,i = the heat flux in air-water [cal/(cm2 d)]
Js ,i = the heat flux in sediment-water [cal/(cm2 d)] [15].

B. Study Area

The present work was undertaken for Surat city which is one of the fastest-growing smart cities in Gujarat, India. The study area includes the 22.39 km long stretch of the Tapiriver, flowing between Kamrej to Causeway. This segment of the river is the most affected as it receives waste discharge from various point sources and non-point sources. The activities that influence the quality of river Tapi are mainlyagricultural runoff, washing clothes, religious activities waste discharge, cattle farming, open defecation, cremation, etc. The discharge of untreated/partially treated wastewater from Kathor, Valak, Varacha, Kholwad, Abrama, Uttaran, and Aswini Kumar villages is mainly contributing to the deterioration of river water quality.

C. Model Input, Calibration, and Validation

Considering the cross-section of the study area, the entire 22.39-kilometer stretch of the Tapi River from Kamrej to the causeway was divided into 21 unequal sub-reaches. Manning's equation was used to create the river's hydraulic model [17]. The average monthly water flow, temperature, pH, BOD, organic-N, ammonium (Nh4), and inorganic suspended solids (ISS) have been considered in the model. The model was calibrated and validated with available data. Multiple trial-and-error approaches were used with various rate coefficient combinations. The model performance was evaluated in terms of Root Mean Square Error (RMSE) and Mean Absolute Error (MAE).

D. Scenario Evaluation

The calibrated model was used to analyze the effect of temperature on DO and BOD. As the water quality is maximum affected in the summer seasons the study has been carried out for March, April, and May. The average value of maximum, minimum, and average temperature of summer from 1991 to 2021 was used to assess the effects of temperature on DO and BOD which is shown in Table 1.

Table 1. Maximum, Minimum, and Average Temperature Data

Seasons	Month	Maximum Temp. (°C)	Minimum Temp. (°C)	Average Temp. (°C)
Summer	March	33	21.6	27.3
	April	34.9	24.9	29.6
	May	34.2	27.2	30.2

III. RESULT AND DISCUSSION

A. Model Calibration and Validation

Figure 1 depicts the calibration results, while Figure 2 depicts the modeling validation results of DO and BOD. The model result was evaluated with mean absolute error and root mean square error. The results show a good correlation between observed and predicted values of DO and BOD which is shown in Table 2.

Table 2. Statistics of DO and BOD for Calibration and Validation

Particular	DO	BOD
Calibration of model		
Mean Absolute Error (MAE)	0.03	0.36
Root Mean Square Error (RMSE)	0.016	0.24
Validation of model		
Mean Absolute Error (MAE)	0.13	0.42
Root Mean Square Error (RMSE)	0.026	0.72

The model has been calibrated with available results of DO and BOD along the stretch of Tapi which indicates a good correlation with observed and calibrated results. The available point and non-point sources data have been further used to validate the results stretch of Tapi. From the validation has been observed that the entire stretch of 22.39 km failed to meet the river water quality standards. In the stretch of the river from the upstream side up to 15 km, river water quality was significantly good as in most of the locations DO was observed greater than 4 mg/l. However, after 15 km there was a significant reduction in DO value.From the study, it has been observed that the downside of 9 km in most of the stretches DO level has been observed as less than 4 mg/l which indicated a significant deterioration ofwater quality. Figure 2(b) shows BOD value is increasing from upstream to downstream. To meet drinking water quality standards BOD value ≤ 2mg/l but it was observed in the range of 6 mg/l to 17.5mg/l it indicating river water quality is very poor.

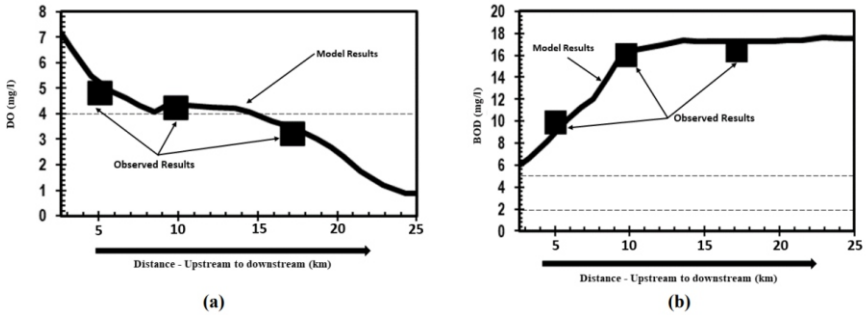

Figure 1. Model Calibration results of river Tapi (a) DO, (b) BOD

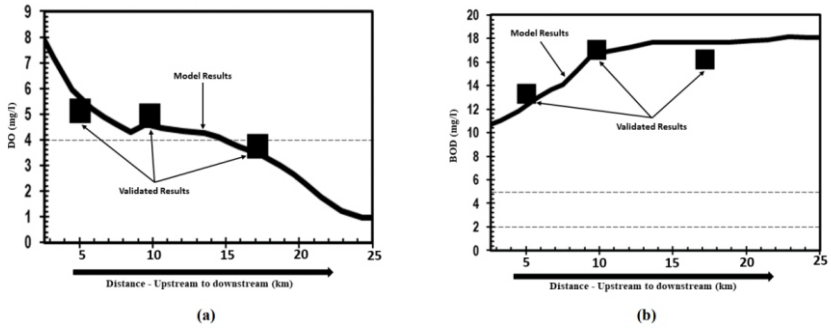

Figure 2. Model Validation results of river Tapi (a) DO, (b) BOD

B. Effects of Maximum, Minimum, And Average Temperature on Do and Bod

The rate of chemical reactions in water, the interaction of pollutants, the rate of photosynthesis in aquatic plants, and the rate of metabolism, parasites, and other pathogens with water are affected by temperature. The chemical reaction accelerates the rate of BOD degradation by microbes during the deoxygenation reaction [18]. It was observed that variations in DO and BOD concentrations were influenced by variations in ambient and water temperature.

As the temperature is influencing parameters for DO and BOD, the temperature data from 1991 to 2021 were considered forthe study. In Surat city month of March, April and May are recorded as the hottest month. So, in the study maximum, minimum, and average temperatures of March, April and May have been considered. The average maximum, minimum, and average temperature from 1991 to 2021 is as per table 1. Is used in model results. The variation in a DO and BOD concerningmaximum, minimum, and the average temperature is represented in figure 3(a) & (b), figure 4(a) & (b), and figure 5(a) & (b) respectively. The baseline temperature is considered as 22 °C as per the model calibration and validation conditions.

From the graph, it has been observed that as temperature increases beyond 33°C in most of the stretches of the river DO has been observed as less than 4mg/l. Considering the minimum temperature criteria at least the river can maintain 4 mg/l DO at most of the point. However, the river water quality was deteriorating downstream at 9 km.

As the average temperature is reported as higher than the minimum temperature in the case of average temperature DO has been dropped significantly lower. However, in the case of BOD similar increasing trend has been observed irrespective of maximum, minimum, and average temperature.

Analyzing the Effect of Temperature on DO and BOD of the Tapi River using QUAL2Kw Model

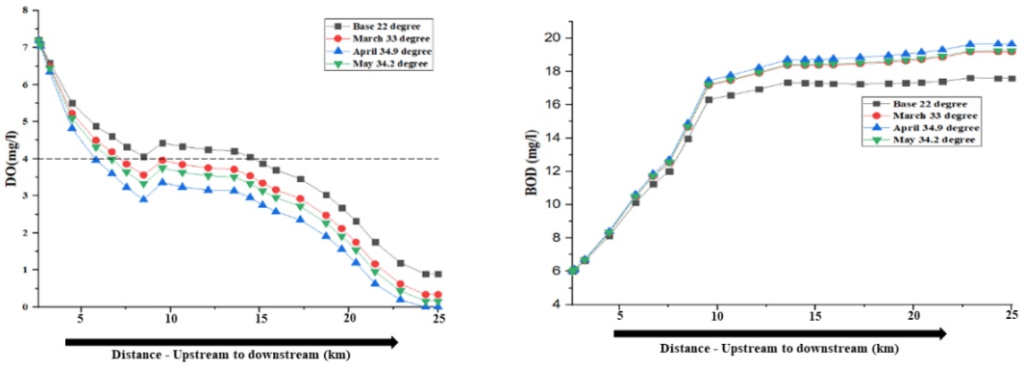

Figure 3. Results of maximum temperature condition for the months March, April and May (a) DO, (b) BOD

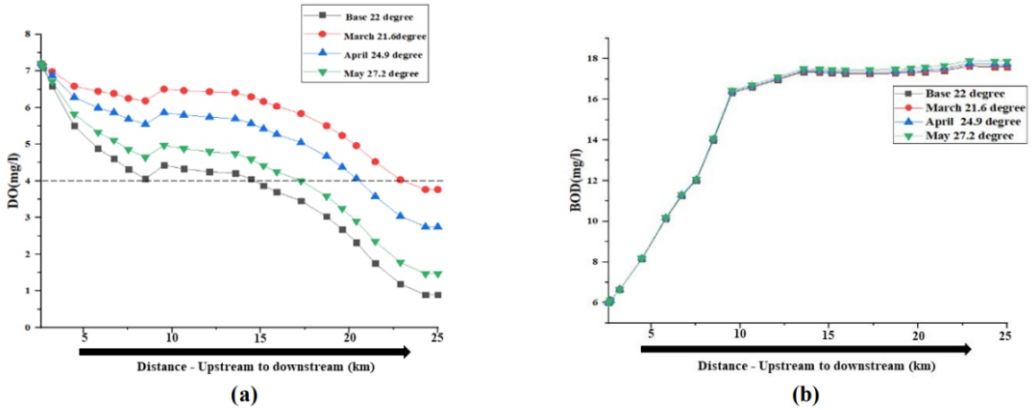

Figure 4. Results of minimum temperature conditions for March, April, and May (a) DO, (b) BOD

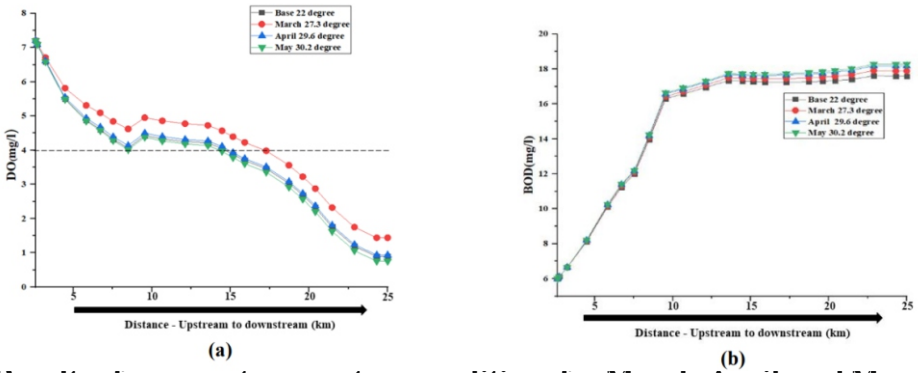

Figure 5. Results of average temperature conditions for March, April, and May (a) DO, (b) BOD

IV. CONCLUSION

In this research work QUAL2Kw, a modal is utilized to simulate water quality. This model shows a strong correlation between calibrated and validated values of the DO and BOD table. The Tapi river was most influenced by various point and non-point sources and anthropogenic activities. The calibrated model can also be used to simulate the effects of temperature on water quality parameters. During March, April, and May the river water quality was most significantly deteriorating as in most of the stretches the minimum DO level obtained was 4 mg/l. In some of the stretches, DO was observed to be enriched because of the growth of microalgae as shown in figure 4(a). BOD throughout the stretch was observed as an incremental increase up to some extent with a constant value of less than 18 mg/l.

Thus, the condition of the Tapi river is having worst water quality during the summer season. This research would beurban planners to make decisions to control pollutants entering the river and to evaluate the different conditions to maintain.

DECLARATION

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Ethics Approval	Not relevant.
Consent to Participate	Not applicable.
Consent for Publication	Not applicable.
Availability of Data and Material	The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.
Authors Contributions	HP has done a detailed literature survey for this study. She also collected samples, conducted all the experiments, along with data interpretation, and generates the result using QUAL2KW software. NJ provided administrative and technical support in addition to critical comments and revisions in the manuscript as the supervisor for the study. The experimental study was conducted under her supervision. Both authors read and approved the final manuscript.
Code Availability	Not applicable.

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Applications Integration in a Semi-VirtualizedEnvironment

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ABSTRACT

Enterprise application integration quickly arose as aproblem for companies and solutions were proposed including point-to-point architecture, ETL (Extract, Transform and Load), EAI (Enterprise Application Integration) and ESBs (Enterprise Service Bus). With the rise of virtualization, how applications in a physical environment could interact with those that are in a virtualized environment. The objective of this paper is to study and define a Service Oriented Architecture (SOA) in a semi-virtualized environment. The authors propose an architecture which allows service integration in a semi-virtualized environment. This study uses a survey-based technique to seek which technology can be used in the considered environment. A state-of-the-art of the various IT designs and solutions enabling SOA implementation is presented. ESB technology has been retained for this study. A literary review is done on ESB to examine how it could be used in the semi-virtualized context. The findings of this study propose an architecture which allows service integration in a semi-virtualized environment. After an in-depth examination of different deployment possibilities and technical solutions proposed for this purpose, a new architecture based on the Enterprise Service Bus (ESB) is proposed for semi-virtualized context. This architecture is organized around two ESB solutions each deployed in an environment and interconnected by a communication bridge which ensures message routing between the two ESB buses. A practical deployment phase is carried out for illustration under Talend Open Studio with encouraging results. The proposed architecture is a good solution for companies whose information systems operate in a semi-virtualized environment.

Keywords: Application Integration, Eia, Esb, Soa,Virtualization, Semi-Virtualized Context.

I. INTRODUCTION

The objective of this work is to propose an architecture implementing SOA in a semi-virtualized context. Many companies have information systems (IS) made up of several components such as business applications [1, 2], ERP [3] [4] [5] [6], Customer Relationship Management (CRM), databases, etc. Each component is deployed to meet a specific need within a well-defined scope. Applications and software used on daily activities are therefore not necessarily required to communicate with each other [2]. Data are partitioned. There are two major questions [7]: how to ensure data consistency and data propagation between several subsystems and how to initiate, in response to an event in a given subsystem, a processing in another subsystem which is foreign to it? The diversification of components and business processes in IS forces companies to resort to integration architectures. Integration platforms link all business applications together in order to cross and combine data used by each of them [7] [8] [9] [10]. They optimize the use of data for company users. Formerly known as "point to point", integration can now be automated thanks to numerous technical solutions, in particular Service Oriented Architecture (SOA) [11, 12]. A distinction can be made between data integration which consists of synchronizing databases used by the various IT components, and application integration which takes place through the transmission of messages between applications. Four (4) technical solution families are offered in these two integration categories: ETL (Extract, Transform and Load) [13] [14] [15], point-to-point architecture [11], EAI (Enterprise Application Integration) [16] [17]18] and ESB (Enterprise Service Bus) [19] [20] [21].

ETLs are solutions intended to extract data from various data sources, transform them into a format understandable to its target and load them into one or more target databases [14, 15]. They are much more suited to the processing of big data in the case of data loading in data warehouses. ETLs only respond to the consistency and propagation of data between multiple subsystems. ETLs are a solution that fails to effectively address the challenges of modern integration and is not implemented in SOA in a semi-virtualized context.

Point-to-point architecture, also known as strong coupling, appeared in the early 1990s using specific connectors to connect each application to another without any middle layer.It is a mechanism by which the client is linked directly to its server via a protocol, a specific format, and potentially hard-fixed addresses [11]. Any modification of one of the components may require a new delivery of the others in order to get the system continuing to operate. This is often called “spaghetti dish syndrome”. It is an architecture whereevolution and maintenance become more and more complex as the size of information system increases. It remains proprietary solution, very expensive and above all does not use recognized standards protocols to facilitate their opening to the outside world.

EAIs (Enterprise Application Integration) come with a new architecture based on the so-called "hub and spokes” topology allowing inter-application information exchange through a central point (hub) [16]. Communication between applications is ensured at this point according to its own standards. EAI intervenes at application level thanks to specific connectors (spoke) to be able to exploit data consumed and stored by each of applications.

This solution is a very effective way to break the strong coupling employed by point-to-point architecture, but it still has a proprietary character. Its internal topology, the protocols used and the exchange formats are all proprietary as well as its connectors allowing it to access applications remain largely vendor-specific despite the attempt at standardization. Depending on its technical specifications, its complexity and above all its proprietary nature, this solution is not profitable for companies in terms of cost and time savings [17, 18].

ESBs (Enterprise Service Buses) are a new generation of application integration solutions, seen in some ways as the heir to EAI [7, 19]. ESBs are built on open standards such as XML for message description and Web Services for data exchange. Unlike EAIs, ESBs do not intervene directly in system applications but via Web Services modules within each of them [20, 22]. All of these service modules are then directed and shared to a central flow where exchange takes place on the application bus. Deployment of new tools and components in the information system is thus facilitated thanks to this method. Because of their architectures based on message buses and especially their implementation totally based on known communication standards and their ability to exchange messages with other ESB solutions from different manufacturers, EBS have become the favored technology of integration for implementations of Service Oriented Architecture [19]. Given their advantages, it is the best suited solution on which an architecture based on SOA in a semi-virtualized context [23] could be defined. Thus, a SOA implementation architecture using ESB-type solutions for the integration of services in a semi-virtualized context is proposed.

In the rest of this paper, materials and methods are presented in point 2 and results in point 3. Then, discussions are presented in point 4. And, the paper ends with a conclusion.

II. MATERIALS AND METHODS

A literary review is done on ESB to examine how it could be used in the semi-virtualized context. Enterprise Service Bus (ESB) is the main technology used in the work. Enterprise Service Bus (ESB) is defined by Roy Schulte [24] as "a new architecture that leverages Web services, message-oriented systems, intelligent routing and transformation." ESB acts as a lightweight and ubiquitous backbone of integration through which software services and application components flow. Other definitions followed that of Roy Schulte [24], their synthesis retains ESB as a middleware solution based on a service-oriented model and on bus principles allowing interoperability between heterogeneous applications and facilitating the implementation of the SOA by promoting the use of Web Services [25]. ESB is most often considered as new generation of EAIs built on standards such as XML, JMS (Java Message Service) or Web Services. Major difference with EAI is that ESB offers fully distributed integration through the use of service containers which contain the integration logic and can be dropped anywhere on the network [20, 22]. An ESB service container abstracts a service and isolates it from its communication protocol, invocation methods, message exchange patterns, QoS requirements, and other infrastructure needs. Real breakthrough of ESBs is their ability to virtualize services.

A. Principles of a ESB

From a strictly technical point of view, the role of an ESB boils down to connection and mediation between heterogeneous services and applications of an IS as well as decoupling consumers and service providers. As a mediator between clients and service providers, ESB is based on the following principles [19]:

- Dynamic discovery: services as well as associated semantics are recorded in a shared directory;
- Choreography of business processes and orchestration of associated services: a tool automatically orchestrates necessary services for implementation of collaborative processes.
- Strong distribution: services are distributed over the company's network or over the Internet.
- Message communication: services exchange messages represented by textual documents.

B. Main characteristics of an ESB

In order to fully play its role, an ESB must have some characteristics and functionalities of which mains are [7, 20, 22]:

- Connectivity and communication: An ESB must allow communication with multiple protocols and formats based on standards recognized by all (SOAP, XML, JSON, JMS, etc.) synchronously or asynchronously. To do this, it must in particular be able to interact with Message Oriented Middleware (MOM) embedded or not within the ESB.
- Mediation, routing and orchestration: An ESB must make it possible to decouple suppliers and consumers of data. It must therefore provide a mechanism making it possible to distribute the messages from a supplier to one or more consumers in a transparent manner for both. Mediation is the main added value of an ESB. In this field, it must therefore offer a rich semantics, capable of making exchanges more reliable and simplifying implementation.
- Transformation: since a supplier and a consumer do not necessarily dialogue in the same language, an ESB must provide means for transforming messages.
- Monitoring (monitoring tool): As central point, ESB must allow monitoring and reliability of exchanges which pass through it thanks in particular to:

▪ guarantee of message delivery while keeping unused messages (application unavailable, failure of a transaction, etc.);
▪ functionalities making it possible to monitor processing operations carried out and the messages received;
▪ service security management (authentication, authorization, confidentiality and audit);
▪ control of SLAs (Service Level Agreement) and ability to modify bus behavior (priorities, etc.) to ensure these SLAs.

C. Types of deployment of ESB solutions

ESBs are increasingly used in SOA projects under different approaches at infrastructure deployment level [7, 22]. Each approach has advantages and disadvantages. Two approaches which can be useful to the definition of a new architecture are presented:
- separate ESB servers in company, each solving a specific integration problem for a specific department;
- a distributed ESB in company connecting all parts of the information system.

The first approach is to let each department manage its SOA by implementing its own ESB solution. The department manages the integration of the application and the development of its business processes. By using separate and independent ESBs, each department is free to adopt solution it wants. But when communication with other partners is required, it must explicitly access or provide certain services using standard "bridge" technology such as web services. In this case, the communication relies on protocols such as http, and quality of service such as reliability or security must be implemented manually [7].

The second way to implement a SOA infrastructure is to have unified ESB across the company. The ESB is deployed only once and ensuring communication between the various department servers. Invocation of a service by another service will be done in a simple way, since consumer contacts the ESB in the same way as he does for a local service [7]. From this perspective, ESB can be considered as a real backbone of this infrastructure like an Ethernet network. In more practical terms, ESB is a set of natively interconnected nodes. A node is a connection point for consumers or service providers. Unified ESB deployment approach has multiple technical advantages. Communication between subsystems is simplified by facilitating services invocation methods that become like calling a simple local service. Its deployment and maintenance are easier compared to the separate approach. From an organizational point of view, this approach can be a source of conflict of competence between the administrators who manage the different business services. In a large company in particular where the business services are multiple, they are often organized by department. ESBs in their default configurations allow generalized access to all services they connect and provide an administrator with the privilege to modify them. To resolve this generalized access problem which could likely be source of insecurity, a method of segmentation of an ESB into a sub-part called a domain defining the management limit is implemented.

D. Domains in a unified ESB

In ESB architecture, domains and subdomains are techniques for defining boundaries between entities. Thus, from a technical point of view, each "node" of the ESB can only be managed by the administrator of the relevant subdomain. He is therefore the only person authorized to start, stop, install connectors and deploy services on this node. The administrator will be able to manage the ports used by the ESB nodes in his domain and has option of deploying proxies or firewalls to protect him. A business service deployed on a domain node can be public or private. A private service is visible only in the registry and to consumers in its domain. In addition, it is only accessible to service consumers in its domain. Tools for monitoring processes and services have access to information that concerns their own domains and that

of public domains. It is not possible to visualize processes of a private domain or statistical information concerning its services.

III. RESULTS

The proposed architecture is based on the deployment of two separate ESBs (one in each environment) then linked together by bridge technique:

- An ESB deployed in the physical environment: allows the integration of applications or services that operate in this environment in a simple manner;
- An ESB deployed in the virtual environment: enables the same scenario of the virtual environment to be carried out;
- A communication bridge between the two environments to ensure exchange of messages between the two ESB buses, this will therefore allow an interaction between the subsystems of these two distinct environments.

A. Physical Environment Architecture

Architecture planned as part of the implementation of SOA in the physical environment is nothing more than ordinary deployment of the technical solutions provided for this purpose. In this specific case, a unified ESB solution will mediate between different services running in this environment. Fig. 1 gives an overview of this architecture.

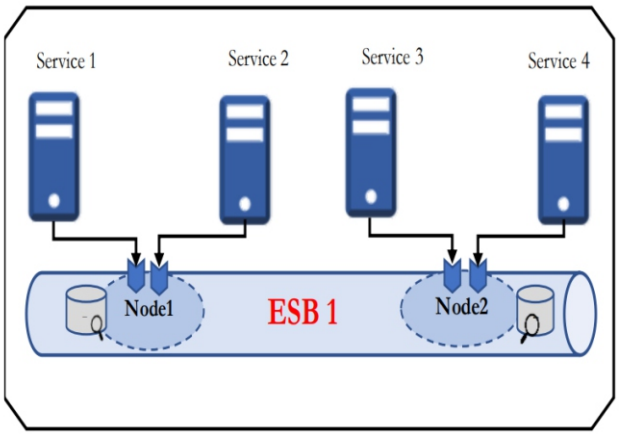

Figure 1: Deployment Architecture in Physical Environment

B. Virtual Environment Architecture

As expected, interoperability between services in each environment must be ensured by an independent ESB, and the exchange between them will be through the bridging technique. Fig. 2 shows schematically this deployment.

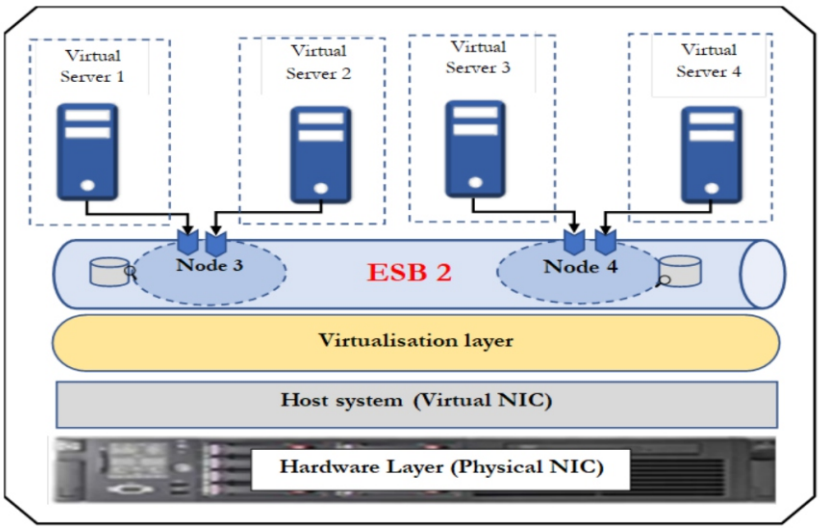

Figure 2: Deployment architecture in virtual environment

C. Overall architecture

Overall architecture is the combination of two architectures presented above. Their communication is made possible by a communication bridge which provides specific routing between physical and virtual network interfaces. This technique will allow message packets sent from one bus to be conveyed to another. Fig. 3 schematically presents this overall architecture.

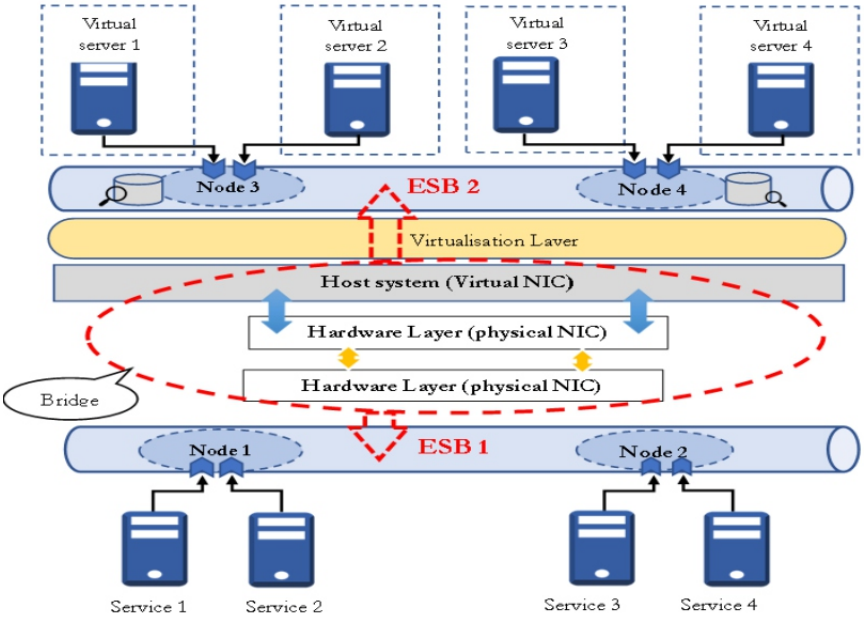

Figure 3: Overall architecture

IV. DISCUSSIONS

The limitations associated with point-to-point integration can hinder a business's growth and are usually mitigated by adopting an ESB. With ESB technology, the integration of systems and applications has become easier and faster, supporting enterprise-wide change and growth. The flexibility of the ESB bus is an essential advantage. Version updates or application location changes, fluctuations that occur anywhere on the network are no longer a problem. The ESB also facilitates orchestration which refers to the technical ability to coordinate different applications. It is also called "routing" or "mediation".

These advantages and the limitations of the previous technologies mentioned above, lead to choose ESBs for the definition of the architecture. To show the feasibility of the proposed architecture, a deployment scenario in a semi-virtualized environment in proposed: Imagine a commercial company that carried out its activities in a traditional way in physical stores with a Customer Relationship Management (CRM) and an inventory management (ERP), each deployed in a separate physical server. The company decides to set up an online commerce service (e-commerce) to boost its businesses and at the same time a platform allowing it to create a real-time dashboard based on the commercial flow to better plan its business and make good decisions. The proposed architecture allows a rational use of its resources. This involves deploying two new services on a single physical server using virtualization technology. That seems very important in terms of investment, management, maintenance, etc. This situation reflects reality of many businesses today. For theimplementation, Talend Studio [26] is used. Installation and configuration of Talend Open Studio for ESB (TOS-ESB, open-source version) were made. Then Web services were created and exposed in a service directory, so they could be accessed and invoked by other consumer services. They are:

- A Web service (supplier) providing information on the stock status of a product requested by the consumer (e-commerce platform). These items are collected from the inventory management database (ERP);
- A Web service (supplier) making it possible to provide detailed information about a client requested by the consumer (e-commerce platform). This information is obtained by querying the customer relationship management (CRM) application;
- A Web service (supplier) making it possible to expose to consumers (dashboard platform) the trade flows necessary for displaying summary information on the company's current affairs;
- Three jobs for the consumer side allowing to collect the input flows and send the request to each supplier;
- A bridge configuration making it possible to exchange messages between the two ESB solutions deployed in the different IT environments (physical and virtual).

Once the Web services are built and tested in Talend Studio, to put it into operation, it will have to be run in a Talend Runtime container OSGi. In the lack of a compatible technical environment, services were exported and executed in a Talend ESB container for demonstration purposes. This demonstration allows seeing step by step the implementation of a Web Service in Talend Studio using a job listening to all requests and another to consume the Services. It also allows seeing the exchanges between the services in the Talend ESB container in a physical and virtual context.

V. CONCLUSION

Information Systems (IS) of many companies are generally based on heterogeneous software and data sources, resulting from successive use of various technologies, or acquisition from other companies. This heterogeneity leads IT departments to consider integration issue as a major issuewhen the companies seek to make different departments communicate with each other in order to optimize their business processes. Companies whose IS operate in a hybrid environment (part of the IS function in a

physical environment and another in a virtual environment) also need to make the different departments communicate. Services integration in this specific context is considered. Service Oriented Architecture (SOA) and technical solutions relating to the integration problem are tackled. An architecture allowing the integration of services in a semi-virtualized environment is proposed. This architecture is organized around two ESB solutions each deployed in an environment and interconnected by a communication bridge which ensures message routing between the two ESB buses. An implementation in Talend Studio showed that this architecture is achievable. It is a solution for companies whose information systems operate in hybrid mode.

DECLARATION

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Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	I am only the sole author of the article.

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Stochastic Resource Algorithm for EffectiveUtilization of Bandwidth for IoT Sensor Networks in Arecanut Agriculture Applications

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ABSTRACT

Cognitive radio technology is growing positive solution for the effective utilization of the bandwidth for IoTdevice networks. The fixed spectrum allocation scheme leads to insufficient spectrum utilization, to overcome this problem, the stochastic resource allocation algorithm is proposed in the present work. This method of internet spectrum allocation considerably increases the performance of IoT sensor network by utilizing the internet spectrum by non-cognitive inactive IoT sensors (white space/spectrum holes) by continuous spectrum sensing. In this paper we have discussed the effective resource allocation for interweave and underlay conditions and also at variable interference constraints (short time and longtime spectrum sensing) of IoT network. The arecanut plantation for agriculture scenario is considered in the present paper and the sensor environment simulation is performed using MATLAB.

Keywords: Primary, Secondary Users, Resource Management,Stochastic Approximation, Imperfect Channel Information,Lagrange's Multipliers.

I. INTRODUCTION

The wireless communication technology, is improving day by day it has reached 5G today. As there is continues progress in the technology from last decade, internet spectrum demand also growing in parallel. As this internet spectrum availability is limited by international distributors, satisfying the all-client sensors in IoT implemented world with available bandwidth is becoming major challenge in the internet networking field. Utilizing the internet beyond the available spectrum that means more than gega hertz may start to cause severe injury to the birds and human beings. International level auctions are made in purchasing internet spectrum band for the upcoming IoT framework implementations. So, the internet spectrum scarcity has been started as the huge number of IoT client devices/ sensors are connected together. So managing all the huge number of IoT sensors connected together to IoT servers become very potential research problem.

Cognitive radio technology is becoming a solution for the problem to meet the required IOT internet demand even though we have finite internet resource of spectrum available from Indian IT authority for 4g spectrum distribution. To achieve this dynamic resource allocation has been stored, many algorithms related to dynamic resource allocation are discussed in [1-3].

The proposed stochastic resource allocation algorithm is one of the dynamic resource allocation methods used for the effective utilization of available IoT spectrum. The present paper proposed a dynamic resource allocation algorithm to sense the channel spectrum by analyzing the average power, sub optimal power of channel by considering the Rayleigh power fading. The instantaneous power and

sample average power of the interleave and underlay spectrums are calculated and the results are depicted using MATLAB.

II. RELATED WORK

Many authors have discussed about different algorithm related to dynamic resource allocation. Optimization problem has been solved & by, analyzing of average power, & sub optional power of channel by assuming Rayleigh fading channel. An effort was made to reduce to power consuming by sensor nodes in the IoT communication [2] many resources are concentrating on interference management in fem to cell network.

These femto cell networks are cooperative networks to the radio network. The analysis of power allocation strategy based on the interferences behavioral study (previous history) by using the two state Markov chain model is done [3]. Many works carried on dynamic resource allocation of sub carriers based on channel state information for orthogonal frequency division multiple accesses. Many schemes are developed to exploit the knowledge of perfect instantaneous CSI. Paper [4] mainly concentrates on resource allocation by having perfect instantaneous CSI.

If CSI is not considered it is called stochastic algorithm.Stochastic algorithms are able to sense wireless IoT sensor data channels dynamically to achieve optional strategy, when prior knowledge of channel is known optimal scheme can be obtained using Lagrange's dual gradient iteration [5]. The separating the design of wireless networks in various layers and problem in each fading state is discussed in [6].

Interference power constraint for cognitive radio to protect primary user translation is discussed in [7]. The various capacity limits achieved by primary user fading like ergodic and outage capacity is discussed in the paper [8].

Xiang zhang et al., has explained the technique of spectrum sensing with static algorithm [9]. Amar abdul Ahamad khadar et al., has presented a survey of CR based IoT and mentions some previous works. It highlights with details the spectrum sensing stage for both narrowband and wideband [10]. Very important technical issues related to the cognitive radio based IoT network are discussed in the paper [11].

The overall idea, applications and the need of cognitive radios in the IoT frame work device applications are discussed in the paper [12]. Dina Tarek et al., has given clear view for the spectrum sensing techniques with the survey of all available techniques for the spectrum sensing and resource allocation methods [13]. Banhammer et al., has discussed the motivations and research challenges in the cognitive radios' implementation in the IoT and high lightened the challenge of spectrum sharing in dynamic scenario [14]. Idrees et al., has presented the basic functionalities of the both CR and IoT technology and present a five layered framework for CR enabled IoT.

In addition to the framework, we also proposed and develop a spectrum sensing algorithm for CR-based IoT architecture, meeting the efficiency and time sensitivity requirements [15]. Alberti et al, has developed an embedded and low-cost cooperative spectrum sensing solution, which has been experimentally implemented [16].

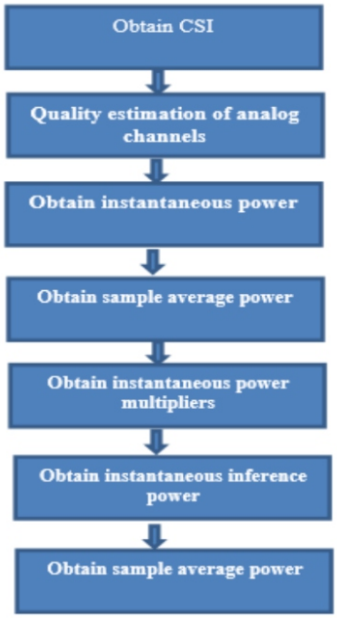
III. INTERFERENCE CONSTRAINTS

In our proposed system we have considered two types of interference constraints first one is short term constraint which involves channel state information, this short-term constraint will reduce the probability of exceeding the threshold interference over very short time. Another is long term constraint it takes an advantage of diversity of interfering channel to reduce the probability of exceeding the threshold over long time (fraction of time). In long term constraint the mathematical output terms are

multiplied using Lagrange's multiplier whose values depends on previous history of the channel/system. The proposed stochastic algorithm first estimates the probability of interference and then estimate the optimum value of Lagrange's multipliers based on these two it allocates the spectrum resource.

IV. FLOW DIAGRAM OF PROPOSED ALGORITHM

As shown in the flow diagram Figure 1, first step is to obtain the channel state information by estimating the average power of the channel and then we sample it. After these steps we obtain the instantaneous power by Lagrange's multipliers and interfering power levels are calculated to get threshold power level. By having this data of threshold, we will fix the threshold power level which prevent secondary user to exceed the threshold power level.



V. MATHEMATICAL ANALYSIS

In this proposed algorithm, we have considered "M" secondary users who can transmit their data over "k" different channels in opportunistic manner.

Let h m k, 2 [n] be the instantaneous power of the channel between mth secondary transmitter and its expected receiver on the kth band at certain time "n". Here, the subscript 2 states that the channel belongs to the secondary transceivers in the IoT framework. Here, we consider that in case the licensed user transmitters are at far distance from the SU (Secondary Users) receivers. This is the fact that in IoT-CRN (Cognitive Radio Network) the CSI (Channel State Information) of certain PU (Primary User) network can't be perfectly known because it is infeasible to sense all sensor data channels at each same instant and therefore there would always be probabilistic and varying information of the primary CSI (Channel State Information). Therefore,estimating CSI under interweave and underlay conditions is very crucial in IoT-CRN modeling. The discussion of CSI in IoT frame work sensor channel settings is presented in the following sections.

A. Perfect and imperfect channel state information in IoT- CRN

In case of the interweave CRN setting, the network controller requires the information whether individual spectrum or channel is being used or not.

To measure the spectrum occupancy, let ak be a variable representing the activity of PUs network at certain time instant on kth band. Here, ak[n] =1 represents that at certain time instant the kth PU ak [n] = 0 is active and using its resource. On contrary, states for the idleness of kth band at instant. Here, we define a verification factor (2*1) represented as

$$F\ ak[n]:=\ [Pr\ \{ak\ [n]\ =\ 0\}\ ,\ Pr\ \{ak\ [n]\ =\ 1\}]T\ \ .....(1)$$

Where, the probability mass of depends on the previous behavior of the system till last nth instant.
Consider, Sk [n] be a Boolean variable with Sk [n] = 1 representing the scenario when kth band has been sensed at certain instant n, otherwise Sk [n] = 0. Furthermore, consider ak [n] be the estimated value of measured at certain time instant n, during the time of consideration. Here, in the proposed algorithm, we have considered two predominant types of imperfect CSI. They are Outdated CSI (Sk [n] = 0) and noisy CSI (probability of noise addition during sensing process is more therefore in this case ak [n] is not equal to ak [n].
To deal with outdated CSI, it is required to retrieve the dynamics of ak [n] throughout defined observation time. Here, we have followed a first-order Markov process for estimating outdated CSI.
Considering Q as a transition probability matrix and hence the entry at i, jth instant is:

$$Qij = Pr\{ak[n] = i\} / Pr\ \{ak\ [n - 1] = j\} \qquad ----------(2)$$

To deal with the sensing errors, in this paper we have considered two factors called the Probability of False Alarm (PFA) and Probability Miss Detection (PMD). These two arerepresented mathematically as

$$PMD\ = \{ak\ [n] = 0\}/\{ak\ [n] = 1\}\ and$$

$$PFA = \{a\hat{}k[n] = 0\}/\ \{\ ak\ [n] = 1\}$$

Now, we have defined 2x1 matrix, such that

$$q1\ = [1 - PFA, PMD\ ]T$$

$$q1\ = [PFA, 1 - PMD\ ]T$$

In this paper, we have used Hidden Markov Model (HMM) to estimate CSI, and therefore the recursive Bayesian estimation can be employed for retrieving the instantaneous verification factor fak [n]. Thus, the verification factor can be updated as:

$$fak\ [n] = Qfak\ [n - 1]$$

$$fa\hat{}k\ [n] = fak\ [n - 1]$$

we have optimized fak by means of Bayesian rule. If we consider the [n] be the lth entry of the the vector, hence

$$[fak[n-1]l] = ([q0]l[fa\hat{}k[n]l)/q0T\ fa\hat{}k\ [n]$$
$$[fak[n]]l = ([q0]l[fak[n]]l)/\ q1\ fa\hat{}k\ [n]$$

VI. ESTIMATION OF LAGRANGES MULTPLIERS

The main use of the Lagrange multipliers (LMs) is that generally one can observe the most universal difficulty in the integral or differential calculus concepts is that discovering the maxima and minima points also it can be spelled as extreme of the particular function as shown in the Figure 2.

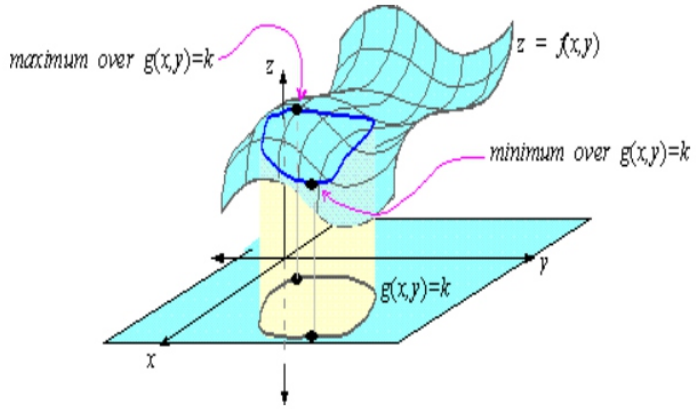


Fig. 2: Example of Langarangian Multipliers Approach To Find Maxima and Minima

Πmo, θ0, v 0 are the variables used to optimize the particular function in Langarangian approach. There are many methods are used estimate Lagrengian multipliers. This method usesthe fixed step size multiplication therefore it has some limitations. The main limitations of this approach are in every step, it requires averaging all possible states of h (including channel imperfections). Every time channel statistics of users must be recomputed. Alternative approaches are used to obtain the multipliers. These approaches do not aim at the optimal values but calculate the values that are updated at every time instant. The main advantages of this approach, especially for IoT- CRN settings, are: The computational complexity is very low; They can compatible with non-stationary channels. Convenient when the primary user transmitters are very close to the secondary users receivers. To overcome the limitation of Lagrangian Multiplier approach evolutionary computing or genetic algorithm based Lagrangian multiplier optimization is used in the proposed algorithm. The proposed genetic algorithm based Lagrangian multipliers calculation in the stochastic resource allocation of spectrum is shown in Figure 3.

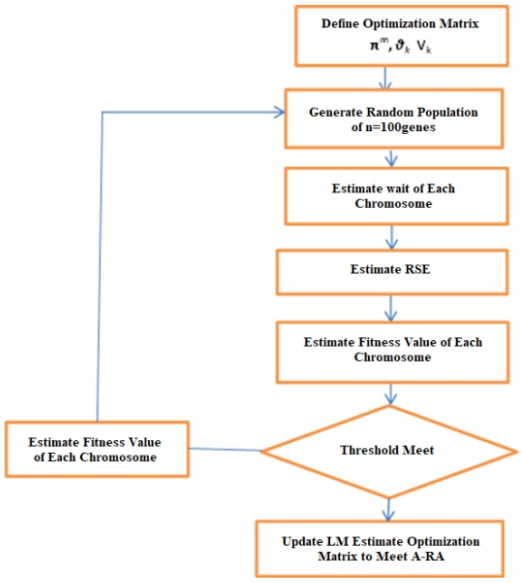


Fig 3: The Proposed Genetic Algorithm to Calculate the Lagrangian Multipliers

Algorithm for the proposed evolutionary computational based genetic algorithm for the calculation of Lagrangian multipliers is explained in this section:

Step-1: Optimization variable definition: In this step the multiplier variables, m[n], k[n] and vk [n] have been defined, which have to be used for lagrangian relaxation to meet A-RA objectives and interference control.

Step-2 Population Generation: The population foroptimization variables has been generated using equation [7]. The retrieved values of m[n + 1], k[n + 1], vk [n + 1] have been used as the set of chromosomes. Here, initially, the random selected chromosomes would be used to perform competition and crossover with defined genetic operators, (Pc, Pm), where the initial values of Pc and Pm are 0.6 and 01 respectively.

Step-3 Chromosome Weight Estimation: The weight for Πm[n], θk [n], vk [n] have been estimated.

$$\omega_n = \begin{cases} \dfrac{-X_{nl}+2*10^{l-2}+X_{nl}+2*10^{l-3}..X_{(n+1)l}}{10^{l-2}} & \text{if } 0 < X_{nl+1} < 5 \\ \dfrac{+X_{nl}+2*10^{l-2}+X_{nl}+2*10^{l-3}..X_{(n+1)l}}{10^{l-2}} & \text{if } 5 < X_{nl+1} < 9 \end{cases}$$

Where ωn the weight estimated (distinct for Πm[n], θk [n], vk [n]) and l is the length of chromosomes. In the proposed algorithm, the real positive weight value has been used for multiplier weight estimation.

Step-4 Error Estimation: The error estimated is:

$$E_j = \begin{cases} \pi^{m*} - \pi^{m}{}_{0j} = \blacktriangle \pi^{m} \\ \theta_k^{*} - \theta_{k0j} = \blacktriangle \theta_k \\ V_k^{*} - V_{k0j} = \blacktriangle V_k \end{cases}$$

Thus, the cumulative error function Ej = ΔΠm , Δθk, ΔVk. considering these errors as input, the fitness value has been estimated. The fitness value is predicted to be taken by subtracting the cumulative error function from root means square error therefore RMSE will become.

$$\text{RMSE} - E_j = \sqrt{\frac{\sum_{j=1}^{N} E_j}{N}}$$

Step 5 Fitness value estimation: $\frac{1}{RmsE} - Ej = \frac{1}{\sqrt{\frac{\sum_{j=1}^{N} E_j}{N}}}$

Step 6 Chromosome Ranking and mutation: In order to enhance the performance of proposed scheme for minimal computational complexity, in this proposed algorithm, the ranking for chromosomes has been estimated. The chromosomes with minimal ranking are mutated.

Step 7 intended to make πm, θk and Vk , approximate to m[n], k and v k[n]. Therefore in this genetic algorithm implementation for IoT CRN scenario, once the errors (m, k and k) become bare minimum to justify m = m, k = k, v K = vk then genetic algorithm run processed is stopped and the final retrieved value of m[n], k[n], vk[n] is used as Lagrangian multiplier which would ensure weighted sum rate maximization for IoT spectrum resource allocation problem with assured expected interference constrains (for interweave and underlay setup). Thus, the average-power optimization can be achieved as discussed above to ensure optimal unused resource allocation to the secondary users (SUs) without introducing interference to the primary users (Pus)

VII. SIMULATION RESULT

Simulation results for all the cases and conditions are tested and simulated in mat lab by taking 500 sensor nodes for IoT frame work with considering k=10, M=5, N=500, Pfa = 0.02, Pmd= 0.01. the results are tested for 10 iterations of multipliers. The power achieved is tabulated and compared with the actual power to compare the accuracy of the algorithm. The instantaneous power of the data transferring channels is calculated using the proposed algorithm the obtained result is shown in the Table 1.

Table I: Instantaneous power for Interweave condition

Iteration	Actual power	Estimated power
1	0.3968	0.3968
2	0.5000	0.5000
3	0.1905	0.1905
4	0.5635	0.5635
5	0.6349	0.6349
6	0.2619	0.2619
7	0.4365	0.4365
8	0.6508	0.6508
9	0.3492	0.3492
10	0.6032	0.6032

The instantaneous power of the data transferring channels in underlay networks is calculated using the proposed algorithm the obtained result is shown in the Table 2.

Table II Instantaneous Power for Underlay condition

Iteration	Actual power	Estimated power
1	0.2540	0.2540
2	0.1984	0.1984
3	0.1825	0.1825
4	0.1825	0.1825
5	0.2222	0.2222
6	0.2302	0.2302
7	0.2222	0.2222
8	0.2302	0.2302
9	0.1984	0.1984
10	0.1587	0.1587

The results have been tabulating by considering both for interview and under lay condition. The graphs generated by taking 500 nodes and 10 iterations. The average powers of channels for interview network condition are shown in the Table 3.

Table III: The average powers of channels for interview network

Iteration	Actual power	Estimated power
1	0.1429	0.1667
2	0.8254	0.8333
3	0.6270	0.6190
4	0.5159	0.4921
5	0.2778	0.2540
6	0.4603	0.5079
7	0.3175	0.2619
8	0.6270	0.5714
9	0.5397	0.5159
10	0.3810	0.3571

Table IV: The average powers of channels for underlay network condition are shown in the Table 4.

Iteration	Actual power	Estimated power
1	0.1905	0.2143
2	0.2540	0.8333
3	0.1508	0.1825
4	0.2222	0.2222
5	0.1270	0.1508
6	0.0794	0.0794
7	0.1111	0.1270
8	0.2460	0.2460
9	0.4048	0.4127
10	0.1587	0.1508

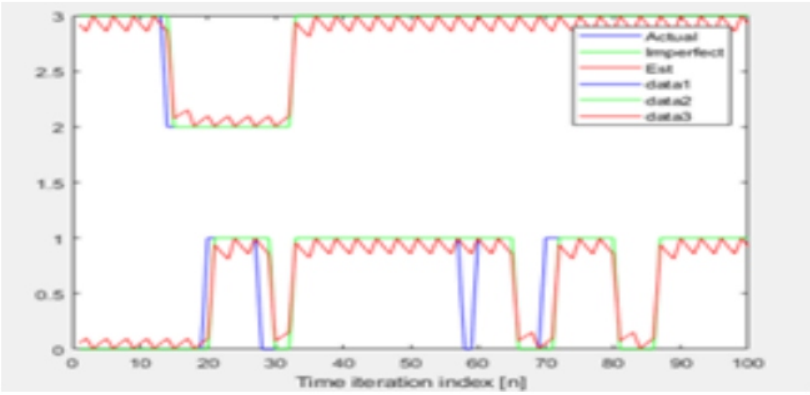


Fig. 4. CSI estimation graph IoT network under imperfect condition Blue line indicates actual estimation of CSI, Green line indicates the imperfect estimation, red line indicates the estimated values of the CSI for IoT sensor network.

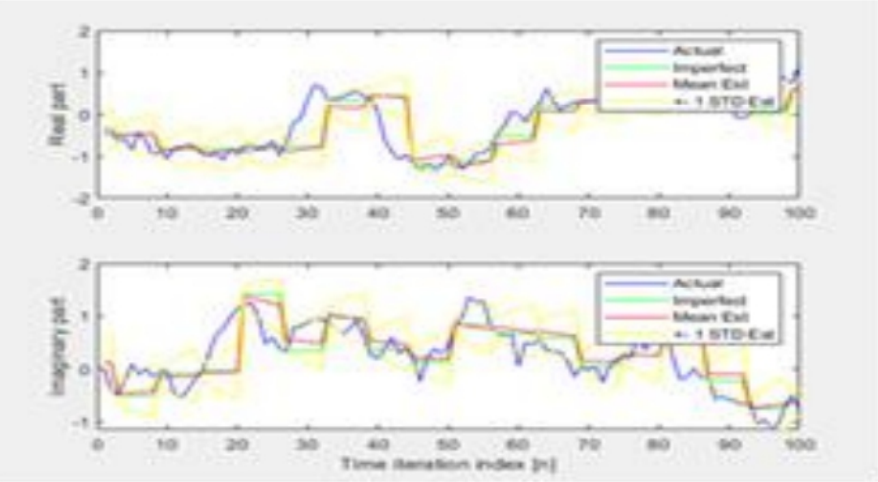


Fig. 5. Quality estimation graph under Interweave IoT Network condition

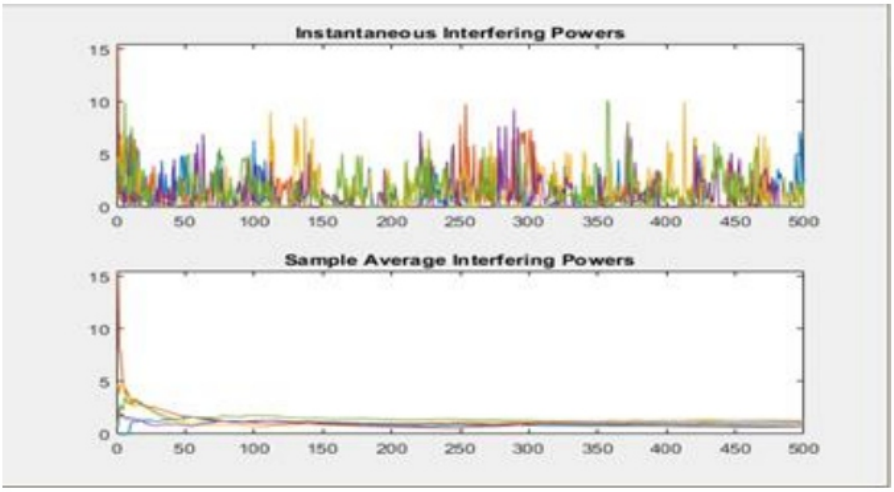


Fig 6. Instantaneous power, sample average power, instantaneous power multipliers Estimation at primary under Interweave network condition.

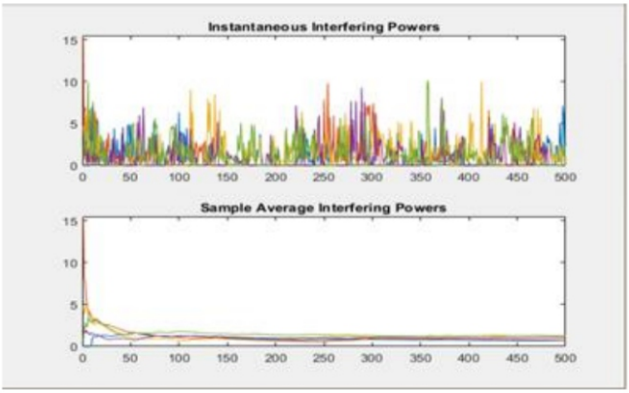


Fig 7. Instantaneous interfering power average Interference power for interweave network for under lay conditions.

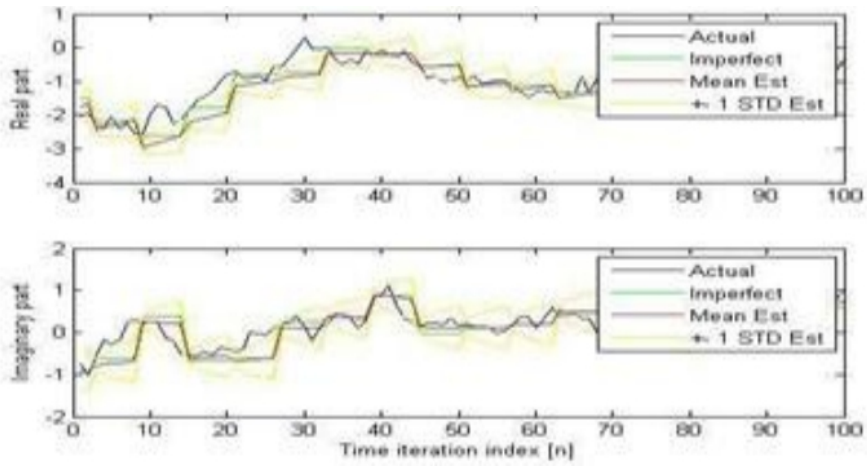


Fig 8. CSI estimation graph for actual, imperfect and estimated situations for Underlay Network.

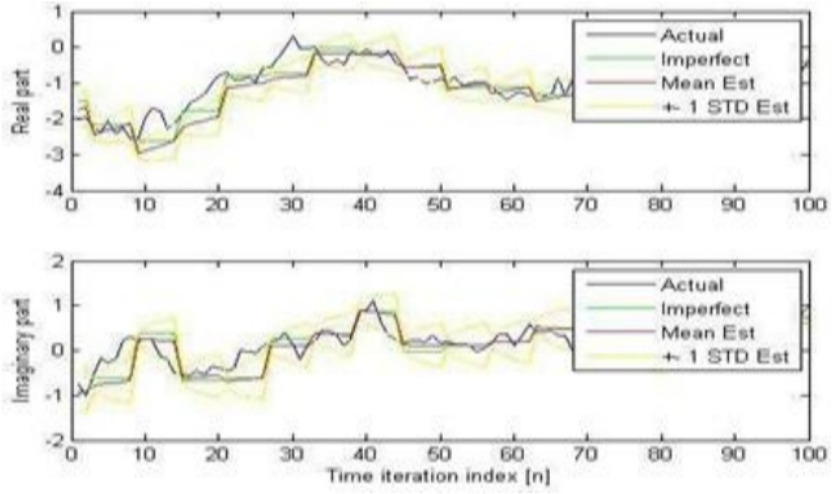


Fig 9. Quality estimation graph for Underlay Network

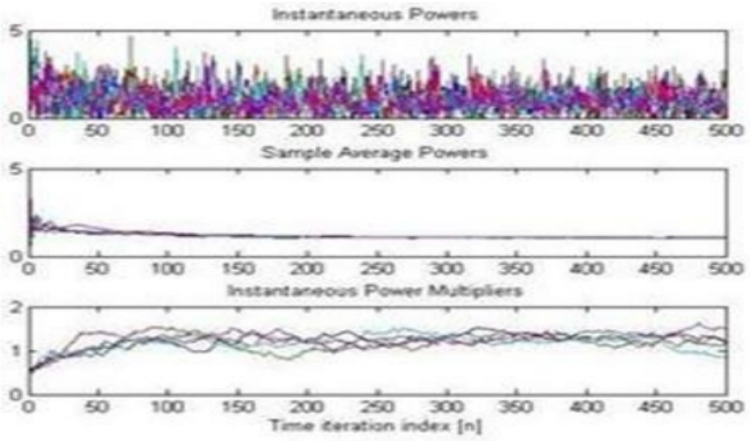


Fig 10. Instantaneous power, sample average power, instantaneous power multipliers estimation at primary user for Underlay network.

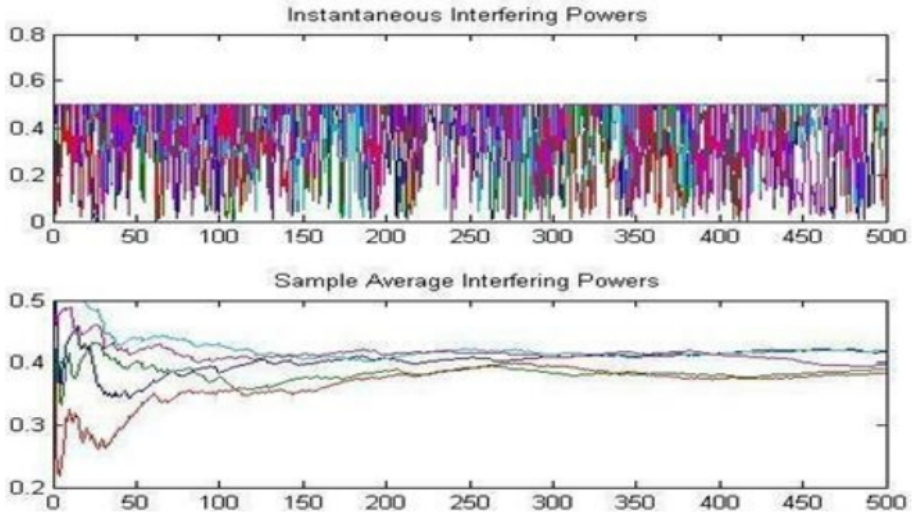


Fig 11. Instantaneous interfering powers and sample average interference power for Underlay Network.

VIII. CONCLUSION

Stochastic resource allocation algorithm is one of the major solutions for the underutilized spectrum in IoT. This algorithm is subjected to two parameters viz., probability of interference and average power. In this paper we discussed two types of interference constraint, short term constraint where channel state information fault are imperfection confirms that probability of interfering at any instant does not exceed given threshold. Another constraint is long term constraint here we considered diversity of interfering channel to confirm that instant of time during interference occurred does not exceed the threshold and finally those terms were multiplied by Lagrange's multipliers based on their previous channel history and ultimately genuine spectrum management is performed using cognitive radio technology for users involved in wireless communication.

DECLARATION

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Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	First author: data analysis process and practical implementation done. Second author: literature survey modelling. Third author: mathematical concept analysis.

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Multi Wear Response Optimization of Ti-6Al-7Nb Biomedical Alloy

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ABSTRACT

Titanium-Niobium (Ti-Nb) based alloys are predominantly used as an implant material within the Bio-medical field due to their unique characteristics such as non-toxicity, better Osseo-integration, high resistance to corrosion, high strength to weight quantitative relation and biocompatibility. This paper proposes to optimize the control parameters for multi-response optimization of Ti-6Al-7Nb bio-medical alloy based Grey Relational Analysis combined with the Taguchi approach. Wear rate (WR), coefficient of friction (COF), and frictional force were the response characteristics studied (FF). The Taguchi methodology is used in conjunction with the grey interpersonal evaluation as a performance index to determine the best set of control parameters. Applied Load, Rotational Speed, and Time were the control parameters evaluated. Experimentations are designed using L9 Taguchi's orthogonal array and carried out on a pin-on-disc setup in agreement by ASTM G99. The experimental outcomes display that the applied load has the greatest impact on the Ti-6Al-7Nb bio-medical alloy's various wear characteristics. This approach has been successfully rummage-sale to recover the wear response of Ti-6Al-7Nb bio-medical alloy.

Keywords: Bio-Medical Alloy, Pin-On-Disc, Grey Interpersonal, Optimization and Taguchi Method.

I. INTRODUCTION

Humans regularly use biomedical materials as constructions and implants to replace missing or injured biological structures and improve their excellence of lifetime [1] [2] [3]. As people get older, they may have joint inflammation and pain, which increases the request for artificial instruments made of biomedical resources to substitute malfunctioning hard tissues [4]. Metals have been employed in a diversity of medicinal purposes for decades [5]. Co alloys, Ti alloys, and stainless steels are the most commonly utilised metals and alloys in biomedical applications. Titanium (Ti), in particular, is a metallic material that has been used as an implanted biomaterial for a variety of human organs, including hips, heart valves, blood channel stents, knees, shoulders, and spinal substitutes. All biomaterials must-have characteristics like high strength, high resistance to corrosion, bio-adhesion, bio-functionality, biocompatibility, high wear confrontation, and low coefficient of friction [6].

Because titanium alloys have a lower density and modulus of elasticity than stainless steel andCobalt-Chromium-Molybdenum alloys, their utilisation has expanded significantly since 1970. Ti-6Al-4V titanium alloy has good resistance to pitting corrosion. Because Ti alloys are alloyed with Nickel and have a form memory effect, they are ideal for dental applications [7]. The most common causes of implant failure have been documented to be wear and corrosion. Wearing dentures, plates, screws and heart valves in bone fracture healing, and other biomedical applications of tribology. Wear is a key feature in predicting and controlling metallic biomaterials' lasting therapeutic use [8].

When compared to other metallic biomaterials, titanium alloys have been extensively rummage-sale in biomedical applications due to their better properties such as high specific strength, excellent mechanical capabilities, higher biocompatibility and advanced erosion resistance [9]. The primary rationale for the growth of Ti alloys for bio-medical requests is their wear resistance when in contact with the body's sliding and rubbing surfaces [10]. In general, steel alloys have been utilised extensively in the production of orthopaedic grafts, thus the best excellence and dominance of orthopaedic grafts and instruments, as well as a reasonable price, are the demands of the twenty-first century. The wear response of a bio-implant substrate material is critical for the effective and safe usage of orthopaedic implants. Wear is the loss of material particles as a result of comparative gestures between two surfaces [11].

Numerous features pay to the long-term survival of biomaterial implants in terms of performance. Wear could be the initial prevailing factor in the proper performance of orthopaedic bio graft materials in an aerial context [12]. Because a human boy's bone and bone tissue are subjected to extreme stresses during physical activity, artificial implants with greater load-bearing capability are required. Stainless steel and titanium alloys are used in orthopaedic load-bearing bio grafts like knee and hip joints because of their better mechanical qualities and erosion resistance [13-14]. Surface modification and a good wear mechanism were recommended for the long life and good functionality of an orthopaedic implant material for enhanced sturdiness inside the human body [15]. Wear failure, fatigue failure, and corrosion failure are the three most common failure mechanisms in engineering materials, with wear failure being the most common in joint prostheses [16-17].

The material's tribological responses like wear mechanism and wear rate are mainly depending upon the production process of an alloy. The overall performance of bio-implant alloy depends on the heat treatment techniques [18]. In the human body for the effective usage of bio-implants, it is essential to understand all aspects of bio-implant materials. In orthopaedic implants wear is a serious concern, wear or rubbing between parts leads to the generation of metallic ions. These ions contact tissues and blood which causes big trouble. So, to prevent this it is essential to make use of materials with superior properties [19]. The Taguchi approach based on the regression equation was used to analyse the tribological characteristics of Ti-3Al-2.5V and find the best process parameters. [20]. The outcomes of the attire behaviour of Ti alloy using RSM show that when the increased sliding speed and applied load, the specific wear rate rises and then drops with the increase in sliding distance and speed [21]. The influence of microscopic structure on the dry sliding attire response of Ti alloy using Taguchi's DOE, results reveal that a lamellar microscopic structure has minimal wear resistance followed by equiaxed and bimodal microscopic structures [22]. Wet wear sliding parameters are optimised for Titanium grade 2 and grade 5 bio implant alloy by RSM, the results showed that weight reduction will rise with the rise of applied load and velocity of rubbing [23]. Using a conventional hip joint simulator in simulated body fluid, the wear behaviours of biomedical CoCrMo prosthetic alloys containing varying concentrations of carbon were examined. The abrasion and run-in wear was caused by a few chunks and nodules-phase precipitates found in the low-carbon (LC) alloy. Increased carbon concentration resulted in more globular M23C6-type carbides precipitating. [24]. The effect of surface texturing on the tribological mechanism of nitrided titanium alloy (Ti–6Al–4V) was examined experimentally. In a plasma nitriding furnace, the titanium alloy samples were nitrided for 10 hours at temperatures ranging from 750 to 950 °C. At nitriding temperatures of 900 and 950 °C, the combination treatment of nitriding and surface texturing can significantly reduce the friction coefficient and wear rate [25]. The goal of this study was to evaluate the tribological behaviour of Ti-24Nb-4Zr-8Sn (β -type microstructure) alloy to Ti-6Al-4V (α+β -type microstructure) alloy for a joint prosthesis in terms of the coefficient of friction and tangential force. For both alloys, the coefficient of friction () was only slightly affected by load, yet tangential force increased as load rose [26]. Without discussing the effect of tribo-oxides. The dry sliding wear behaviour

of Ti–6Al–4V alloy descending against itself at various sliding velocities and loads was investigated to validate the alloy's inadequate wear resistance to plastic deformation at low loads and the insufficient defence provided by the surface oxide. The tribological properties of a titanium alloy when sliding on zirconium ceramics without lubrication were investigated. The coefficients of friction and wear resistance of friction pairs are explored in settings where liquid lubricants are not available. The feasibility of using zirconium ceramic materials to improve the reliability and service life of friction units working without lubrication at high temperatures in contact with a titanium alloy has been established as a result of the research [27]. To deal with the difficult problem of boundary lubrication for steel/Ti6Al4V, the promising lubricant combines Zn nanoparticles and a polyethene glycol (PEG) base oil. Tribological tests were conducted to study the performance of boundary lubrication and the process of forming boundary protective layers on the worn surface. The results revealed that PEG suspensions with Zn nanoparticles could achieve low and constant friction coefficient curves after a very short 'run-in' period and that the main wear volume of Ti6Al4V occurred during the 'run-in' phase [28]. The multi-objective optimization of dry sliding wear parameters of AA7068 / TiC metal matrix composites was investigated using Taguchi and Grey relational analysis. Rotating speed (Nr) is the most important process parameter, accounting for 38.08 per cent of the total, followed by slide velocity (Vs), accounting for 30.99 per cent [29]. Grey relational and statistical analysis were used to optimise the milling settings of Ti6Al4V alloy. The most significant parameter for multi-objective optimization during the face milling of Ti6Al4V is surface roughness and depth of cut, which improved by 55.81 per cent and 23.98 per cent, respectively [30]. To optimise the responses, a Grey relational analysis approach was used. The results demonstrated that the chosen parameters have a considerable impact on the alloy samples' responses.

A compacting pressure of 760MPa, a sintering period of 6 hours, and a magnesium content of 15wt% were found to be the optimum levels of the influencing parameters [31]. Grey relational analysis is used to enhance electric discharge machining parameters for orthopaedic applications. The most important process parameters, according to the results of the experiments, are voltage and current [32]. GRA was used to optimize PMWEDM settings. The most significant parameters for surface roughness were found to be powder concentration and pulse on time, whereas the most significant characteristics for surface roughness were found to be pulse off time and gap voltage [33]. Grey interpersonal examination was rummage-sale to optimise carbon steel Ck45 revolving procedure limits. Depth of cut, feed rate and cutting speed all had a percentage contribution of 12.63 per cent, 8.41 per cent, and 34.62 per cent, respectively, in determining the major performance characteristics. The proportion input of the Grey interpersonal grade was considerably influenced by two factors: depth of cut and cutting speed, most important component in the performance was the depth of cut [34].

The GRA approach was used to find the best laser drilling parameters with many performances attributes. The best parameter setting results in a tiny HAZ (Heat-affected zone), maximum material removal rate and fine hole [35]. Electro Discharge in Wires GRA is used to optimise machining settings. Wire feed rate, pulse on time, pulse off time, wire tension, voltage and applied current are the sequence of control parameters. GRA and the Taguchi approach were used to achieve multi-objective optimization of machining settings for drilling Al/SiC MMC. The drilling of Al/SiC MMC is influenced by feed rate, cutting speed and point angle conferring to the findings. Point angle has the greatest influence (43.21%), followed by 26.21% of feed and 28.64% of cutting speed [36]. Using the GRA Technique, milling parameters of toughened 465 steel were optimised. Cutting speed, with a high significance of 53.04 per cent, is followed by the depth of cut, with a significance of 38.09 per cent [37].

From the literature assessment, it is obvious that no comprehensive work on the optimization of attire physiognomies of the biomedical alloy Ti-6Al-7Nb exists. By integrating GRA and statistical approaches, this study attempts to analyse the essential parameters determining the wear retort of the biomedical alloy Ti-6Al-7Nb. Also, to identify the best set of control parameters for the Ti-6Al-7Nb biomedical alloy that minimises wear, COF, and frictional force (FF).

II. THE EXPERIMENTAL SETUP,MEASUREMENTS AND OPTIMIZATION

Titanium (Ti-6Al-7Nb) Alloy, graded ASTM F 1295, was chosen as the material for this project. Because of its lightweight, higher strength/weight ratio, advanced erosion resistance, biocompatibility, non-toxic, better Osseo integration, and long-range availability, Ti-6Al-7Nb alloy is widely used in the medical field, including spinal fixators, orthopedic grafts, dental implants, and artificial hip joints. Because the liberation of vanadium ions from the Ti–6Al–4V alloy poses a difficulty, in the long run, this alloy may be considered the best substitute material for the commonly used Ti-6Al-4V alloy. In this study, test specimens with smooth ends measuring 9 mm in diameter and 50 mm in length were constructed for the wear test. Waterproof silicon carbide emery sheets of various grit sizes were used to polish the surface. After that, before starting the test, wipe it clean with acetone. The test specimens of the required dimensions are shown in Figure 1.

Fig. 1. Ti-6Al-7Nb alloy Test Specimens

The experiments were prepared and carried out on a computerised Pin-on-Disc machine in agreement with ASTM G99-04 requirements using Taguchi's L9 orthogonal array. The applied load, rotating speed, and time are the independently controlled process parameters investigated in this study. All of the components used in this study are multi-level variables, and their outcomes are not linearly related, therefore the usage of three levels for each factor is confirmed. Table 1 shows the control factors and their stages. Wear, COF and FF were the output characteristics studied in this study. Figure 2 shows a snapshot of the experimental setup.

Fig. 2. Photograph of the experimental setup

Table 1. Control factors and their levels

Process parameters	Units	Notation	Levels		
			1	2	3
Applied Load	N	L	30	50	70
Rotational Speed	RPM	RS	300	500	700
Time	SEC	T	300	420	600

By combining GRA and statistical approaches, this study proposes an excellent method for determining the critical control parameters controlling the wear response. Furthermore, the ideal set of control variables for obtaining the lowest FF GRA, WR and COF are presented in Table 2.

Table 2. Experimental Runs and Responses

Test Run	Applied Load(N)	Rotational Speed (RPM)	Time (Sec)	Measured Responses		
				Wear (µm)	Coefficient of friction	Frictional force
1	30	300	300	85	0.422	12.72
2	30	500	420	123	0.373	11.20
3	30	700	600	229	0.331	9.82
4	50	300	420	146	0.424	21.13
5	50	500	600	115	0.363	18.80
6	50	700	300	254	0.351	17.30
7	70	300	600	156	0.423	28.50
8	70	500	300	162	0.384	26.12
9	70	700	420	337	0.361	25.80

A. Optimization of wear responses

The signal-to-noise (S/N) ratio is the summary statistic (η) in the Taguchi approach. An S/N ratio is a useful tool for predicting how control factors affect attributes. The S/N ratio was assessed using the smaller-is-better (SB) Principle.

$$\eta = 10 \log \frac{1}{\sigma^2} = -10 \log \sigma^2 \quad (1)$$

For, Smaller-the-better (SB)

$$\sigma^2 = \frac{1}{n}(y_1^2 + y_2^2 + \cdots + y_n^2) \quad (2)$$

Where (η) represent the computed worth of the S/N ratio. Yn denotes the slow trial value and n is a frequent numeral. Wear, COF and frictional force are in the group of smaller-the-better presentation features. The experimental result along with the mean S/N ratio is shown in Table 3.

The main effects plots shown in Figure 3 (a-c) show the main effect plots for wear, coefficient of friction and frictional force. From the Figure 3 (a-b) response plot for wear and coefficient of friction, it is inferred that the rotational speed is the most prominent parameter followed by applied load and time. From Figure 3 ©, it is clear that the frictional force is affected by applied load and followed by rotational speed and time.

Fig. 3 (a). Response plot for wear

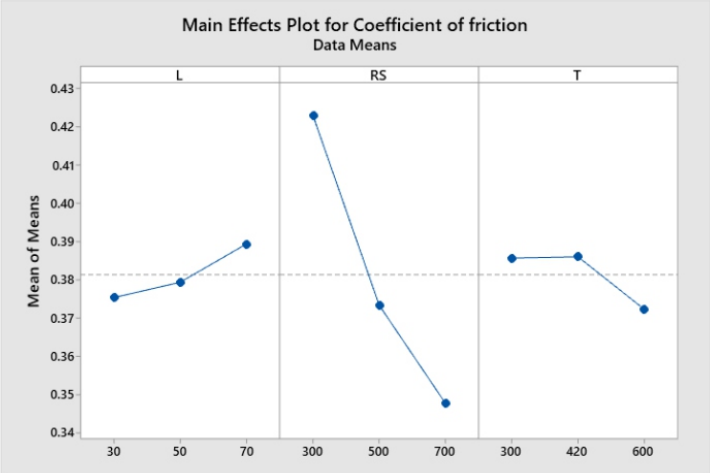

Fig. 3 (b) Response plot for Coefficient of friction

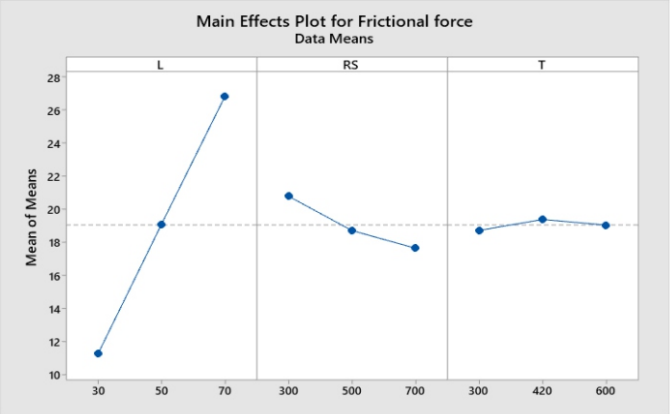

Fig. 3 (c) Response plot for Coefficient of friction

Fig. 3 (a-c) Reponse plots for the responses

The statistical significance of the control parameters impacting tribological behaviour was investigated using an ANOVA analysis. The goal was to see how the applied load, rotational speed, and time affected the whole alteration of the outcomes. The ANOVA findings with the COF, WR, and FF are shown in Table 5, Table 6, and Table 7. The investigation was carried out with a 5% level of significance, which equates to a 95% level of confidence. The F-values and proportion contributions are also shown in the ANOVA Table. The relevance of the factors can be understood by comparing the F-values to the tabulated ones. If a parameter's obtained F value is more than its calculated value, that limit has a considerable impact on the retort adjustable. Table 4, Table 5, and Table 6 show that within the given test range, rotating speed has the most significant impact on machinability. The P-values in Table 4, Table 5, and Table 6 reveal that process parameters have a significant impact. From there, it's clear that rotational speed has a greater impact in this study. Statistical analysis of means was used to quantify the percentage contribution of elements such as FF, COF and WR to the variation in responses. The equation gives formula for calculating % contribution is shown as Equation 3. The computed % contribution factor for various output limits such as FF, COF and Wear are presented in Table 7. Table 7 displays the percentage influence of each factor. The rotational speed is the most important controlling factor for the coefficient of friction (92.74%) and the wear (79.21%), whereas the applied load is the most important influencing factor for frictional force (95.7%).

Table 3. ANOVA for Wear

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Applied Load (N)	2	8134.2	8134.2	4067.1	2287.75	0.000
Rotational speed (RPM)	2	40450.9	40450.9	20225.4	11376.81	0.000
Time (Sec)	2	2473.6	2473.6	1236.8	695.69	0.001
Residual Error	2	3.6	3.6	1.8		
Total	8	51062.2				

Table 4. ANOVA for Coefficient of friction

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Applied Load (N)	2	0.00031	0.00031	0.000156	24.63	0.039
Rotational speed (RPM)	2	0.00880	0.00880	0.004400	694.79	0.001
Time (Sec)	2	0.00036	0.00036	0.000182	28.79	0.034
Residual Error	2	0.00001	0.00001	0.000006		
Total	8	0.00949				

Table 5. ANOVA for Frictional force

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Applied Load (N)	2	363.175	363.175	181.588	19249.58	0.000
Rotational speed (RPM)	2	15.331	15.331	7.665	812.59	0.001
Time (Sec)	2	0.660	0.660	0.330	34.99	0.028
Residual Error	2	0.019	0.019	0.009		
Total	8	379.185				

Table 6. Percentage contribution of factors

Parameter	Wear % Contribution	Coefficient of friction % Contribution	Frictional force % Contribution
Applied load	15.9	3.3	95.7
Rotational speed	79.21	92.74	4.04
Time	4.8	3.84	0.17
Error	0.007	0.13	0.005

A unique optimization methodology combines the Taguchi technique through Grey Relational Analysis (GRA). The grey principle is based on the unpredictability of small random trials, which has evolved into an assessment method for resolving challenges with insufficient statistics and complexity. A 'White' system is one in which all data is known, while a 'Black' system is one in which certain statistics are hidden. If any system exists between these two extremes, it is referred regarded as a 'Grey' system, which has weak or limited statistics [17]. In GRA, a normalization assessment approach is used to rapidly resolve the difficult multi-response characterization.

$$\text{Percentage contribution} = \frac{\text{Sum of Squares}}{\text{Total of Sum of Squares}} \qquad (3)$$

Normalization is achieved by deviating the data series inAboriginals by their average during pre-processing or grey relational creation of accumulated data [18]. WR, COF and FF are the data to be standardised in this inquiry FF. Because the GRA may produce incorrect findings if these wear responses have different measurement units, they must be arranged under identical units. It's the process of converting a novel order series into a similar series [19].

As a result, the experimental findings are normalised from 0 to 1. Lowe-the better criterion was utilised in this experiment for processing wear retorts such as WR, COF, and FF and is given by Equation 4.

$$X_i(K) = \frac{\text{Max } Y_i(K) - Y_i(K)}{\text{Max } Y_i(K) - \text{Min } Y_i(K)} \quad (4)$$

Where xi (K) is the rate afterwards grey interpersonal generation, Min Yi (K) is the smallest Yi (K) value for the Kthresponse, and Max Yi (K) is the greatest Yi (K) value for the Kth response. After the data has been processed, the GRC (grey interpersonal factor) must be calculated using Equation 5.

$$\xi_i = \frac{\Delta_{min} - \Delta_{max}}{\Delta_{oi}(k) - \zeta\Delta_{max}} \quad (5)$$

where "Δoi (k) =||xo (k) – xi (k) || is the difference of absolute value between x0 (k) and xi (k), ζ=Distinguishing coefficient (0 ~ 1), ζ= 0.5 commonly used, Δ min= minimum value of the deviational sequence, Δ max = maximum value of the deviational sequence. After finding the GRC the grade of grey relation is found using the following relation (6).

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\xi_i(k) \quad (6)$$

The GRG for the kith experiment is γi and the number of wear responses is n. The GRG will be used to determine the best control factors. The grey relation grade depicts the association among the orders as well as the result of the comparability and orientation sequences. The GRG is equivalent to 1 when both sequences are equal. GRG with a higher value tends to have optimal parameters [20]. Multi-retort optimization is reduced to a single grey relational grade optimization in another way.

III. RESULTS AND DISCUSSIONS

In the Bio-medical field, Titanium-Niobium based alloys are widely used due to their unique characteristics such as non-toxicity, better Osseo-integration, high strength/weight ratio, high erosion resistance and biocompatibility. During the Wear test of Titanium (Ti-6Al-7Nb) alloy the Wear, COF and Frictional force (FF) would be kept minimum to avoid failure of the implant. In this investigation, lower values of Wear, COF and Frictional force (FF) were the desirable targets. The statistics dispensation of each retort characteristic had been resolute by equation 4 and is shown in Table 8. The GRC and GRG for each response characteristic are determined by equations 5 and 6 and are exposed in Table 9. From Table 9, it is inferred that trail 3, having parameters L1, RS3, and T3 has a higher GRG of 0. 819624. Despite this, the relative significance of each control factor was too designed to find the best mixture of the control factors additional precisely carried out using response graphs and Analysis of Variance (ANOVA).

Table 7. Data processing of each performance parameter

Exp. No.	Wear	COF	Frictional Force
1	1	0	0.836
2	0.767123	0.65094	0.92119
3	0.589041	1	1
4	0.824658	0.08491	0.39936
5	0.613699	0.50943	0.51651
6	0.416438	0.82075	0.59638
7	0.673973	0.20755	0
8	0.780822	0.53774	0.13312
9	0	0.5283	0.1278

A. Statistical Analysis

The reaction graphs and retort table were rummage-sale to analyse the impact of control limits on wear characteristics. Table 9 shows the average GRG standardsat each level of specified control limits. By picking the greatest value of the GRG, it provides the foundation for the most optimal setting of the control parameter levels.

Table 8. GRC and GRG for each performance characteristic

Exp No.	Wear Rate (WR)	Coefficient of Friction (COF)	Frictional Force (FF)	GRG	Rank
1	1	0.3333	0.7530	0.735	2
2	0.6822	0.5888	0.8638	0.711	3
3	0.5488	1	1	0.819	1
4	0.7403	0.3533	0.4542	0.455	7
5	0.5641	0.5047	0.5083	0.555	5
6	0.4614	0.7361	0.5533	0.583	4
7	0.6053	0.3868	0.3333	0.441	9
8	0.6952	0.5196	0.3657	0.526	6
9	0.3333	0.5145	0.3643	0.434	8

Low wear, low coefficient of friction (COF), and low frictional force are all achieved by increasing the levels of grey relationship grades (FF)

The ideal process factor combinations have been determined as L1, RS3, and T2 by retort Table 10 and retort Figure 4. The load applied is a very essential factor for multi-wear response features of Ti-6Al-7Nb alloy, according to the rank (Max-Min Value). ANOVA is used to corroborate the results.

Table 9. Response table for GRG

Parameter	1	2	3	Rank
Applied load (N)	**0.7556**	0.5318	0.4676	**1**
Rotational Speed (RPM)	0.5444	0.5981	**0.6124**	**3**
Time (Sec)	0.6153	0.5339	**0.6057**	**2**

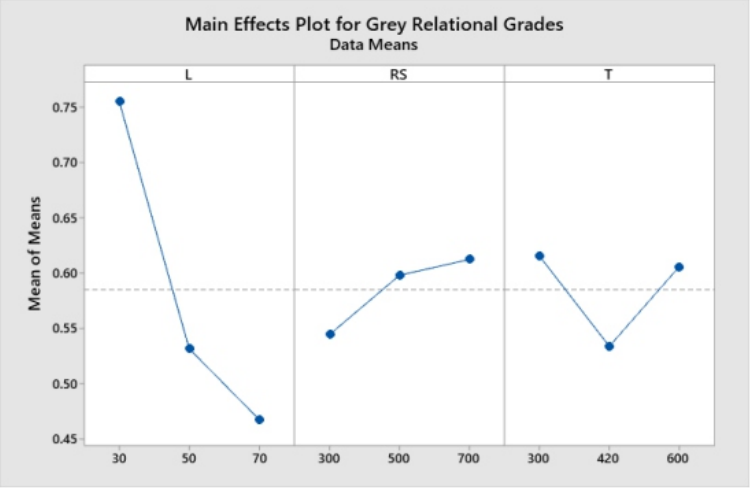

Fig. 4. Response graph for the grey relational grade

ANOVA is useful for finding the control parameter that has an important effect on the wear retorts. The F-test is rummage-sale to regulate each control factor's statistical relative significance. Table 10 shows that the most influential control parameter is applied load, which accounts for 84.62% of the total contribution, followed by time and rotating speed.

Table 10. ANOVA for GRG

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value	Contribution (%)
Applied Load (N)	2	28.2432	28.2432	14.1216	198.55	0.005	84.62
Rotational speed (RPM)	2	1.9297	1.9297	0.9649	13.57	0.069	5.78
Time (Sec)	2	3.0596	3.0596	1.5298	21.51	0.044	9.16
Residual Error	2	0.1422	0.1422	0.0711			0.43
Total	8	33.3747					

IV. CONCLUSIONS

This study resolves to use Taguchi-GRA to optimise dry descending attire parameters of Ti-6Al-7Nb biomedical alloy with numerous attire characteristics, such as Wear, Coefficient of friction and frictional force.

• The greater the GRG, the closer you are to the ideal situation.

• The findings of the Grey and statistical analyses reveal that the applied load is the most critical influencing factor that influences the Ti-6Al-7Nb Biomedical alloy's various wear properties.

• Conferring to the retort table, the biggest standards of GRG result in the best combination of control parameters, namely a 30 N applied load, a revolving speed of 700 rpm, and a time of 420 seconds.

• Wear, COF, and frictional force are the best combinations of these factors for minimising wear characteristics.

•The applied load is the most influencing factor of the frictional force and Rotational speed is mostly affecting the coefficient of friction and wear.

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Anthors Contributions	All authors have equal participation in this article.

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Low-cost Magnetic Resonance ConsoleArchitecture using an Open Source for LaboratoryScale Systems

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ABSTRACT

MRIsystems with proprietary hardware must use pulse programming, which is less expensive. Pulse programming consoles use Digital Signal Processor, Complex Programming Logic Device, and microcontrollers, which are typically restricted to particular architectures. General–purpose, extremely affordable electronics board featuring these architectures are now capable enough to be directly implemented in MRI consoles. Here we present the architectural details of various consoles with novel designs and their limitations. Finally, we propose a console design which was created utilising widely accessible Arduino Boards to connect to Pulseq-GPI implementations at a reduced cost of $225.

Keywords: Direct Digital Synthesizer, Microcontrollers, MR Console Architectures, Pulseq-GPI

I. INTRODUCTION

Magnetic Resonance Imaging (MRI) system consoles have different architectures depending on the type of data and logic processing device, its implementation and the software to run the system. MRI pulse sequences require an intelligent console that coordinates real-time operation of RF and gradient systems, data gathering, and processing. The use of proprietary software, hardware, and interfaces prevents any growth or adjustment to novel methods and experiments. A significant design challenge is posed by meeting contemporary requirements for large number of channels, real-time imaging capability and customizable interfaces. While radio frequency sampling and synthesis are easily handled by Software Defined Radio (SDR), effective data management and real-time control still pose a challenge. Scalable modular system architecture is necessary for the effective and versatile implementation of such systems. Peripheral Component Interconnect (PCI) cards, which offer high-throughput low-latency connectivity at the expense of scalability, cost efficiency, and design time. Although performing tasks in real-time with software or a microcontroller may offer considerable flexibility, it places severe limits on programme design and makes wasteful use of the processing power and hardware resources that are available.

II. ARCHITECTURES

The console architectures are classified based on the processing device and its hardware / software capabilities:Microcontrollers (μCs) are self-contained systems with aprocessor, fixed amount of memory and peripherals on a single integrated circuit. They have the capability of mixedsignal processing at reduced costs and programming complexity.

S. Handa et al., have demonstrated a single chip pulse programmer (PPG) using ADμC7026 microcontroller board,[1] which consists of a 32-bit reduced instruction set computer central processing unit (RISC CPU) core(ARM7TDMI) with a clock frequency of 41.78 MHz, 62 kilo bytes (kB) of programming (flash) memory and 8 kB of static random access memory (SRAM), a 16-channel analog to digital converter (ADC)and 4 digital to analog converters (DACs), two timers, and a 40-bit digital input/output (I/O) port. The board was integrated with a personal computer (PC) via the universal serial bus (USB) to RS-232C converter circuit, and on the other end with a MRI transceiver and gradient driver. The programs for the microcontroller and host PC were developed using KEIL development suite and GNU C compiler on Linux emulation platform, respectively. The cost of the board is approximately U.S. $10, with limitations of relatively long delay time between event and event data memory. The work of M. Tsuda et al., interfaced a PC withthree32-bit ARM based RISC μCs, and digital oscilloscopes with an inbuilt and external arbitrary waveform generator (AWG).[2]. The μCs used were Arduino DUE with a clock frequency of 84 MHz, two 12-bit DACs,96kB SRAM and 54 I/O pins. Pico Scope 3205B (250 MHz sampling speed) along with an external AWG-100 (100 MHz sampling speed) was used in one design and an oscilloscope with a built-in AWG (Pico Scope 5242B) (1GHz sampling speed) was used in another. The programs were developed using Qt 5.3.0 and C++ on the host PC which downloads the target programs on the μCs using Arduino Integrated development environment. The total cost of the either console waslessthan $ 1500. Although under sampling and phase correction were required, the system provided flexibility in pulse sequence design.

An inexpensive widely available Arduino Duemilanove board based on ATmega 328 μC (16MHz clock frequency) using the arduino open source programming platform, with a single USB connection to the host PC was used for MR spectroscopic measurements in earth's field by Carl A Michal.[3]The μC has 14 digital I/O pins, 6 analog input pinsthat acted as a pulse programmer, audio frequency synthesizer, ADC and could produce trains of phase coherent radio frequency pulses with reproducible timing allowing signal averaging and phase cycling. The μC was used as a state machine and pre-calculated states and events were downloaded from the host PC as the available memory was limited for to run sequences in real time. The cost of the system is within $ 200 and restricted to spectroscopic sequences.

M. Twieg et al., have demonstrated an open source, fully packed and functional NMR relaxometry platform based on AT32UC3C1512 μC from Atmel.[4] The 32-bit CPU operating at 64 MHz with 512 kB flash, 64kB SRAM, 16 ADC channels and 2 DACs allowed for more sophisticated and configurable pulse sequences, and faster handling of sequence events. The board was integrated with a PC running Matlab and an AD9958 DDS module for RF signals, to define experiments and analyse sampled data. The cost of the chip is less than $ 750.

Meghan E. Halse work on "Terranova" contained a Digital Signal Processor board at the core for pulse programming and signal acquisition functionality that used USB Interface to communicate with the PC.[5] The interfacing software used was Prospa.

Field Programmable Gate Arrays (FPGA) are integrated circuits that contain an array of programmable logic blocks that can be configured using a hardware description language to perform complex combinational functions. They are generally higher in cost and programming complexities compared to microcontrollers but are more versatile.

A home-built MRI system with digital spectrometer was demonstrated by S. Jie et.al.[6] The console design consisted of XC2S200 (Xilinx) RF waveform generator, digital receiver, gradient waveform generator, and pulse generator boards are all logically controlled by an FPGA processor. The boards were interfaced with a PC using PLX9052 chips, serving as a bridge between local bus and PCI bus. In addition, one or two 16-bit SRAMs of 256kB were attached to each board for each board for the purpose of storing data.AD9854 DDS chip, running on a clock frequency of 50 Mhz was used for RF Pulse generation. The receiver was based on AD9874 chip for software radio technology, and the gradient board utilizes AD5542 DAC chip for each channel. Delphi 7.0 running on the host PC was used to create the software winMRI, which controls hardware and displays gathered data in real time. The system was implemented at a cost of $ 12000.

K. Takeda displayed that a single FPGA chip was sufficient to work as a PPG, DDS, a digital receiver and PC interfaces for command/data transfer.[7]. The system consists of an Altera EP2C70F672C8 (Cyclone II) FPGA chip controlled by a 30 MHz crystal and a number of auxiliary boards for USB connectivity, direct-digital synthesis (DDS), RF transmission, signal acquisition, etc. Each of the three RF channels in this spectrometer has the ability to modulate the amplitude, phase, and frequency of RF irradiation at frequencies up to 400 MHz. The mother board is surrounded by the other modules. The source codes for the VHDL written programmes for the core modules that the FPGA uses to execute them in parallel are accessible on the author's website.

Preeti Hemnani et al., have demonstrated in detail the setup of FPGA as a Pulse programmer and a direct digital synthesizer.[8] Their architecture requires a DDS integratedwith an external DAC to generate coherent and accurate Phase and frequency modulated pulses for very short intervals. The pulse programmer was mapped as a finite state machine, to generate accurate timing pulses for durations as short as 1μs. Labview was the application software for the FPGA and communication with the PC was established through PCI bus.

H-Y Chen et al., have successfully demonstrated the improved capabilities of the system using Cyclone II, Altera FPGA, operating at 50 MHz.[9] To do away with the requirement for an external DAC, they have integrated the digital frequency generation with an amplifier (MAX4384EUD+; Maxim Integrated, CA) and a bandpass filter. The custom logic blocks are used to run the NMR pulse programme. An FPGA-programmed direct memory access (DMA) controller is used to play back the pulse sequence. By altering the speed of the clock used to time the events of the pulse sequence, even the device's time resolution can be altered in this design. The on-board digitizer provides the data acquisition. The data is read from the memory and sent to a host computer over a USB port using the same processor.

A digital I/O board was used as a pulse programmer by Hashimoto et al., which has a 32-bit input/output lines with a maximum transmit rate of 20 MHz, 32 MB on-board memory, 30 DAC outputs, and a mixer with filter.[10]Cyclone III, ALTERA FPGA was configured as the I/O board, running at a clock frequency of 60 MHz. It communicates with the PC via USB. The interfacing software was developed using C/C++ and .NET framework 2.0 of Visual Studio 2008 running on Windows 7.

In a radio communication system known as Software Defined Radio (SDR), software on an embedded system is used to implement components that were previously implemented in hardware. ADCs, DACs, an FPGA for basic filtering and signal down- and up-conversion, and a USB interface are the typical components of SDRs. SDRs are inexpensive, easy to program and operate at relatively high frequencies. Two architectures based on SDR are discussed.

C. J. Hasselwander et al., assembled a console comprising of two GNU Radio compatible SDRs one for RF excitation and reception and other for gradient pulse generation.[11] The two SDRs are synchronised through pulses generated by the master in the master-slave SDR configuration. The software systems were built in python programming language in GNU radio and the authors have also released a software package implemented for four different sequences on the same platform. The total SDR hardware cost was $2000.

A. Asfour et al., worked on a fully digital RF electronics for the design of NMR systems at low field.[12] The system consisted of a DDS AD9852, for pulse generation, a SDRbased on an evaluation board of CLC5902 (National semiconductor) chip, for digital reception of NMR signals and a Digital Signal Processor (DSP) ADSP-2106x SHARC,for system control and for the generation of the gradient signals (pulse programmer). The DDS is used for pulse generation and the SDR is used as a receiver, and the DSP controls the DDS and SDR via its parallel external bus and was also interfaced with a PC. The SDR was integrated as close to the receiving coil to minimize noise and distortion associated with analog mixing stage. The software for the system was developed using LabWindows/CVI environment and DSP assembly language.

Programmable Logic Devices (CPLD's) having complexity between that of programmable logic arrays and FPGAs, with architectural features of both.

Pascal P. Stang et al., demonstrated a scalable console called "MEDUSA" using programmable logic for frequency synthesizing, sampling and synchronization.[13] It consisted of 16 modules over a 16-bit parallel data link with a dedicated logic core and system controller. The hardware included anAltera MAX-II EPM1270 CPLD logic core with identification registers,a Cypress CY7C1061 2Mbyte high speed SRAM, and DMA. Logic core was responsible for timing, sampling and data flow. The LPC2214 60Mhz 32-bit ARM-7 system controller was responsible for coordination of different modules. Matlab was used for system programming.The cores of the CPLD were developed using Verilog HDL. USB High-Speed (480Mbit/sec) support is implemented using a Cypress Semiconductor CY7C68013A FX2 USB peripheral interface.

Rapid sequence prototyping is supported by the alternative programming environment Pulseq, which is open-source and independent of hardware.

Layton, Kelvin J et al., proposes a new file format that may be used to store hardware events and timing data for MR pulse sequences in an effective manner [14]. The file is converted to the proper instructions for running the sequence on MR hardware using platform-specific interpreter modules. Sequences can be created using a graphical interface or highlevel languages like MATLAB.

Keerthi Sravan R. et al., To access to Pulseq, author demonstrated an open-source implementation of Pulseq in GPI Lab [15,16]. Additionally, it makes it possible to combine the pulse sequence design with the other components of the MR research pipeline—simulation, reconstruction, image analysis, and visualization—on a single platform using GPI. Through a gradient remembered echo, the Pulseq-GPI implementation is shown to be capable of constructing all of the sequences that Pulseq currently offers.

Commercially available consoles such as Portable Lab is abench top MRI scanner with hands-on examples optimized for scientific as well as educational use. It isa tool for developing and testing of MR hardware and MR sequences on desktop with six Digital I/Os3MTM Mini Delta Ribbon (MDR); 20 pins (10220-55G3PC) and open MATLAB interface [17] whereas MEDUSA, an open system combines distributed processing and buffering with scalability provided by the Universal Serial Bus. Fast programmable logic is used in Medusa's modular design for sampling and synchronization.[13]. Another popular MRI system is Terranova- MRI: Earth's field MRI teaching system [18], which is straightforward, portable, and user-friendly. It provides a fantastic starting point for education for new researchers in the field of NMR and was created specifically to study a variety of contemporary pulsed FT NMR and MRI teaching system [18], which is straightforward, portable, and user-friendly. It

provides a fantastic starting point for education for new researchers in the field of NMR and was created specifically to study a variety of contemporary pulsed FT NMR and MRI experiments and concepts.

III. IMPLEMENTATION

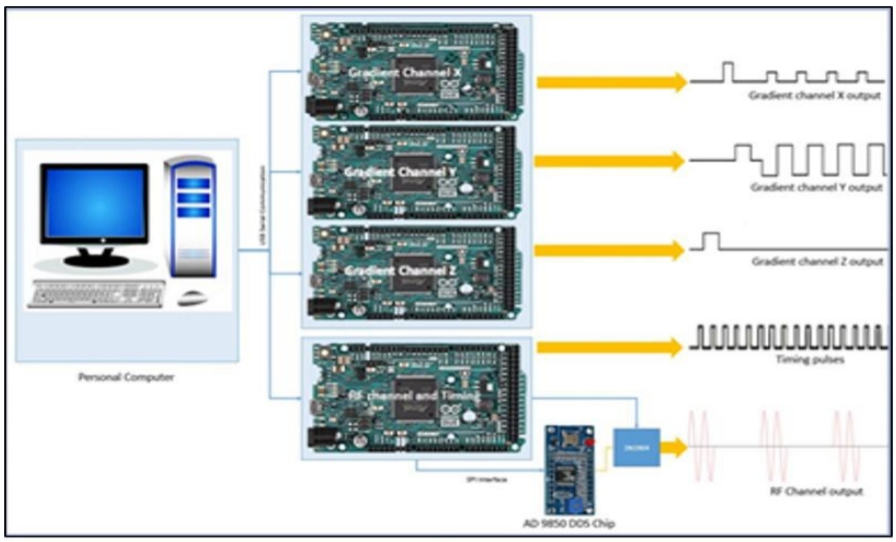
The reported pulse programming console implementations make use of DSPs, complex programming logic devices (CPLDs), and microcontrollers, which are often limited to specific architectures and require more time and money to create. As a result, at a reduced cost of $225, MR consoles for laboratory scale systems on an open-source platform were constructed for 9.5mT using accessible Arduino Boards to connect with Pulseq-GPI implementations. Data extracted from the Pulseq-GPI, stored and uploaded as a text file will support the microcontroller to play a 5s dwell period RF pulse and gradient waveforms (GX and Gy). At this moment, efforts are being made to integrate an analogue to digital converter for the Gradient Recalled Echo (GRE) sequence and speed up the uploading of the full sequence's waveforms.

A. Methods:

1. Hardware description: As illustrated in figure 1a, theconsole is made up of 32-bit general-purpose Arduino DUE boards, for each gradient channel Gx and Gy, for timing and regulating radio frequency (RF) pulses, and one board that can be readily expanded to include the third gradient channel (Gz). The AD9850 Direct Digital Synthesizer chip was connected to the RF-timer board, and it was programmed to produce a 405kHz RF sine wave, the output of which was sent to the collector of a 2N3904 transistor. Rectangular RF pulses were produced by switching the transistor's output with RF timer pulses. The gradient waveforms were played out on the internal Digital to Analog Converter outputs of the gradient boards Gx and Gy. To upload waveform data, each board is connected to a personal computer via the USB serial communication protocol.

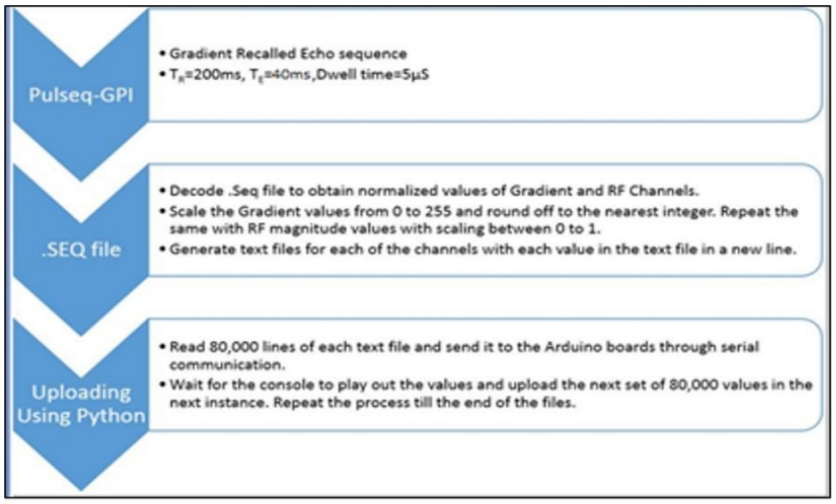
2. Software implementation:

As seen in figure 1b, the Pulseq-GPI based implementation creates a .seq file that has been decoded into three distinct gradient files and one RF pulse file. These files were then uploaded to each of the corresponding boards using Python running on a PC.



(a)

Figure 1 (a) This shows X, Y, Z gradient channel boards with outputs of each channel and RF channel. A serial peripheral interface (SPI) is connected to AD 9850 DDS chip. This chip is controlled by RF and timing Arduino board.



(b)

Figure 1 (b): Flow chart shows the events from Pulseq- GPI to generation of RF and Gradient waveforms.

In one occasion, 80,000 values, or data for two TR, were transferred to the boards and played out, taking around 11.2 seconds. Using scheduled interrupts from the DUE board, the timer produced precise synchronization pulses every 5 s for each instance. The transistor switch is controlled by the RF timer board based on the stored magnitudes of RF pulse as illustrated in figure 2a. The gradient boards are interrupt-driven and generate voltage values on their DACs with externally triggered interrupts, are illustrated in figure 2b.

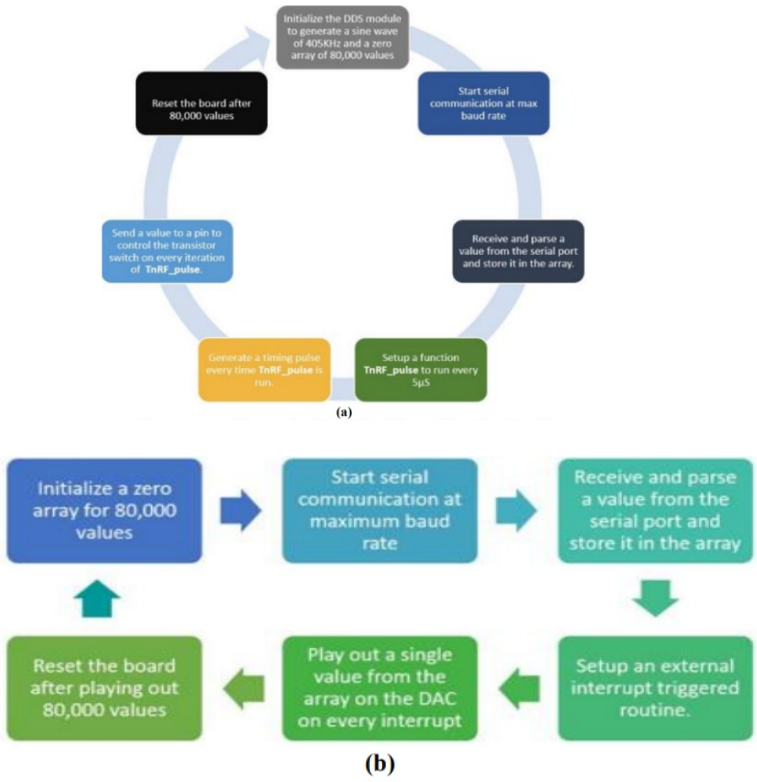


Figure 2: (a) shows the program flow diagrams for the Timer-RF of channel from Arduino DUE board and (b) shows the program flow diagram of Gradient Channel Board.

The system, consists of three boards and can play any two gradient channels together with an RF channel. This may be extended to include a fourth board for a third gradient channel. Figure lists the price of the console being created.

3. Cost of components:

Components	Cost	Source
Arduino Due	$38*5= $190	Arduino Store
AD 9850 DDS Chip	$15	EBay
2N3904 Transistor & wires	$5	Regional vendors
Total= $210 + (approx. Shipping costs) $15 = $225		

Figure 3: Arduino Due boards for three gradient channel, ADC channel board, a timer board for RF channel are listed. They are sourced from regional vendors with a cost of $225.

B. Results:

The designed hardware is a cost-effective solution to generate three Gradient and RF Channel waveforms. Hardware implementation using Arduino reduces the complexity of the MR pipeline design and development processes. Figure 4a shows the plot of uploaded data and Figure 4b and 4c shows 2 TRs with a dwell time of 5µs for 400ms of RF channel and Gradient channel waveforms. The RF channel and Gz channel output is illustrated separately in figure 4d & 4e, similarly Gx and Gy values are displayed in figure 4f.

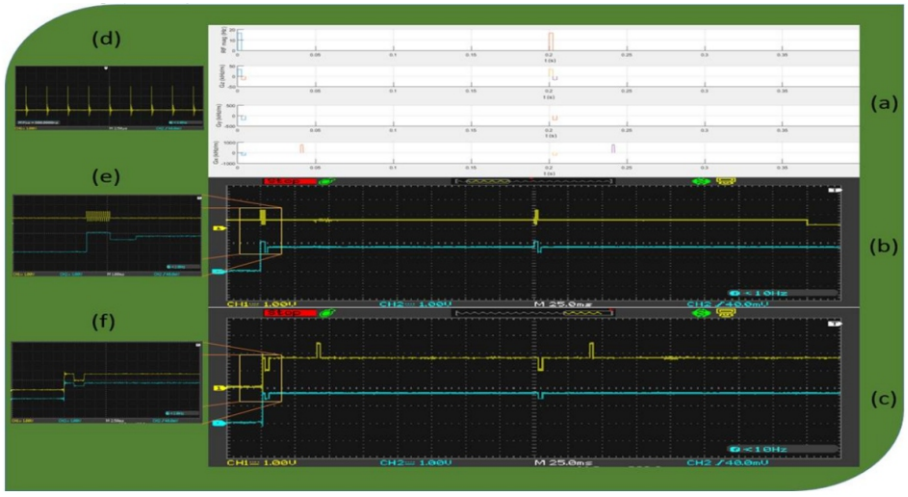


Figure 4: (a) shows the plot for the repetition time (TR) of 400ms for three gradient waveforms with RF channel shown separately. (b) Timing diagram of Gz channel (blue) and RF channel (yellow) (c) X Gradient (yellow) and Z gradient (blue) are shown. (d) Synchronization pulses of 5µs from RF channel (e) Timing diagram of X- Gradient (blue) and RF channel (yellow) (f) Timing diagram of X- Gradient (yellow) and Y Gradient (blue).

IV. DISCUSSION AND CONCLUSION

The system provides an affordable way to produce waveforms created using Pulseq-GPI. The system is being integrated with an ADC (for receive) in order to reduce the time required to upload the data for one instance (400ms) and/or interface the system with external memory cards to store larger sequence values. Future work involves interfacing the console with coil driver apparatus and integrate with low field lab scale MRI systems.

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Authors Contributions	Chennagiri Rajarao Padma, Methodology, Software, investigation, Visualization, Validation, Writing the draft K.M. Ravikumar, Conceptualization, Validation, review and editing, and Supervision

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