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Aims and Scope

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Contents

Data Collection Through Adaptive Cluster Head Selection Schemein Wireless Body Area Networks

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ABSTRACT

Due to the development in the field of Wireless Sensor Networks (WSNs), its major application, Wireless Body Area Network (WBAN) haspresently become a major area of interest for the developers and researchers. Efficient data collection is the key feature of any effective wireless body area network. Prioritizing nodes and cluster head selection schemes plays an important role in WBAN. Human body exhibits postural mobility which affects distances and connections between different sensor nodes. In this context, we propose maximum consensus based cluster head selection scheme, which allows cluster head selection by using Link State. Nodal priority through transmission poweris also introduced to make WBAN more effective. This scheme results in reduced mean power consumption and also reduces network delay. A comparison with IEEE 802.15.6 based CSMA/CA protocol with different locations of cluster headis presented in this paper. These results show that our proposed scheme outperforms IEEE 802.15.6 based CSMA/CA protocol in terms of mean power consumption, network delay, network throughput and network bandwidth efficiency.

Keywords - WBAN, CSMA/CA, LST, Adaptive Cluster head, Nodal Priority

I. INTRODUCTION

A wireless sensor network (WSN) consistsof sensor nodes to examine and monitor the environmental factors such as temperature, sound etc. and send their data to the base station as discussed in [1], [2], [3].Wireless Body Area Network (WBAN) is a special application of WSN to monitor things remotely. A WBAN is a special purpose sensor network which is developed to manage and communicate between various medical sensors, which are positioned inside and outside the human body [4]. A special example of WBAN is presented in Figure 1.In tier 1, these sensors, sense body temperature, heart beat rate, pulse rate and other required data and send it to personal coordinator through ZigBee or Bluetooth. The personal server or personal coordinator in tier 2 send these values to medical server through internet. The health care provider (doctor) sitting in tier 3 examines the results and gives precautions and medical treatments to the patient [5]

Human beings generally change their postures as shown in Figure 2. As the human body moves, the wireless connectivity amongst the nodes also varies. In this situation, the data cluster head has to be changed and adjusted as distance between sensor nodes varies. Another thing, which is very important for a cluster head is its accessibility by all neighboring nodes. This would ensure that each node sends its data to the cluster head, which will ultimately increase the reliability of WBAN.

Our proposed scheme is called Adaptive Cluster HeadSelectionSchemewith Nodal Priority for wireless body area networks, in which we are selecting a cluster head on the basis of link state. We have used Omnet++ with Mixim framework, which makes simulation, more realistic and reliable [6]. MoBAN mobility model, which is discussed in [7] is also used to establish postures for human body.

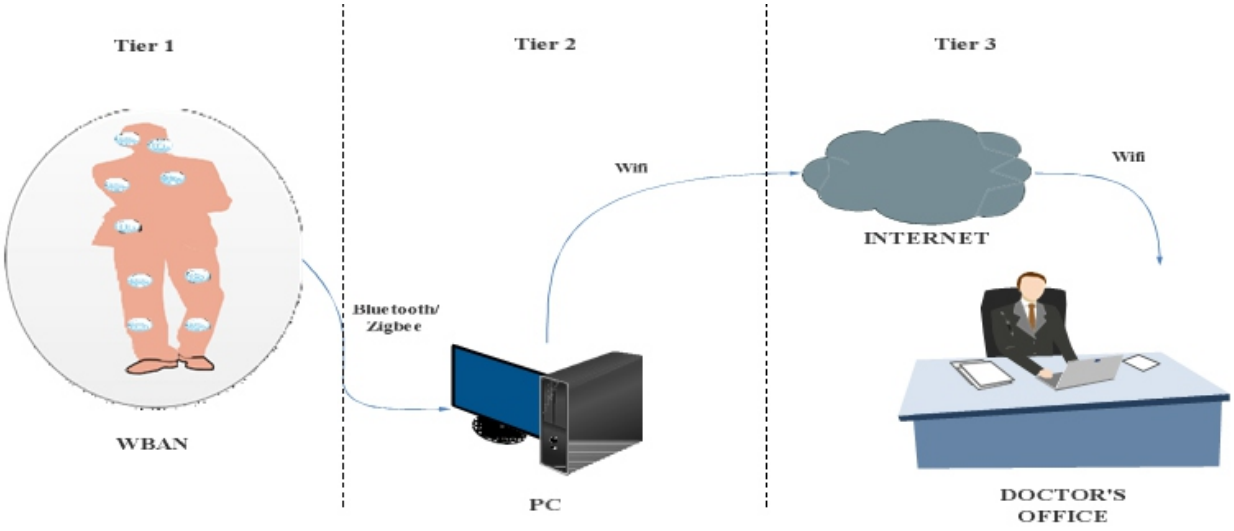

Figure 1. Wireless Body Area Network

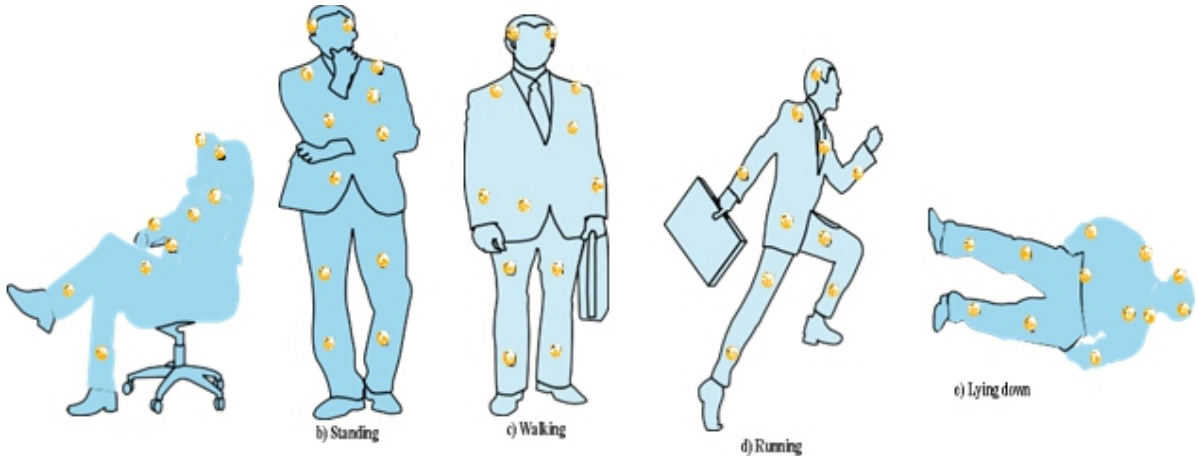

Figure 2. Human Body Postures

The rest of the paper is organized as follows: In section 2, related work is discussed, motivation is presented in Section 3, proposed scheme is described in Section 4, performance parameters are discussed in Section 5, Section 6 containsresults and analysis, and we conclude our findings in Section 7.

II.RELATED WORK

A lot of work has been done in the field of wireless body area networks.Our work also comprises of using the proper MAC scheme for assigning nodal priority. Thecommonly used MAC layer protocols include S- MAC, B-MAC, LMAC, Wise MAC and IEEE 802.15.6 based CSMA/CA Protocol.

Sensor MACprotocol is one of the energy efficient MACprotocols. According to[8] ,SMAC reduces energy consumption by avoiding collisions, idle listening ,overhearing, and minimizing control packet overheads. Periodic sleeping is an integral working component of SMAC, and according to conditions a node will go to sleep state if there is no data transmission or reception. During the sleep state, the node turns its radio off, and sets a timer for switching to awake status later B-MAC commonly called Berkeley MAC protocol is LPL (Low power listening) based protocol discussed in [9].Its objective is to assign greater sleep intervals to nodes for optimum network lifetime and waking up after regular intervals to check for ongoing data communication.

Lightweight Medium Access protocol also known as LMAC is TDMA based protocol. According to [10], [11], LMAC network is self-organizing in terms of slot assignment and synchronization.

Wise MACis also an energy efficient MACprotocol, which is defined in [12], [13]. Wise MACis based upon non persistent CSMA and reduces power consumption by using preamble sampling and by reducing idle listening.

MAClayer protocol, which we chose to enhance is IEEE 802.15.6 based CSMA/CA protocol. In CSMA/CA the node detects the channel for idleness, if the channel is idle, then node will broadcast the data through the channel and if channel is busy, node will wait for random time and will try again [14]. In IEEE 802.15.6 based CSMA/CA Protocol, the node sets a back off counter between 1 and contention window size. If the channel is idle, the node will decrement the back off counter by one for each idle CSMA slots. And when the back off counter becomes zero, the node will transmit the data or frame. If the channel is found busy, the node will lock its back off counter until the channel becomes idle. Here in [15], another counter which counts the number of failures is presented. Two cases are presented here, the first one in which number of failures is odd, then Contention Window (CW) size will remain unchanged and if the number of failures is even, then CW size will be doubled. After successful data transmission, CW is set to initial CW.

III. MOTIVATION

Main objective of proposed scheme is to make WBAN more reliable and energy efficient by introducing idea of acknowledgement and adaptive cluster head selection in CSMA/CA protocol.

By introducing acknowledgements, we can ensure that the two nodes are connected and data transmission is taking place successfully. There is no such mechanism in IEEE 802.15.6 based CSMA/CA protocol. Another approach that we have introduced is the idea of adaptive cluster head selection with nodal priority in CSMA/CA protocol which reduces data loss and also increases network throughput thus ultimately making CSMA/CA more efficient and effective.

IV. PROPOSED SCHEME

Easily accessible cluster head for data packets is very important for wireless body area network. As we know that in WBAN, distances and connectivity between different nodes vary according to the posture, as shown in Figure 3 and Figure 4. Using fixed cluster head has no significance because other nodes may or may not access that particular node. So, it is required to use cluster head which keeps changing throughout network lifetime. Routing table is commonly used to select a random cluster head for data packets, as done in Omnet++/Mixim, but depending on the routing table only is not a very effective technique. The reason is that a randomcluster head may or may not be accessible by other nodes, which will ultimately create problems in WBAN, because information from every node will help doctors to treat patient in an effective way. So, information gathering from every node is the key feature of an effective WBAN.

In such situation, adaptive cluster head for data packets, which keeps changing depending upon the number of connections that each node holds thus contributing to enhance performance of the overall network. Introducing priority for nodes will further make this scheme more efficient.So, we propose adaptive cluster head selection with nodal priority. Explanation of our proposed scheme is done in this section.

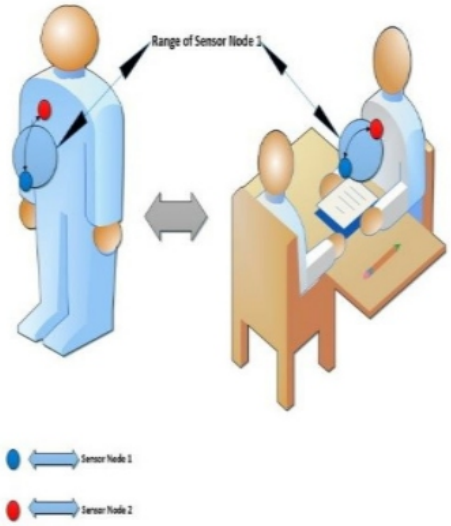

Figure3.Illustration of Range Changing of Sensor Nodes with Postural Changes

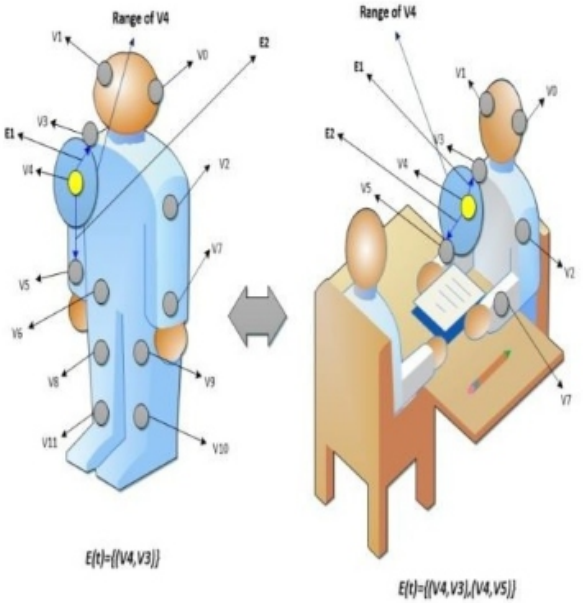

Figure 4. Illustration of Variation in No. of Connections with Postural changes

According to Figure 5, after initializing important parameters like CWmin count, backoff_count, channel idleness will be checked, if idle, then backoff_count will be decremented until it becomes zero. Consequently, each node will broadcast control packet, upon the reception of control packets from other nodes, each node will acknowledge the sender that the control packet has been received. Link State Link state table is a very important feature of our scheme. This table contains information about number of connections that each node holds. This table is maintained at each node. The complete procedure for updating this table and selecting adaptive cluster head on the basis of LST is illustrated through flow chart in Figure 5.

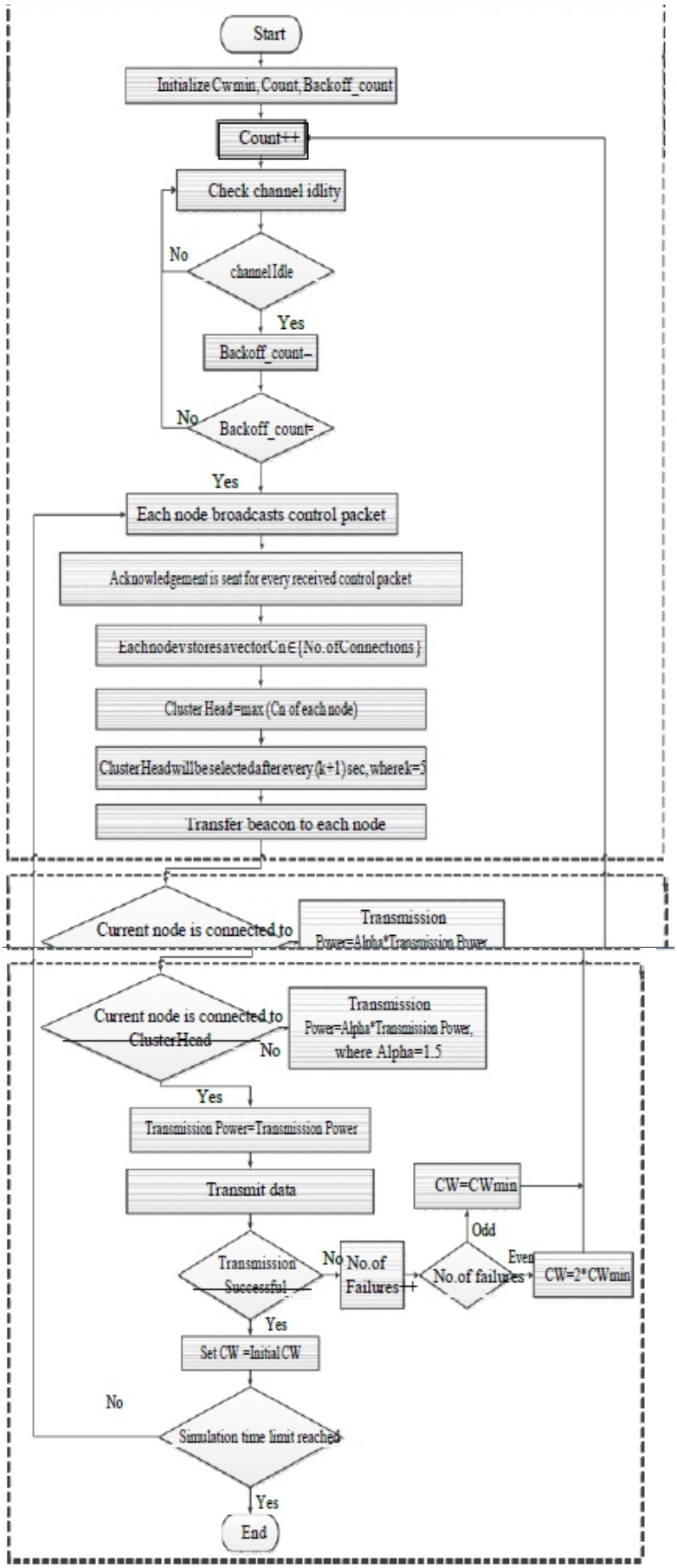

Figure 5. Flow Chart of Proposed Scheme

Table (LST) will be updated (Incrementing No. of Links) after reception of acknowledgement otherwise it will remain unchanged. The nodehaving maximum value in LST shows that it has maximum number of connections as compared to other nodes for current posture. So, there will be a competition between all sensors nodes to become "Cluster Head" on the basis of value stored in their LST. Node with maximum value in LST will become cluster head for other nodes. Power of those nodes which are not directly connected to the cluster head, will be increased, so that, each node can send its data to the cluster head. After that, data will be transmitted, if transmission is not successful, then number of failures will be counted, if odd, then contention window will remain same otherwise it will be doubled. The reason is that even number of failures would confirm that there is a problem in contention window, which stops transmission. A simple example for cluster head selection is given in figure 6. According to Figure 6, at time t_{k+1} , node 5, will become cluster head node because of holding maximum no. of connections. At t_{k+21} , node 3, will become cluster head.

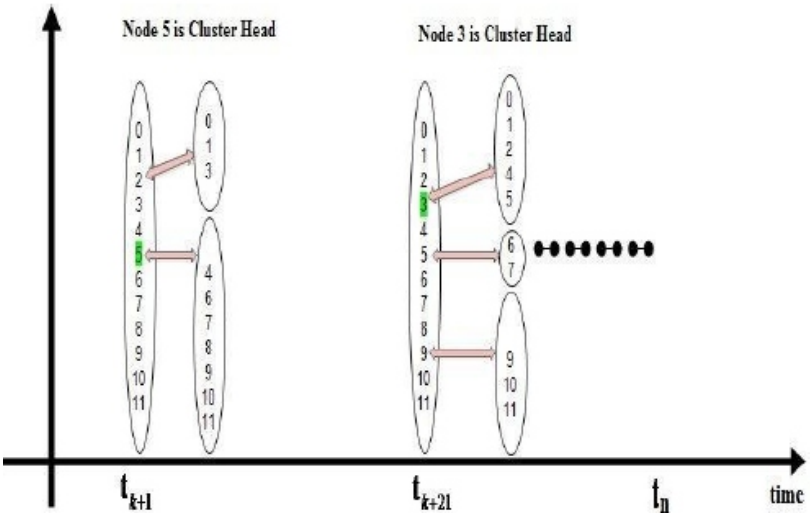

Figure 6. Example Related To Flow Chart

V. PERFORMANCE PARAMETERS

Important notations and parameters list is given in Table 1 and Table 2 respectively. User priority list is presented in Table 3.

T_p	Preamble transmission time
R_s	Preamble transmission symbol rate
T_{PHY}	PHY layer header transmission time
R_{hdr}	Header rate of PHY layer
R_{DATA}	Transmission rate of data
T_s	Slot length
T_{pSIFS}	Short inter-frame spacing time
T_{pMIFS}	Minimum inter-frame spacing time
MHR	Mac header
FTR	Mac footer
τ	Propagation time
n'	Frames transmitted in single burst
x	Payload Size

Table 1. Notations used in calculation

PARAMETER NAME	VALUE
Saturation	-90 dB_m
Alpha	3
Carrier frequency	2.412 GHz
Time R_x to T_x	0.00021s
Time R_x to Sleep	0.000031s
Time T_x to R_x	0.00012s
Time T_x to Sleep	0.000032s
Time Sleep to R_x	0.000102s
Time Sleep to T_x	0.000203s
T_{pMIFS}	20 μs
T_{pSIFS}	50 μs
T_p	88bit/ R_s
τ	1 μs
T_{PHY}	31bits/ R_{hdr}
Queue Length	5
Slot Duration	0.00035s
Max T_x Attempts	14
Bit Rate	200000 bps
Contention Window/ $CW_{\min}$	16
T_x Power	100 mW
MHR	56
FTR	16
R_s	187500
R_{hdr}	57500
Pdelay	0.000001
x	2000

Table 2. Simulation parameters

User	Transmission Power (mW)	Priority
0	1	1st
1	0.96	2nd
2	0.92	3rd
3	0.88	4th
4	0.84	5th
5	0.80	6th
6	0.76	7th
7	0.72	8th
8	0.68	9th
9	0.64	10th
10	0.60	11th
11	0.56	12th

Table 3. Priority List

Mathematical formulae used to calculate delay, throughput and bandwidth efficiency are given below. Formula to calculate delay normally, is given below;

$$Delay(x) = T_{avg\_backoff} + T_{DATA} + T_{I-ACK} + 2T_{pSIFS} + 2 \quad (1)$$

The average back off time can be found as;

$$T_{avg\_backoff} = \frac{CW_{\min} \cdot T_s}{2} \quad (2)$$

The transmission time of data is T_{DATA} and can be obtained as;

$$T_{DATA} = T_p + T_{PHY} + \frac{(MHR + x + FTR)}{R_{DATA}} \quad (3)$$

The transmission time of immediate acknowledgment can be obtained as;

$$T_{I-ACK} = T_P + T_{PHY} + \frac{(MHR + FTR)}{R_{DATA}} \quad (4)$$

Maximum throughput (MT) of network is directly related to overhead.

The MT is defined as the ratio of payload size (x) to the total transmission delay per payload size Delay(x), as given below [7];

$$MT = \frac{x}{Delay(x)} \quad (5)$$

Maximum throughput (MT) in case of immediate acknowledgement as in [3];

$$MT_{I-ACK} = \frac{x}{(T_{avg\_backoff} + T_{DATA} + T_{I-ACK} + 2T_{pSIFS} +} \quad (6)$$

The bandwidth efficiency is inversely proportional to the basic data rate;

$$\square = \frac{M \quad T}{R_{DATA}} \quad (7)$$

VI. PERFORMANCE ANALYSIS

Mobile Network Performance Analysis:

Figure 7 shows delay versus time comparison between fixed cluster head, random cluster head selection scheme, adaptive cluster head selection scheme and adaptive cluster head selection scheme with priority for mobile network. In these results, lower delay is achieved in adaptive cluster head selection scheme with priority.

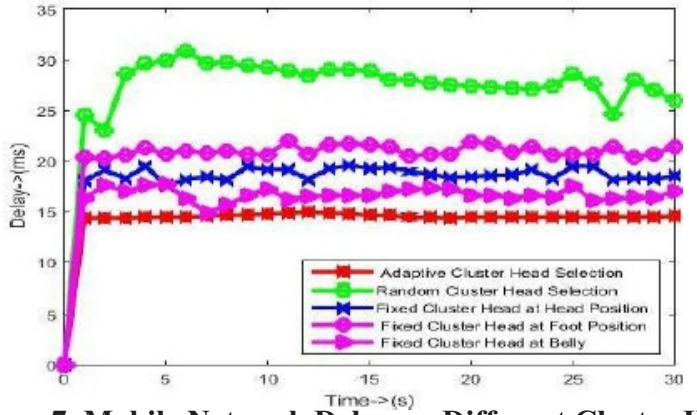

Figure 7. Mobile Network Delay on Different Cluster Head

Figure 8 shows throughput versus time comparison between fixed cluster head, random cluster head selection scheme, adaptive cluster head selection scheme and adaptive cluster head selection scheme with priority for mobile network. As depicted from results, higher throughput is achieved in adaptive cluster head selection scheme with priority.

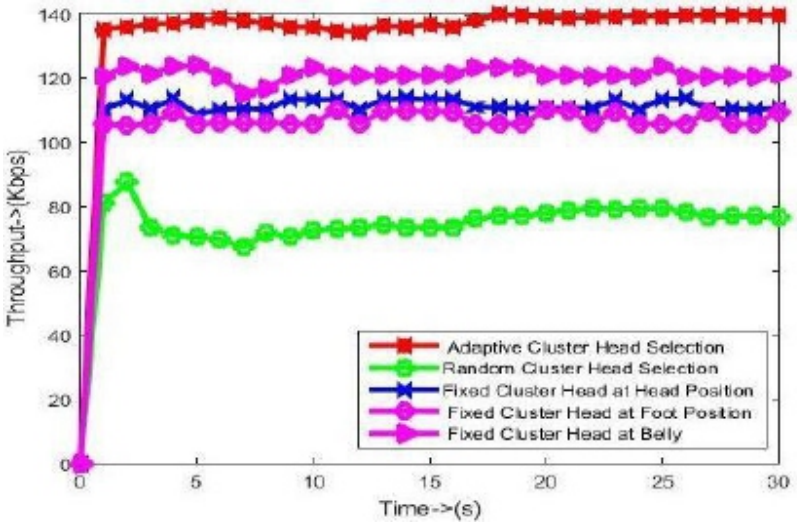

Figure 8. Mobile Network Throughput on Different Cluster Head

Figure 9 shows bandwidth efficiency versus time comparison between fixed cluster head, random cluster head selection scheme, adaptive cluster head selection scheme and adaptive cluster head selection scheme with priority for mobile network. As seen from results, higher bandwidth efficiency is achieved in adaptive cluster head selection scheme with priority.

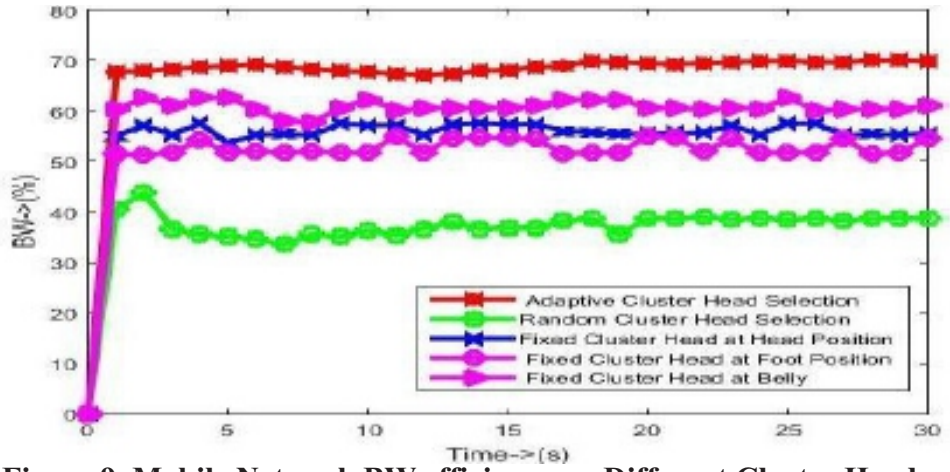

Figure 9. Mobile Network BW efficiency on Different Cluster Head

Figure 10 shows power consumption comparison between fixed cluster head, random cluster head selection scheme, adaptive cluster head selection scheme and adaptive cluster head selection scheme with priority for mobile network. As shown from results, low power consumption is achieved in adaptive cluster head selection scheme with priority.

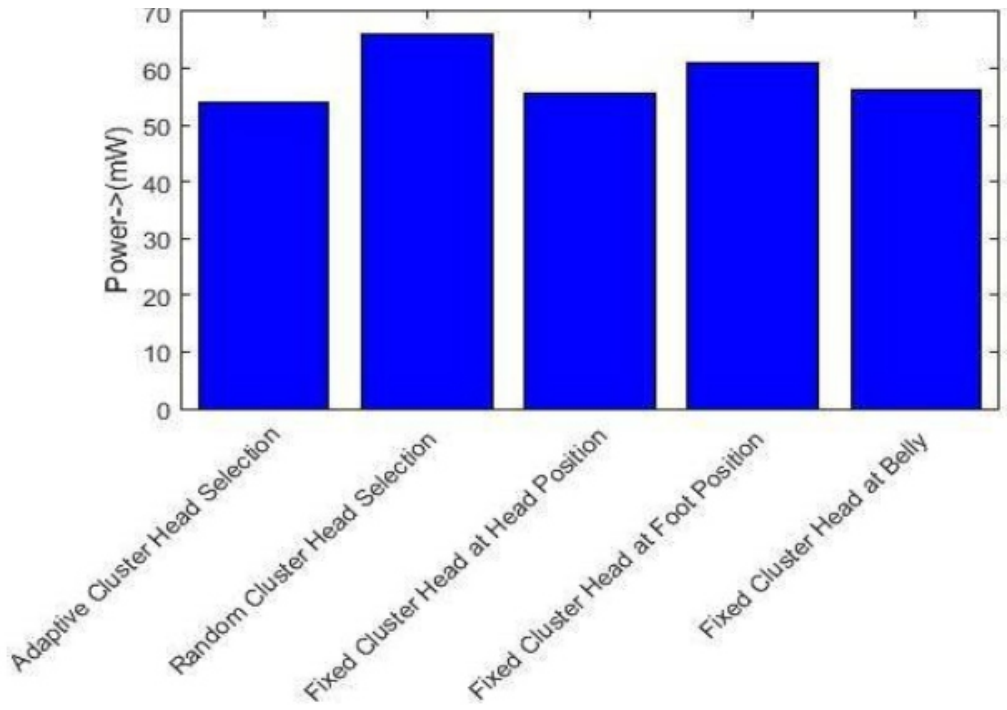

Figure 10. Mobile Network Power Consumption on Different Cluster Head

As the cluster head node has maximum number of connections available in Adaptive cluster head selection scheme, that's why it is easier for other nodes to access cluster head, which results in better performance. Adding priority further enhances its performance.

While in random cluster head selection scheme, destination node may or may not have enough amount of connections to accommodate nodes, which results in more delay, more power consumption and lower throughput.

Fixed cluster head selection schemes show better results as compared to random cluster head selection schemes, because in this case, randomly selected cluster head is not easily accessible as compared to fixed cluster heads for current posture.

Another important thing which is depicted from these results is that adaptive cluster headselection scheme and adaptive cluster head selection scheme with priority show steady behavior after 20 seconds, because at that time, network has adopted a cluster head, which gives ultimate performance. This behavior is lackingin random cluster head selection scheme.

CONCLUSIONS

Inappropriate cluster head selection scheme is one of the major factors of data loss in WBAN. Adaptive cluster head selection scheme with nodal priority is proposed in this paper. This scheme is based upon adaptive cluster head selection using link state table which helps in reducing network delay, mean power consumption and increasing network throughput. In the proposed scheme, cluster head for data packet will be adaptive to the variation in number of connections that each node holds. The numberof connections for every node is present in link state table. The node havingmaximum number of connections will be selected as the cluster head and other nodes will consequently communicate with this node. Nodal priority through power is also introduced to make WBAN more efficient. Our proposed

scheme outperforms IEEE 802.15.6 based CSMA/CA in all major aspects i.e. meanpower consumption, network delay, network throughput and network bandwidth efficiency. Thus our proposed scheme has shown significant improvement in IEEE 802.15.6 based CSMA/CA.

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Evolving A Small Software Organization's Project Management Process to Cmmi Level 2 using Scrum

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A B S T R A C T

The rapid pace of change in information technology has caused increasing frustration to the heavyweight plans, specifications, and other documentation imposed by contractual inertia and maturity model compliance criteria [1]. Struggling with these challenges, many software organizations start to adopt Scrum which is one of the most used agile methods. It is useful for software organizations to update their software development process based on CMMI for a more disciplined process base without losing their agility using Scrum. This paper is to draw on a real-world use case on a software group which meets the definition of a small organization whose product portfolio covers a variety of products including embedded components and remote monitoring systems for heavy construction machinery. A case study is presented wherein the organization has embarked on a software improvement initiation for one of their projects to conform to CMMI Level 2 requirements while simultaneously transitioning the same team to implement Scrum. A significant output of this work is a functional mapping between the elements of Scrum and the goals and practices of CMMI Level 2 to demonstrate that the software development processes as defined by the Scrum fulfill the requirements of a CMMI Level 2 project.

Keywords - Software Engineering, Software Process Improvement, Agile Methods, Scrum, Capability Maturity Model Integration, CMMI, Project Management Process, Small Software Development Organizations.

I. INTRODUCTION

In recent years, two dominant trends associated with software development methodologies have emerged to improve customer satisfaction, product quality, team productivity, and to establish more predictable milestones in software organizations.

The first trend followed primarily by large software organizations is the adoption of the CMMI (Capability Maturity Model Integrated) model [2]. CMMI provides a systematic, planned, and consistent framework for the institutionalization of software development processes to produce quality products in a sustainable and scalable way. The second trend is the adoption of agile software development methods by smaller software organizations. Agile methods provide an iterative and adaptive solution to increase the ability of the project team to adapt quickly to frequent and continuous changes occurring in the project's environment during the project's execution. They also speed up the release of usable software product releases in such a challenging environment. Small- and medium-sized software companies that would like to work as sub-contractors of CMMI- compliant contractors in large-scale global projects tend towards adopting software processes that meet CMMI process requirements, but without sacrificing their agility.

The company narrated in this case study is a developer of embedded and remote monitoring software for a national construction machinery manufacturer. Initially, its practiced but undocumented software development processes were mainly consisted of an ad-hoc combination of practices borrowed from various agile methods. The company had a vision of jointly developing new software products with some global international companies as a subcontractor. They were in search of help and guidance to find and implement a cost- effective and practical solution to reach a higher quality level of production with more disciplined software development processes.

We, as process consultants from the academia, advised the company management to adopt the Scrum method and offered help for ensuring CMMI compliance in a year with some specific additions and customizations to the Scrum agile practices. A software process improvement project has been carried out with an active university-industry cooperation and presented here as a software engineering case study. During the study, a functional mapping was developed between the elements of Scrum and the requirements of the CMMI Level 2 project planning and project monitoring and control process areas. The discovered process gaps were closed by additional custom-designed practices, and the new processes were efficiently implemented in a pilot project using a set of open-source software tools, like Jira and Confluence. The CMMI compliance of the implementation was finally tested with a process self-assessment at the closing.

This paper is divided as follows: Section 2 presents the related work, Section 3 summarizes the basics of CMMI and Scrum; Section 4 explains the research considerations and the case study design; Section 5 describes how the field procedure is constituted, data is collected, and any deviations in the project; Section 6 presents the status & gap analysis results for thesoftware organization; Sections 7-9 discusses the mapping between CMMI Project Management Process Areas and Scrum elements; and the last section concludes the paper with final remarks.

II. RELATED WORK

Most of the previous studies in the literature show that agile methods and CMMI framework are compatible with each other [3-17].

Vriens [4] showed that CMM Level 2 requirements can be met when the XP and Scrum agile methods are used together. Kahkönen and Abrahamsson [12] have experimentally proved that software development processes using the practices of the XP meet the requirements of the CMMI. Pikkarainen and Mantyniemi [15] proposed a mapping to demonstrate the relationship between the agile practices and the CMMI's specific goals (SGs) in the Project Planning, and Requirement Management process areas. They also supported this with an experimental application. Sutherland et al. [7] and Jakobsen et al. [16] showed the relationships between the Scrum practices and the CMMI Level 5 requirements. Machic and Zabkar [17] conducted a study to show how the CMMI measurement and analysis practices could be implemented with the Scrum-based software development process. Marcal et al. [6], set out from a matching study by Pikkarainen and Mantyniemi [15], conducted a more detailed but theoretical mapping study between CMMI Project Management process areas and Scrum elements. The relationship between the specific practices of CMMI Maturity Level 2 and 3 process areas and Scrum was studied by two other groups: Jakobsen et al. [18], and Potter and Sakry [19] with positive outcomes.

The case studies, on the other hand, generally focus on how the CMMI could be applied together with agile methods [20-25]. There are very few case studies that show the explicit mapping between Scrum and CMMI [15, 25]. Pikkarainen and Mantyniemi [15] presented three case studies to validate the mapping between the agile practices and the CMM's specific goals in the Project Planning and Requirement Management Process Areas. Garzas and Paulk [25] conducted a software process improvement study to show the collaboration between CMMI and Scrum using the data obtained from 12 Spanish software companies.

Our work augments the Scrum practices to provide a full CMMI Level 2 compliance in project management process area and does validation on a pilot project implementation.

III. CMMI AND SCRUM

According to the Software Engineering Institute (SEI), CMMI is a reference process improvement maturity model for the development of products and services [2]. CMMI presents the best practices to be implemented during the development and maintenance activities in the software product lifecycle. CMMI Staged Model defines five levels and 22 process areas. The two Project Management process areas, where we focus in this study, are in the second or managed level: Project Planning (PP), Project Monitoring and Control (PMC).

Scrum, on the other hand, is an agile product development framework based on empirical process management principles. Scrum processes are carried out in a cycle called 'Sprint' and are governed mainly by items (tasks, activities, and works) based on principles of transparency, observation, and adaptation [3].

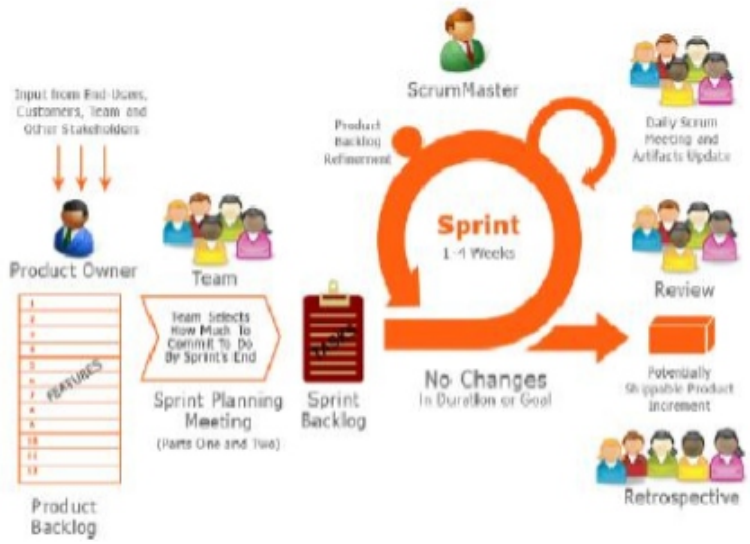


Figure 1: Scrum Framework [26]

The schematic structure of the Scrum framework is shown in Figure 1. Each Sprint is usually set at a time interval of 1 to 4 weeks. All phases of traditional software development processes (requirement determination, design, implementation, testing, etc.) are applied together in a Sprint. The Sprint Planning, Daily Scrum, Sprint Assessment, and Sprint Retrospective meetings that are executed during the Sprint are called Scrum events. A self-organized and cross-functional Scrum Team consists of Product Owner, Development Team, and Scrum Master. Work products arising from the functioning of Scrum are defined as Product Backlog, Sprint Backlog, and Product Increment. The evaluation of these work products is done according to the 'Definition of Done' used during operation.

IV. RESEARH CONSIDERATIONS AND CASE STUDY DESIGN

In this study, our initial goal was to raise the organization to the CMMI Level 2 as soon and as efficiently as possible within a software process improvement project and doing this transformation without interrupting the execution of the organization's active projects.

To achieve this goal, we decided to start with Scrum to formalize the currently followed but not documented agile practices of the organization. These were complemented with specific practices from CMMI. We used some open-source software tools to support the project management process.

Along with this direction, the following Research Question (RQ) was raised for this study: How does a small software organization achieve CMMI Level 2 in project management processes by using Scrum software development method?

Initially, a detailed status & gap analysis conducted by the advisors in two months helped to determine the status of the organizational project management process and what needs to be done to comply with the CMMI Level 2 requirements. And then, the senior management and technical managers reviewed the results and approved the initiation of the software process improvement project that targets to develop Scrum-based processes that also satisfies CMMI requirements.

One of the active projects in the software organization was selected as a pilot project for this purpose. Software process improvement (SPI) team consisted of the senior manager, technical manager, process improvement advisors, and the project's development team that is led by a senior software engineer who had Scrum experience and a Scrum Master certificate.

The first step was the induction and orientation of the SPI team through short training sessions in software process improvement, CMMI, and Scrum for a month. In the meantime, the team agreed to a 5-month high-level project plan, or a process improvement roadmap, as shown in Figure 2. According to the plan, two CMMI Level 2 process areas were to be studied every month, and a consolidation and closure phases for reviewing and consolidating the processes collectively after completing the improvements for each process area were to be carried out in the remaining two months.

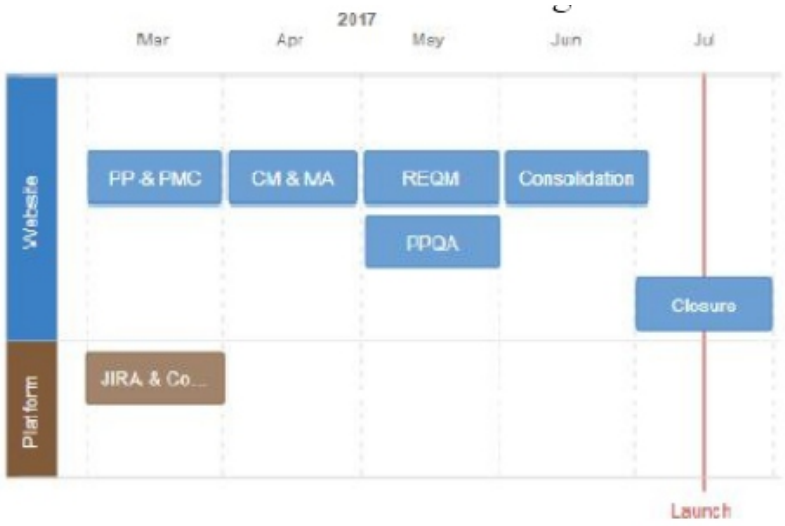


Figure 2. Process Improvement Project Roadmap

V. FIELD PROCEDURE, DATA COLLECTION AND DEVIATIONS IN THE PROJECT

The SPI team collaboratively worked on the project for a maximum of 6 hours per week divided in two sessions in the company's premises. Due to the other workloads of the team members, the planned activities were usually done only during these meeting times. It was assumed that only an additional 25% (~1.5 hours) working time per week would be required for solo studies. Of course, advisors spent many extra hours for getting prepared for the meetings and reviewing the material produced in the meetings.

The advisors initially introduced the CMMI requirements, related Scrum practices, and the process gap for each focused process area in one meeting. This was followed by brainstorming meetings for the rest of the month where the organization process was defined, and documentation was drafted under the supervision of the advisor.

Some deviation from the roadmap was observed and compensated during the last two stages of the roadmap.

VI. STATUS & GAP ANALYSIS

SCAMPI C method [27] was used as a reference to assess the organization's software development processes. The advisors elicited the status information about the processes via some informal group interviews with the whole development team. These interviews also helped discover the currently available process documentation, such as process definitions, and other evidence that shows whether or how the processes were being applied in practice.

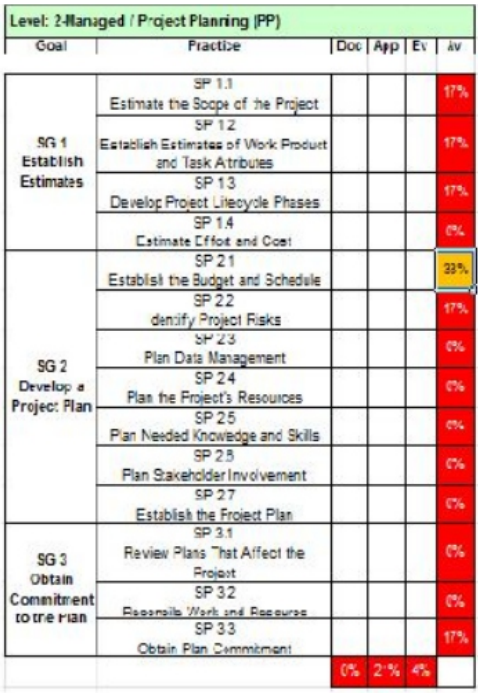
The checklist used in the status & gap analysis included the Specific Goals (SG), the corresponding Specific Practices (SP), and the sub-practices under them for each process area CMMI Level 2. The advisors checked the following three criteria for each specific sub-practice in the checklist:

1. Is the practice documented in any way?
2. Is the process applied in practice?
3. Is there any evidence confirming its application?

The checklists for Project Planning, and Project Monitoring and Control process areas are shown in Figure 3 and 4, respectively. The results are shown with a three-coloring coding. Red color means there is no corresponding documentation or evidence, or the practice is not applied, Yellow color means there are some documentation and evidence, or the practice is partially applied, and Green color means that there is sufficient documentation or evidence, or the practice is fully applied.

At the same time, to increase the presentability of the findings to the senior management, some values were assigned to each coloring code: That is 0 for Red, 1 for Yellow, and 2 for Green color. We obtained the level of implementation for each specific practice by averaging the values assigned to each of its sub-practices. We also computed the level of documentation, application, and evidence for each process area similarly.

The results of the status & gap analysis for the Project Planning process area are given in Figure 3, and the results for the Project Monitoring and Control process area are shown in Figure 4.

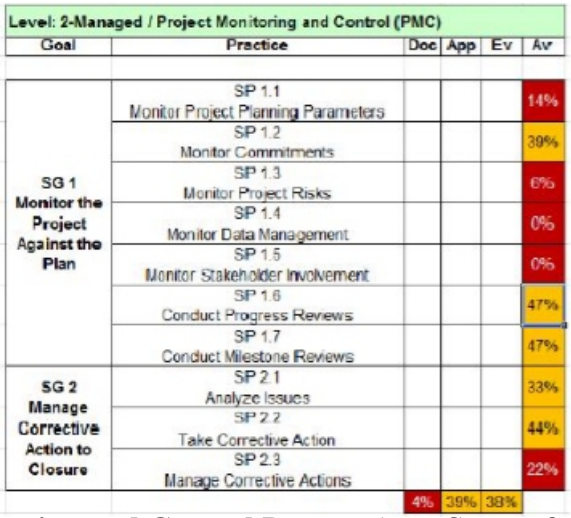


Level: 2-Managed / Project Planning (PP)					
Goal	Practice	Doc	App	Ev	Av
SG 1 Establish Estimates	SP 1.1 Estimate the Scope of the Project				17%
	SP 1.2 Establish Estimates of Work Product and Task Attributes				17%
	SP 1.3 Develop Project Lifecycle Phases				17%
	SP 1.4 Estimate Effort and Cost				0%
SG 2 Develop a Project Plan	SP 2.1 Establish the Budget and Schedule				33%
	SP 2.2 Identify Project Risks				17%
	SP 2.3 Plan Data Management				0%
	SP 2.4 Plan the Project's Resources				0%
	SP 2.5 Plan Needed Knowledge and Skills				0%
	SP 2.6 Plan Stakeholder Involvement				0%
	SP 2.7 Establish the Project Plan				0%
SG 3 Obtain Commitment to the Plan	SP 3.1 Review Plans That Affect the Project				0%
	SP 3.2 Reconcile Work and Resource				0%
	SP 3.3 Obtain Plan Commitment				17%
		0%	2%	4%	

Figure 3: Project Planning Process Area Status & Gap Analysis Results

The status & gap analysis on the Project Planning, and Project Monitoring and Control process areas raised several observations:

1. Although some type of planning for the project budget and schedule was being practiced, the required sub-practices were partially being applied in practice.
2. The project budget and schedule planning activities were being done informally and not documented in most cases.
3. Too many tasks were being assigned to the development team in the weekly meetings. As a result, the work was not being completed and the deadlines set for most of the tasks in the previous weeks were being postponed in the meetings.
4. Although a To Do List was specified at the beginning of the Project, the development team worked without a real schedule and deadline.
5. Although the applied software development process is called as agile by the team, the actual applied process was not following the principles of agile methods properly.



Level: 2-Managed / Project Monitoring and Control (PMC)					
Goal	Practice	Doc	App	Ev	Av
SG 1 Monitor the Project Against the Plan	SP 1.1 Monitor Project Planning Parameters				14%
	SP 1.2 Monitor Commitments				38%
	SP 1.3 Monitor Project Risks				6%
	SP 1.4 Monitor Data Management				0%
	SP 1.5 Monitor Stakeholder Involvement				0%
	SP 1.6 Conduct Progress Reviews				47%
	SP 1.7 Conduct Milestone Reviews				47%
SG 2 Manage Corrective Action to Closure	SP 2.1 Analyze Issues				33%
	SP 2.2 Take Corrective Action				44%
	SP 2.3 Manage Corrective Actions				22%
		4%	39%	38%	

Figure 4: Project Monitoring and Control Process Area Status & Gap Analysis Results

This analysis results together with the advisors' more detailed notes and remarks guided the SPI team throughout the project.

VII. MAPPING CMMI PROJECT PLANNING PROCESS TO SCRUM

The mapping study between Scrum practices and the 14 specific practices of CMMI Level 2 Project Planning Process Area was done based on the staged representation model defined in CMMI_DEV [2]. Table 3 shows the three specific goals enclosing 14 specific practices of the Project Planning Process Area.

Process Area KAYMALARI KALDIRALIM & TABLO YAPARSAK KALKAR	
Specific Goal	**Specific Practice**
SG1 Establish Estimates	SP1.1 Estimate the Scope of the Project
	SP1.2 Establish Estimates of Work Product and Task Attributes
	SP1.3 Define Product Lifecycle Phases
	SP1.4 Determine Estimates of Effort and Cost
SG2 Develop a Project Plan	SP2.1 Establish the Budget and Schedule
	SP2.2 Identify Project Risks
	SP2.3 Plan Data Management
	SP2.4 Plan the Project Resources
	SP2.5 Plan Needed Knowledge and Skills
	SP2.6 Plan Stakeholder Involvement
	SP2.7 Establish Project Plan
SG3 Obtain Commitment to the Plan	SP 3.1 Review Plans that Affect the Project
	SP 3.2 Reconcile Work and Resource Levels
	SP 3.3 Obtain Plan Commitment

Table.3 Specific Goals and Specific Practices of PP

In the level that we call as the "Low Level," the specific practices SP 1.1, SP 1.2, SP1.4, SP 2.1, SG 3.1, SP 3.2, and SP 3.3 were addressed by adding them in the agenda of related Sprint meetings. In the "High Level", the specific practices (SP 2.2 – SP 2.7) related to planning were addressed through product release cycles in every three months, and the Roadmap Planning Meetings done at the milestones with an agenda that takes the above practices into action.

Scrum does not address properly or openly addresses the risk, data, project resources, needed knowledge and skills, stakeholder involvement plan in the CMMI Project Planning process area's specific practices. Tabular schemas were created for each of these areas and were reviewed in all Roadmap Planning Meetings to satisfy these requirements. Sub-practices in SP 2.6 which were not identified in the Sprint product development process were met by organizing interim meetings with the customers and other project stakeholders.

The Product Backlog and Sprint Backlog were recorded on the Atlassian JIRA tool which is a web-based project management tool developed for Scrum projects. The process documentation requirements

coming from the CMMI were satisfied using the Atlassian Confluence which is the content management system of the "wi-ki" structure. All documents were expressed in the form of hyperlink- related templates and/or checklists.

Finally, a mapping table which maps the Project Planning Process Area's specific practices to corresponding Scrum elements is given in Figure 5. As seen in the table, the documentation workload was reduced and the necessary documentation was simplified by minimizing repetition of information. The integration of this mapping table and the project management tool JIRA mentioned above provided significant benefit in reducing the workload required for process documentation and auditing.

Table 1 and Table 2 represent abbreviations for the meetings organized during software product lifecycle and the plans, guidelines, checklists, templates, etc. created for supporting the processes, respectively.

Meeting Name	Abbreviation
Roadmap Planning Meeting	RPM
Sprint Planning Meeting	SPM
Retrospectives	Rtps
Daily Standup Meeting	DSM
JIRA Backlog Meeting	JBM

Table.1 Abbreviations for Meetings

Doc/Template/Guideline	Abbreviation
Roadmap Planning Meeting Checklist	RPMC
Sprint Planning Meeting Checklist	SPMC
Sprint Review Meeting Checklist	SRMC
Project Plan	PP
Risk Management Plan	RMP
Data Management Plan	DMP
Project Resources	PR
Knowledge and Skills	K&S
Team, Stakeholders Document	TSD
Planning & Roadmap	P&R
Retrospectives	Rtps
Stakeholder Involvement Plan	SIP
Decision log	Dlog

Table.2 Abbreviations for Documents, Templates and Guidelines

Specific Goal	Specific Practice	Procedure Definition	Implementation
SG1	SP 1.1	High Level Scope and Estimation @ RPM Low Level Scope and Estimation @ SPM	RPMC SPMC
	SP 1.2		
	SP 1.4		
	SP 1.3	Product Lifecycle Phase Analysis is done in JIRA	Defined on SCRUM loops page in JIRA.
SG2	SP 2.1	High Level Scope and Estimation @ RPM Low Level Scope and Estimation @ SPM	PP
	SP 2.2	Identify Project Risks @ RPM	RMP
	SP 2.3	Plan Data Management @ RPM	DMP
	SP 2.4	Plan the Project's Resources @ RPM	PR
	SP 2.5	Plan Needed Knowledge and Skills @ RPM	K&S
	SP 2.6	Plan Stakeholder Involvement @ RPM	TSD
	SP 2.7	Establish Project Plan @ RPM	PP
SG3	SP 3.1	Review, Reconcile and Commit to Plans @RPM & @ SPM	RPMC SPMC
	SP 3.2		
	SP 3.3		

Figure 5: The CMMI – Scrum PP Mapping Table

VIII. MAPPING CMMI PROJECT MONITORING AND CONTROL PROCESS TO SCRUM

The mapping study between the Scrum practices and 10 specific practices on the CMMI Level 2 Project Monitoring and Control Process Area was done using the staged representation model defined in CMMI_DEV [2] as a reference.

Table 4 represents the two specific goals enclosing 10 specific practices of Project Monitoring and Control Process Area.

Specific Goal	Specific Practice
SG 1 Monitor the Project Against the Plan	SP 1.1 Monitor Project Planning Parameters
	SP 1.2 Monitor Commitments
	SP 1.3 Monitor Project Risks
	SP 1.4 Monitor Data Management
	SP 1.5 Monitor Stakeholder Involvement
	SP 1.6 Conduct Progress Reviews (Periodic)
	SP 1.7 Conduct Milestone Reviews
SG 2 Manage Corrective Actions to Closure	SP 2.1 Analyze Issues
	SP 2.2 Take Corrective Actions
	SP 2.3 Manage Corrective Actions

Table.4 Specific Goals and Specific Practices of Project Monitoring and Control Process Area

CMMI requirements are generally met with the conduct of the Roadmap Planning Meetings at the High Level, and application of the Scrum practices in the Low Level. The review activities corresponding to

practices and the meetings they will be conducted were organized as a table as in Figure 6.. In the meetings, the planning documents were used as checklists. Therefore, such a table summarized all the activities that satisfy the requirements in Project Monitoring and Control process area at once.

This mapping table and the use of project management tool JIRA have reduced the effort and costs required for implementing the project monitoring and control process.

Specific Goal	Specific Practice	Procedure Definition	Implementation
SG 1	SP 1.1	Monitor Project Planning Parameters & Commitments @RPM, SPM,	RPMC SPMC PR K&S Rtps
	SP 1.2		
	SP 1.3	Monitor Project Risks @ RPM, SPM, Rtps & DSM	RMP
	SP 1.4	PMC - Monitor Data Management @ RPM, SPM & Rtps	DMP
	SP 1.5	PMC - Monitor Stakeholder Involvement @RPM, SPM & DSM	
	SP 1.6	PMC - Conduct Progress Reviews (Periodic) @ RPM, SRM, & DSM	SPMC SRMC
	SP 1.7	PMC - Conduct Milestone Reviews @ RPM	RPMC
SG 2	SP 2.1	PMC - Analyze Issues & Manage Corrective Actions @ RPM, SPM, SRM, Rtps, DSM &	RPMC SPMC SRMC Rtps Dlog
	SP 2.2		
	SP 2.3		

Figure 6: The CMMI – Scrum PMC Mapping Table

IX. CMMI SUPPLIER AGGREMENT MANAGEMENT PROCESS AREA

According to CMMI_DEV [2], the provided products and services from suppliers need to be managed from product development to customer delivery with specific practices of the Supplier Agreement Management Process Area. In Scrum, there is no corresponding practice for this type of management of the products, product components, and services acquired from suppliers.

Since the software organization in this case study does not use any subcontractors and is not responsible for the supplier relations in the overall organization, this process area was excluded from our study.

CONCLUSION

This study is a good example of a university-industry collaboration where the advisors from the university helped a small software organization to discipline and institutionalize its processes for developing remote monitoring systems and embedded components. The related Scrum practices were mapped to CMMI Level 2 Project Planning and Project Management and Control process area specific practices practically. The process documentation and process application was supported and eased by using Atlassian Jira and Confluence.

An important caution is that we accepted the specific practices and sub-practices of CMMI process areas as required in this study. Although they are optional in the CMMI framework, this assumption helped us to develop organizational processes that are consistent with best practices.

The stages of the study are given in a case study format where every stage from planning to implementation is briefly explained and some important issues are highlighted for future implementers. A distinctive feature of this study is that the new processes were immediately applied to a pilot project at the improvement work was done. This ensured the gaps and impracticalities to be discovered and taken care of within the timeframe of the study.

According to the results of our mapping study, we assert that the requirements of CMMI Level 2 Project Management related process areas can be satisfied by tailoring and extending the Scrum practices as explained in this paper.

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Analysis of Students' Learning Outcomes using Educational Data Mining Approach

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ABSTRACT

In the academic institution, analysis of students' academic performance is important as an input in improving the quality of students' education. This can be done by analyzing students' academic records stored in the database using educational data mining. This study aims to explore factors that affect students' performance in their professional courses with prerequisites in a specific program. The prediction of students' performance was made using classification techniques in data mining. The study was able to identify performing and at-risk students in terms of their academic performance based on the pattern extracted from the dataset. This research will serve as guidelines for the administrators and faculty members for the improvement of their teaching methodologies.

Keywords - Educational Data Mining, Classification, Performance, Prediction

I. INTRODUCTION

The main goal of an academic institution is to ensure the delivery of instruction to students is achieved. It is where every student learns the fundamental values and knowledge that define the quality of good education. Determining the success factor of students in their studies will depend on their academic performance. Therefore, an in depth understanding and analysis of students performance becomes a very good area of research. It will help the administrators and faculty members to validate the effectivity and efficiency of the different teaching strategies that are being implemented in a particular course. Normally, these are supported by students records that are stored in large repositories and became voluminous over time confined into different storage devices and can be analyzed through data mining.

Data mining (DM) is an interesting method in the process of knowledge discovery that can be obtained through large scale data from databases and data warehouse of an organization. As these data are kept, different techniques are created for research, meta- analysis and discovering useful information by understanding data patterns, exploring unique behavior of a particular variable and identifying the relationship between these variables. DM contributes to the knowledge building of providing decision makers an alternative solution by means of extracting data pattern for analysis. The analytical components of DM includes classification, clustering, association among others that is designed for statistical, visualization and machine learning as part of information extraction for better understanding [3][4][5].

In DM, exploration of educational data is called Educational Data Mining (EDM). EDM is a technique that could be used to analyze students' records through pattern extraction, application of an algorithm and graphical illustration or visualization. Application of EDM is significant in unveiling discovery of new information that lies on the data set stored in large databases, an interesting field of research to help improve better decision making. EDM has been cited in several research studies to be useful in

predicting future students' performance in their learning environment because of its ability to identity at-risk students. Students profile and grades are the common prognostic parameters used to measure students' academic performance in a particular courses or subjects. However, these studies were conducted in general using students profile, academic and course information[4].

In the collegiate level, the curriculum is designed for specific program with general education courses, core courses that are common to all related programs, professional courses that are required for each program and elective courses. In this study, students' academic performance from the professional courses from the Bachelor of Science in Information Technology (BSIT) in a select university will be given emphasis. It will focus more on the courses with prerequisites. The objectives are to a) determine students' performance significant relationship for the courses with prerequisites b) knowledge discovery of the success factors students for learning behaviors and c) production of the best model prediction for student academic performance. Using EDM predictions of students' performance in their professional subjects are significant by understanding and analyzing student educational data that could improve students' performance.

The following sections present the related works in section 2, methodology in section 3, results and discussion in section 4 and section 5 for the conclusion.

II. RELATED WORKS

Application of data mining in analyzing academic data is significant to discover hidden knowledge and pattern extraction. Several studies were conducted to explore the theoretical factors that may affect students' performance. Amjad Abu Saa research study used multiple performance indicators to find a qualitative model which best classifies and predicts the students' performance based on related personal and social factors. Multiple classification technique was used in the study for predicting the students' performance. These were C4.5 decision tree, ID3 decision tree, CART decision Tree and CHAID. The results of the study slightly found out that students' performance was not totally dependent on their academic efforts and there were many other factors that have equal to greater influences as well [3].

A framework in producing a model prediction using selected classification techniques was proposed by Fadhilah Ahmad et al. in their research. It consists of three main stages such as Data Collection and Integration, Data Transformation and Patterns Extraction. The study conducted comparative analysis of three classification techniques such as Decision Tree, Naïve Bayes and Rule Based algorithm. The investigation found out that the classification algorithms can achieve the highest prediction accuracy. The prediction was also successful for students who perform good, average and in poor categories [4].

A similar research on assessing students' performance was conducted by Abeer and Elaraby that is focused on generating classification rules and predicting performance based on recorded students behavior and activities. The result was able to predict those students who needed special attention so that appropriate action could be taken to improve their academic performance [6].

While other research study concentrated on the comparative analysis to test multiple decision tree algorithms using an educational dataset. Yadav, Bhardwaj and Pal used three decision tree classification algorithms and found out that CART method worked better based on produced accuracy and precision using 10-fold cross validations[5].

III. METHODOLOGY

A framework for knowledge discovery in database (KDD) was utilized in the study as illustrated by Dr. Alexander Rieger in Figure 1.

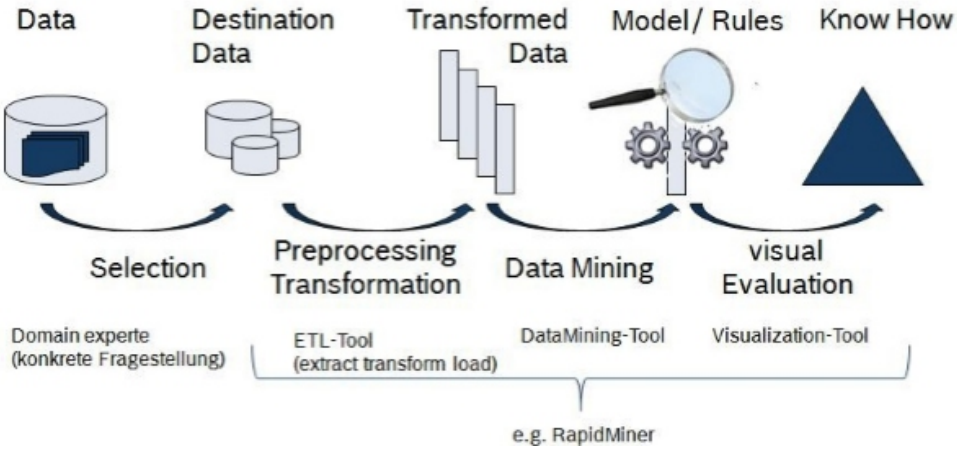

Figure 1 Knowledge Discovery in Database Process

The dataset is extracted from large quantities of data as starting point. Selection of attributes is done for the analysis that is mandatory in all data mining process. A suitable model will be used for preprocessing and transformation of data into structure data for analysis and interpretation [1].

3.1 Data Preparation

The data was collected from a State University in Laguna. It consists of 6,210 students' records from 2013 to 2017 the dataset for the study was extracted from the back up database of the University. It was done using Ubuntu operating system and Xampp as platform for managing the database. Only tables that were directly relative to dataset were used and imported in Comma Separated Value (CSV) format. The attributes of the dataset were described in Table 1 for clarity and easy understanding.

Attributes	Description	Possible Values
Barangay	Name of Barangay where the student live	Mayondon, Malinta, Timugan etc.
Town/City	Name of Town or City	Los Banos, Calamba, Bay etc.
Province	Name of Province	Laguna, Cavite, Batangas etc.
Gender	The gender of the students	Male, Female
Professional Courses	Professional Courses are the required courses of the program	ITEP 101, ITEP 202, ITEP 203,
		ITEP 204, ITEP 205, ITEP 206,
		ITEP 207, ITEP 208, ITEP 308,
		ITEP 309, ITEP 310, ITEP 311,
		ITEP 312, ITEP 313, ITEP 314,
		ITEP 315, ITEP 416
Grades	Final grade of the students at the end of the semester	Excellent, Very Satisfactory, Satisfactory, Fairly Satisfactory, Passed, Incom plete, Conditional and Failed

Table 1 Attributes, Description, and Possible Values of the dataset

The attributes presented in Table 1 were the complete address of the students that was important in analyzing the spatial distribution of students' population. The gender, professional courses, and grades were used for the prediction of students' performance.

Course Code	Description	Pre-requisites
ITEP 101	Networking 1	ITEC 101
ITEP 202	Data Structure	ITEC 103
ITEP 203	Networking 2	ITEP 101
ITEP 204	Database Management System 1	ITEP 202
ITEP 205	PC Troubleshooting and Maintenance	ITEC 206
ITEP 206	Operating System Applications	ITEC 101
ITEP 207	Accounting Principles	Math 211
ITEP 208	Service Culture	ENGL 3
ITEP 309	Object Oriented Programming	ITEP 204
ITEP 310	Systems Analysis and Design	ITEP 204
ITEP 311	Database Management System 2	ITEP 204
ITEP 312	Web Development	ITEP 204
ITEP 313	Methods of Research for IT	ENGL 311
ITEP 314	Software Engineering	ITEP 202
ITEP 315	Multimedia Systems	ITEP 310
ITEP 416	Capstone Project	4^{TH} year status

Table 2 BSIT Professional Courses

Professional courses are subjects that belong to a specific program (e.g. BSIT, BSHRM). A different program requires professional courses depending on its design curriculum in accordance with the Commission on Higher Education (CHED) Memorandum. In this case, Professional courses from the Bachelor of Science in Information Technology (BSIT) from a selected University in Laguna were utilized as described in Table 2.

Attribute	Mode	Least
Barangay	Mayondon [450]	Masaya [21]
Town	Los Banos [1638]	San Pablo [2]
Gender	Male [4634]	Female [2172]
Professional Courses	ITEP 101 [739]	ITEP 416 [121]
Grades	Satisfactory [1978]	Dropped [12]

Table 3 Dataset Summary of Statistics

Table 3 shows the dataset summary of statistics that present the mode (the value with the high frequency) and the least (the value with the least frequency) as illustrated in detail in Figure 2 and Figure 3.

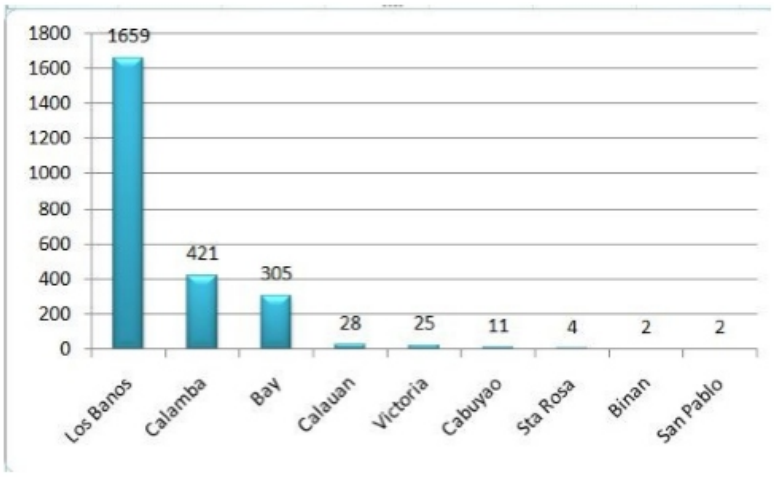

Figure 2 Distribution of Students Population by City/Town

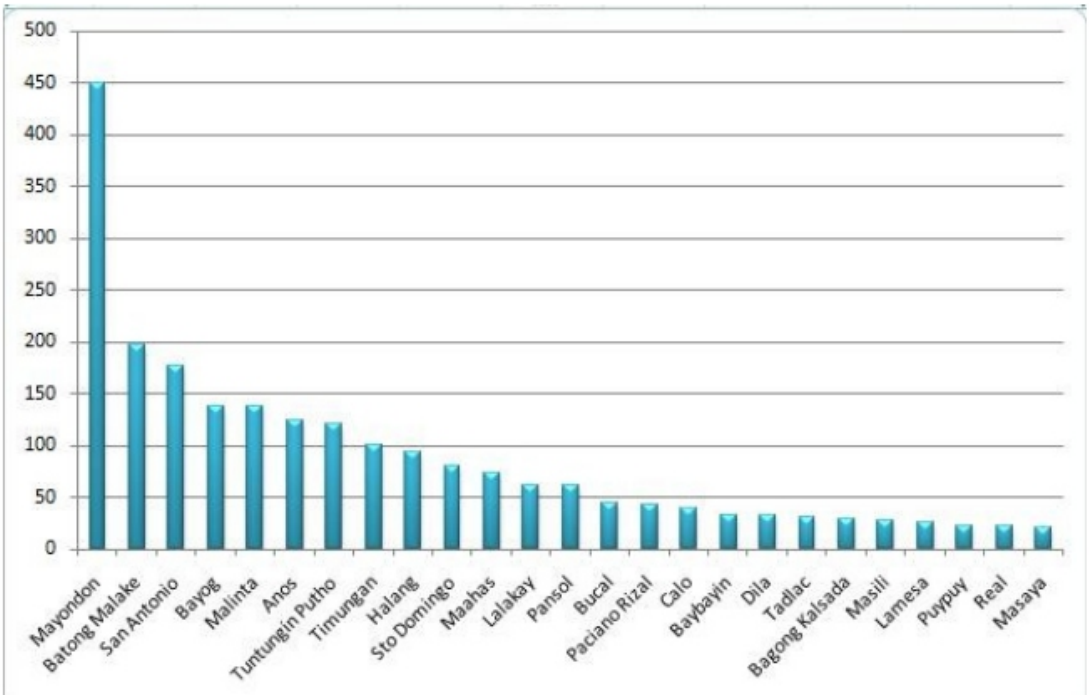

Figure 3 Distribution of Students Population by Barangay

Figure 2 shows that most of the students were residence of Los Banos, Calamba and Bay. This indicates the majority of the University's clientele was from the nearby town/city area. While at the Barangay level in Figure 3 shows that Mayondon, Batong Malake, and San Antonio were the highest in terms of students' population.

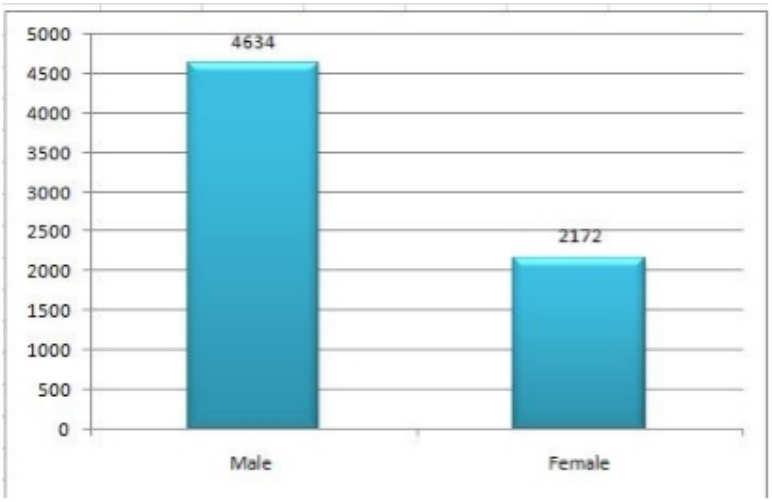

Figure 4 Distributions of Students by Gender

In terms of gender distribution, the male students were dominant than the female students in the BSIT Program as shown in Figure 4.

3.2 Data Transformation

The process of data transformation consists of data selection, data cleaning, and normalization. The data selection phase includes the extraction of students' information needed in the database. Data cleaning followed to check if there were incorrect/missing values to avoid the noise of the results. The final stage was the normalization process on which by means of SQL queries dataset were produced.

3.3 Pattern Extraction

In order to fully understand the data mining process, a model prediction framework in Figure 5 was adopted from Fadhilah Ahmad et.al a step by step process in the analysis of this research study. It shows the structure of the stages involved in Patterns Extraction process [2].

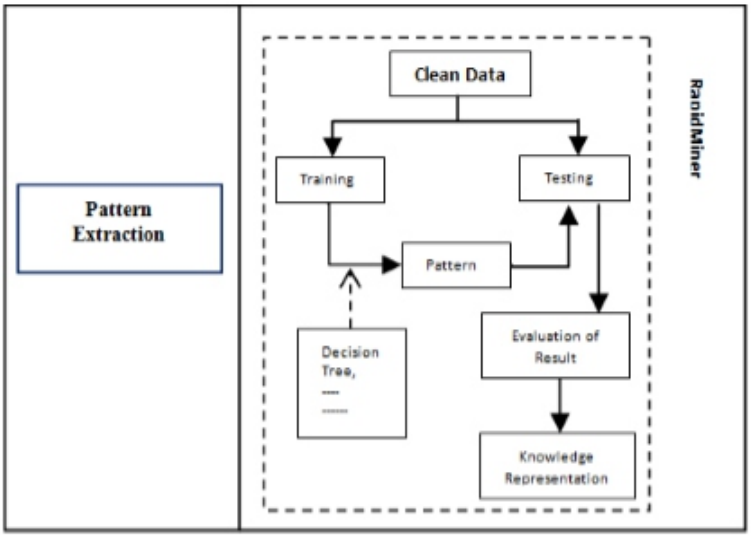

Figure 5 Model Prediction Framework (Fadhilah Ahmad et.al)

3.4 Data Mining Implementation and Results.

There were several techniques in data mining for identifying pattern and data processing. By examining data set attributes deducing of information can be structured to be helpful for decision making. Among these techniques were Classification, Association, Clustering and Sequential Patterns [2].

Classification was the mostly used and studied because it was simple and easy to understand. A method for predicting data object class or category based on learned classes from training dataset [3]. Multiple classification techniques are K-Nearest Neighbor (K-NN), Neural Networks, Decision Trees and Naïve Bayes. In this study, different classification techniques were used such as Naïve Bayes, Rule Induction, and Decision Trees to validate and verify the algorithm outcomes. The results consist of acceptable percentage of accuracy and precision measurement using Rapid Miner as data mining tool.

RESULTS AND DISCUSSIONS

This section presents the results of study after application of data mining process using the different classification algorithms. An interesting fact has been extracted in the process of data mining after generation of probability distribution matrix using the three classification algorithms. Studying students' performance in their professional courses was important as an input to curriculum development and improvement of academic related activities. The focal point of the study was to analyzed students' performance based on the BSIT professional courses in Table 2 co- existed with its pre-requisites.

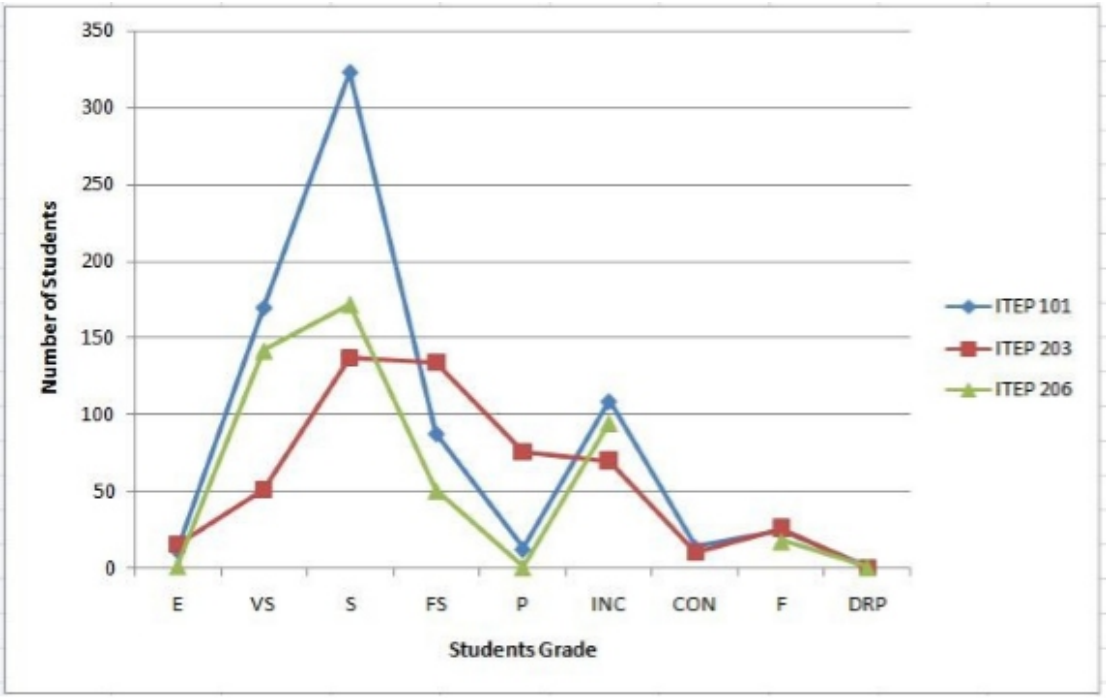

Figure 6 Students rating for ITEP 203, ITEP 206 and ITEP 101 as pre-requisite.

For the students to be allowed to enroll in ITEP 203 Networking 2 and ITEP 206 Operating system a passing grade must be achieved in ITEP 101 Networking 1 as pre-requisite. Figure 6 shows that most of the students perform Satisfactory with 52.87% and Very Satisfactory with 52.09% class recall in these courses meaning students who passed ITEP 101 most likely to passed ITEP 203 and ITEP 206. However, there were higher probabilities that those students who obtained an INC rating in ITEP 101 could have the same result in ITEP 203 and ITEP 206 with 40.78% of class prediction.

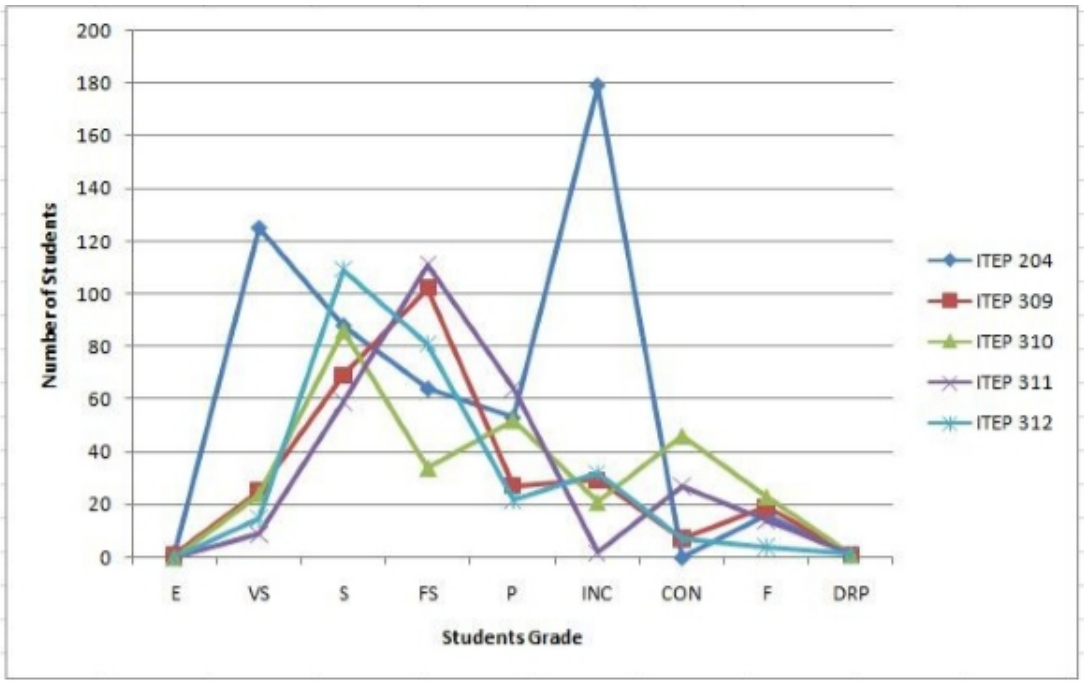

Figure 7 Students rating for ITEP 309, ITEP 310, ITEP 311, ITEP 312 and ITEP 204 as pre-requisite.

In case of Figure 7 ITEP 204 Database Management System 1 was all the pre-requisite of ITEP 309 Object Oriented Programming, ITEP 310 System Analysis and Design, ITEP 311 Database Management System 2 and ITEP 312 Web Development. Failing with ITEP 204 would deeply affect students' academic standings. Furthermore, these 4 courses were taken by students during their 3rd year first semester together with 3 more courses. It will be more challenging since these were major courses with laboratory. The result indicates that most of the students achieved a Satisfactory rating with 72.67% of class recall, 56.64% Fairly Satisfactory and 3.12% for Very Satisfactory. This shows that despite the circumstances and their academic load they still excel in most of the professional courses for 3rd year students.

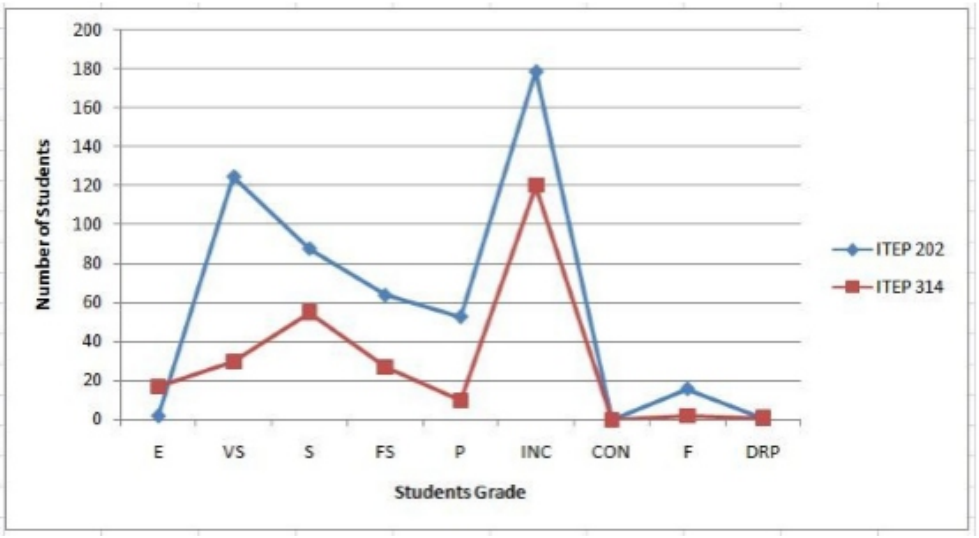

Figure 8 Students rating for ITEP 314 and ITEP 202 as pre-requisite.

The findings with ITEP 202 Data Structure and ITEP 314 Software Engineering needed an in depth research because of the 100% class recall in both courses for an Incomplete marks and with 37.85% class prediction. It shows significant relationship but with ambiguity of the reason. A more detailed dataset that includes attendance, quizzes, major examination, projects and the like must be included in the dataset since; an INC rating was given to students who passed the course but with lacking requirements.

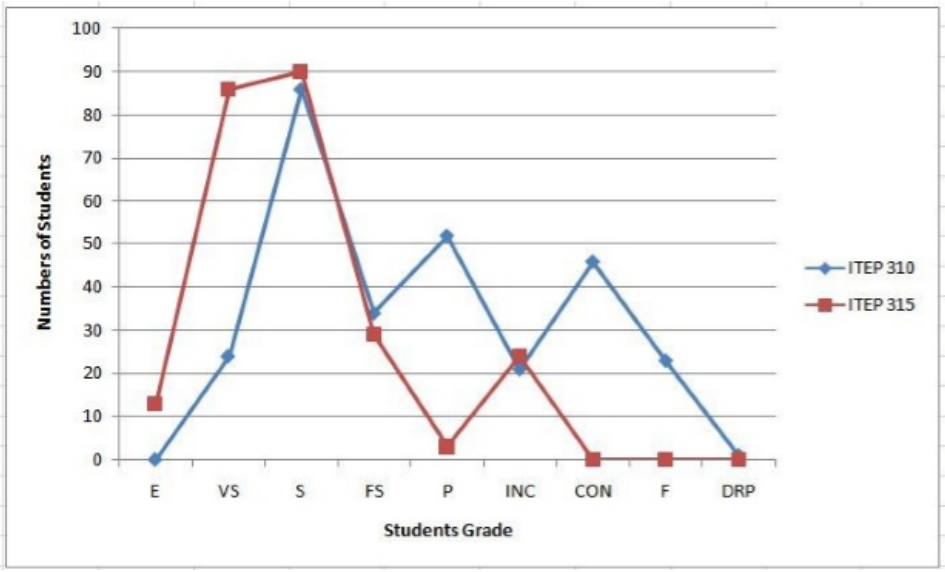

Figure 9 Students rating for ITEP 315 and ITEP 310 as pre-requisite.

ITEP 310 Web Development and ITEP 315 Multimedia System demonstrate a relative result of Satisfactory with 100% class recall and Class Prediction of 33.08%. It means that greater percentage of students would do well if they pass with ITEP 310.

In general, Naïve Bayes classification is a classification technique that assumes that all given attributes in a dataset are independent from each other and estimate the likelihood of a property given the dataset as evidence. To summarize the result of the BSIT Professional Courses the probability distribution matrix was generated by the Bayes model in Table 4 and the graphical illustration is presented in Figure 10.

Probability Distribution Matrix									
Professional Courses	E	VS	FS	S	P	INC	CON	F	DRP
ITEP 101	0.016	0.225	0.117	0.428	0.017	0.145	0.019	0.032	0.001
ITEP 202	0.004	0.237	0.121	0.167	0.100	0.339	0.000	0.030	0.002
ITEP 203	0.029	0.098	0.258	0.264	0.146	0.135	0.019	0.050	0.000
ITEP 204	0.027	0.308	0.171	0.355	0.058	0.067	0.002	0.011	0.002
ITEP 205	0.026	0.234	0.083	0.526	0.026	0.056	0.004	0.042	0.002
ITEP 206	0.004	0.295	0.106	0.357	0.002	0.197	0.000	0.037	0.002
ITEP 207	0.065	0.173	0.185	0.400	0.060	0.085	0.023	0.006	0.002
ITEP 208	0.020	0.317	0.157	0.292	0.031	0.102	0.074	0.004	0.002
ITEP 309	0.004	0.089	0.364	0.246	0.096	0.104	0.025	0.068	0.000
ITEP 310	0.000	0.084	0.118	0.300	0.181	0.073	0.160	0.080	0.003
ITEP 311	0.000	0.031	0.387	0.206	0.223	0.007	0.094	0.049	0.003
ITEP 312	0.000	0.055	0.299	0.042	0.081	0.118	0.026	0.015	0.004
ITEP 313	0.016	0.506	0.031	0.230	0.000	0.218	0.000	0.000	0.000
ITEP 314	0.065	0.115	0.103	0.210	0.038	0.458	0.000	0.008	0.004
ITEP 315	0.053	0.351	0.118	0.367	0.012	0.098	0.000	0.000	0.000
ITEP 416	0.139	0.836	0.000	0.000	0.000	0.025	0.000	0.000	0.000

Table 4 Summary of Bayes Probability Distribution Matrix

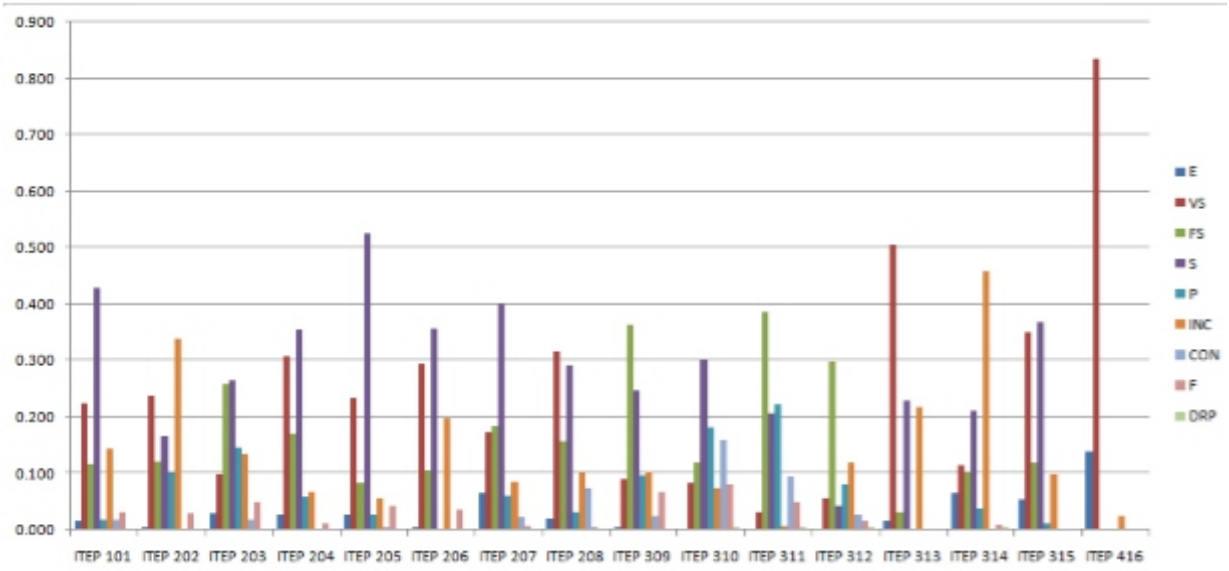

Figure 10 Graphical Illustration of Bayes Probability Distribution Matrix

Naïve Bayes Distribution matrix presents the 16 professional courses and the grades that the students obtained in fraction. ITEP 416 Capstone Project obtained with the highest Excellent and Very Satisfactory rating, in the BSIT curriculum this course was the culminating activity for Fourth Year Graduating Students in the form of system application or an enterprise resource plan. ITEP 311 Database Management System 2 achieved with the utmost Fairly Satisfactory and Passed rating. It emphasizes the importance of database analysis, design and implementation. ITEP 205 PC Troubleshooting and Maintenance was dominant with the Satisfactory rating, the course was designed to provide basic understanding of how personal computers work that also covers the basic of PC repair with an emphasis on troubleshooting and maintenance. ITEP 314 Software Engineering got the highest Incomplete rating. It focused on the basic of software engineering principles including the different software development techniques. ITEP 310 System Analysis and Design has the biggest fraction for the Conditional and Failed rating, the course is focused on the study of the different phase of information systems development. It can be simplified that in all courses, Conditional, Failed and Dropped ratings were at the least fraction. This shows that performance of BSIT Students in their professional courses was a lot better. To fully illustrate the summary of grades of students in all courses, the data is presented in Figure 11.

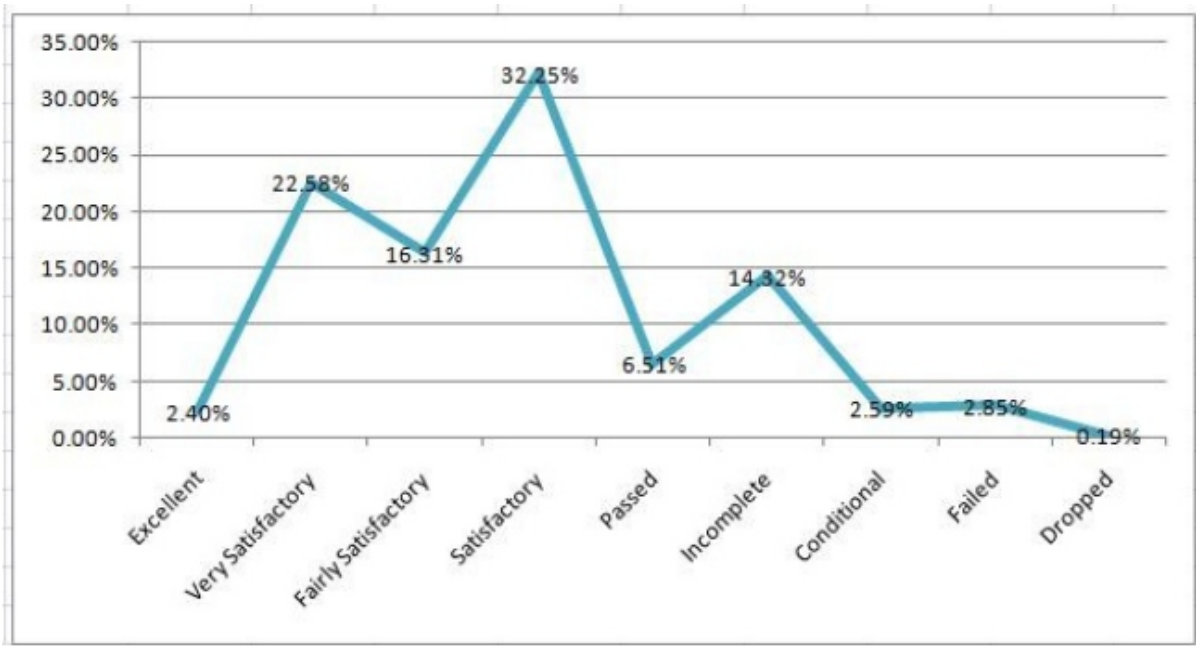

Figure 11 Summary of Grades of Students in all Professional Courses.

The summary of grades shows that students with Satisfactory rating rank the highest in all professional subjects with 32.25%. It shows that majority of students performance was in average level. It was followed by Very Satisfactory with 22.58% that demonstrate students acquired the necessary knowledge above average on the different subject matter. Fairly Satisfactory was in 16.31% that portray students' performance in below average level. Students were considered passed but have lacking requirements were given an Incomplete rating. This obtained 14.32%. Passed rating was given to students that have not acquired the necessary abilities to work proficiently but in the range of passing grades got 6.51%. In terms of students who performed beyond standards and has done exceptional work or Excellent got 2.40%. This was lower than the ratings of Conditional 2.59% and Failed with 2.85% while students who were dropping a course obtained .19% at the very lowest rating.

CONCLUSIONS

Research in Educational Data Mining (EDM) has significant contributions in the process of knowledge discovery. Understanding patterns extracted from the dataset on students' records was an interesting area of research. An academic institution should focus on students' performance and curriculum development. Since students' data was just confined into a large data bank, performing data analytics using EDM has the biggest potential of knowledge discovery.

In this study, performance of students in the BSIT professional courses in a select State University was given emphasis. It shows that all most majority of the students performed Satisfactory and Very Satisfactory. However, the results also show that there was higher probability that students who received an incomplete grade with the course pre-requisites may also be achieved in the subsequent courses. A follow up research on this aspect should be conducted to determine the reason with a detailed dataset composition. A small fraction of excellent rating was also observed higher than conditional and failing students.

The outcome of the study may serve as guidelines for the administrators and faculty members in the making of possible solution from the identified predicament dealing with students' performance. It will also encourage other academic institution to conduct research on students' performance using data mining.

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A Glimpse at Reinforcement Learning Method

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ABSTRACT

This paper aims to describe the main theoretical details of Reinforcement Learning (RL). RL is the closest to human learning among all the other learning methods. Just as an infant learns by itself without any teacher supervision, an agent learns through RL. A rational agent makes inferences between the effects and their consequences. The term state is used to defined one of the possible positions where an agent is in the environment. A Reward maybe defined as a credit or a penalty for each and every state. Actions are possible operations decided by an agent. As an example, an agent navigates through a maze.

Keywords - Bellman equation, Machine learning, Markov property, Reinforcement learning.

INTRODUCTION

For many years, researchers have always desire to design and manufacture machines that are able to learn and move by themselves by taking decisions exploiting what was learned before. If a goal of this caliber is achieved, it is obvious that all walks of human lives would get affected deeply. Currently, machines run exactly the way as they are programmed for. The capabilities of machines are limited with the capabilities and the imagination of their programmers. This dependence of the machines on their programmers prevent researchers from effective and expeditious solutions to complex problems.

However, without the need for any human intervention, the machine may act spontaneously to perform its task from its own experience, which is different from the programmer's experience. This is known as artificial intelligence (AI). To this end, researchers have been inspired by nature on many applications. This inspiration named as biomimicry. AI, just like the approach on how infants learn, would present us with new opportunities. As for learning by itself, take infants for example, they learn by themselves, when they face a problem. If it is the first time, they cannot know how they handled it. First, they take a decision randomly and they expect good things would happen in the face of that decision. However, the randomly taken decisions could very well turn unpleasant. The assessment of these unsatisfactory or satisfactory consequences is evaluated by whether these consequences are suitable for their own purposes. This assessment is carried out all by themselves. For example, let us assume, it wants to taste a piece of chocolate. So, first, he has to grasp it and take it to his mouth. However, he has to find out a way he can control his arm muscles orderly. It is likely that at his first attempt he may not know how it is going. Probably, he will fail at his first attempt by involuntarily hitting the chocolate and causing it to fall down. These problems and consequences help infants learn. However, one must note that feedback not always instantaneous. On the contrary feedback may very well be delayed, or even discernible. For example, a student has to pass an exam and for this reason she has to get a right decision for getting a good score. She is not able to know anything on her studies whether useful or not until seeing the exam result. The feedback of her decision delayed as long trm. In the reinforcement learning problems machine as infant named as agent and good or bad decision consequence named as reward. Actually,

reward Rtis a feedback signal. [2] Agent wants to maximize the total reward as same as infant always wants to reach good taste.

As an example of rewards [2]:

- Defeat chess player at chess

o +/- reward for winning /losing

- Control a solar power station

o + reward for producing power

o – reward for exceeding safety thresholds.

Understanding interaction between agent and its environment that have to be developed by some formulation. In the Figure-1 [2] the brain represents our agent and we have to be developed an algorithm that makes brain the free like individual. Taken actions at each step according to information received from the environment and at every step basically get some rewardsignal. [2]

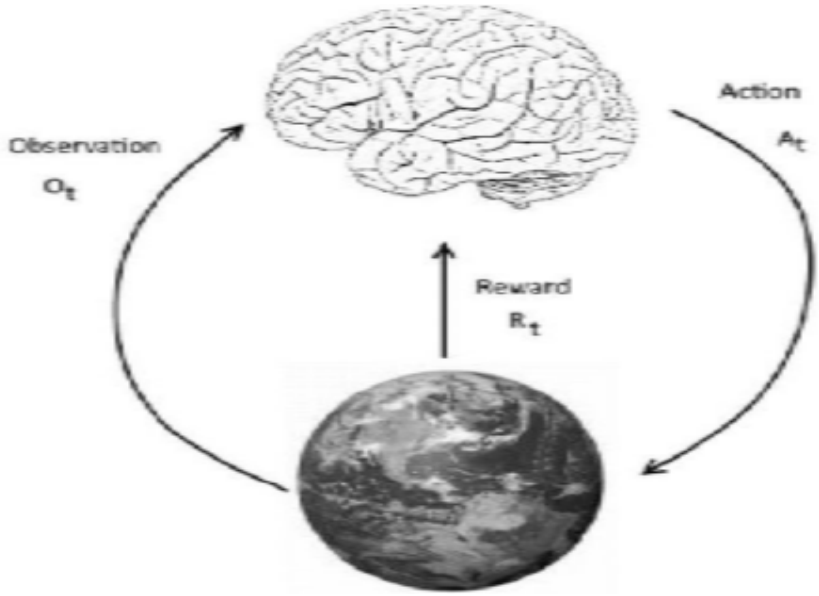

Figure-1 [2]

At every step-in time t the agent executes action At receives observation Ot and receives reward Rt. For next time agent will decide next action from a new state S that is the information what it could be happened. That information consists of history of sequence of observations, actions, rewards. [2]

St=f (Ht) State St is function of history Ht.

If we are talking on machines, our reward will be a certain numeric value and the whole other things have to turn in to mathematical representation. We could divide our learning objectives into mainly three parts. First dynamic programming. It uses transition model to predict utility function. Second, absence of transition model. Monte Carlo helps us to reach state-utility function. And the system divided into two sections. One of them is passive system as method, another is active system as control. Third and most equivalent method for real life learning problems is Temporal Difference Learning and Q-learning.

Before representation of reinforcement learning, in the order, it is needed to get sequential decision problems with Markov decision process to choose best policy that calculated with bellman equations. [3]

III. DETAIL; ANDREY MARKOV & MARKOV DECISION PROCESS, DYNAMIC PROGRAMMING: [1]

Andrey (Andrei) Andreyevich Markov (14 June 1856-20 July 1922) was a Russian mathematician who is known on stochastic processes works. He defined a property that is called Markov property. This says that the future is independent of the past given the present [2] It means that the state is now that is dependent only from the state it was at t-1. His works later became known as Markov Chains and Markov decision Processes. This is consisted of; State-space S, a function A that gives the possible actions for each state, a transition probability function T and a reward function R [4].

Transition probability is the probability of each possible next state s' that according to given any state s and action a, [1]

$$p(s'|s, a) = Pr\{s_{t+1} = s'|S_t = s, A_t = a\} \qquad (2.1)$$

The expected value of the next reward according to given any state s and action a for any next state is; [1]

$$r(s, a, s') = D[R_{t+1}|S_t = s, A_t = a, S_{t+1} = s'] \qquad (2.2)$$

According to Markov Property Markov Chain contains
Possible States $S= \{s_O, s_1, \ldots . s_n\}$

Starting State s_O,
Transition Model T (s, a, s')
Transition model defines transition from s to s' under actiona.

In reinforcement learning decision making process is important. According Markov Chain as general Markov Decision process contains;
Possible States $S= \{s_O, s_1, \ldots . s_n\}$
Starting State s_O,
Possible actions $A= \{a_O, a_1, \ldots . a_n\}$
Transition model T (s, a, s')
Reward function R(S)

Agent could be able to maximize the reward by choosing positive reward state and it has to avoid the negative reward state. Agent reach that aim it have to find a good policy π(s) that return the highest reward to agent. It is named as optimal policy.

Agent can use Bellman Equation to reach optimal policy.

$$U_h = R(s_0) + \gamma R(s_1) + \gamma^2 R(s_2) + \ldots . + \gamma^n R(s_n) \qquad (2.3)$$
$$\gamma \in [0,1]$$

γ is discount factor that describe the choice of the agent for the resent rewards in the face of future rewards. Comparing the utility of single states

$$U(s) = D\left[\sum_{t=0}^{\infty} \gamma^n R(s_n)\right] \qquad (2.4)$$

Utility of a state "s" is associated with the value of its nearby state s'

$$U(s) = R(s) + \gamma \max_a \sum_{s'} T(s,a,s')U(s') \qquad (2.5)$$

Bellman Equation algorithm is the basis of the value iteration algorithm. [3]

Function Value-Iteration (T,R) returns a utility matrix Input T, a transition probability matrix R, a reward matrix

Local variables: U, utility matrix, initially identical to R
U', utility matrix, initially identical to R Repeat
U←U'
For each state ido

$$U'(s_i) \leftarrow R(s_i) + \max_a \sum_j T_{ji}^a U(s_j)$$

End

Until $\max_a |U(s_i) - U'^{(si)}| < \varepsilon$

ReturnU

The algorithm gives us rewards of each state. However optimal policy π(s) is found for generating much reward than the other policies. By taking value iteration algorithm, we are able to estimate the utility of each state. Although we could do that we need to get optimal policy that will help us to maximize reward of each states.

Function Policy-Iteration (T,R) returns a policy Input T, a transition probability matrix R, a reward matrix Local variables:
U, utility matrix, initially identical to R
π , a policy, initially optimal with respect to U
Repeat
U←VALUE-DETERMINATION (U, T, π)
changed=false For each state ido

$$\text{If} \max_a \sum_j T_{ji}^a U(s_j) > \sum_j T^{\pi(s_j)}_{ji} U(s_j) \text{ then}$$

$$\pi(s_i) \leftarrow \text{argmax}_a \sum_j T_{ji}^a U(s_j)$$

changed=false
end
Until changed=false

ReturnU

At the end if the agent has transition model (matrix) it could be able to evaluate and find best policy to follow. If agent know the environment before it moves inside it the system is model based. However generally agents couldn't know anything about the environment that the system called as model free.

Real world conditions are the best example of the model free system. Therefore, an agent needs to approach the problem in a different way and it named as Monte Carlo Method and Control.

III. MONTE CARLO METHOD [1]

While saying Model Free System or Model Free RL it is defining particularly as passive RL and active RL. Both way in Model Free System there is not anything about transition model and reward function.

In the passive RL agent has a policy π that helps to agent to move in the environment. Under the policy π the agent that in the state s always produce the action a. The aim in the passive RL is to learn the Utility Function $U\pi(s)$. The function evaluates state by state.

$$U^{G}(s) = D\left[\sum_{t=0}^{\infty} \gamma^{t} R(s_t)\right] \qquad (3.1)$$

Finding the utility function, we get the expectation of the returns. The monte Carlo Method has some advantages above the MDP, these are;

- Interacting with the environment, it is allowed that learning optimal behavior
- Monte Carlo Method is used with simulations or sample models.
- Small subset of the states is easily focused by Monte Carlo Method.

In the Monte Carlo method agent must have a model of the environment in order to make decision. Therefore, on-line or simulated interactions with an environment, it collects experience of states, actions and rewards. And it could reduce learning time end cost. Because, the learning process could take long time in real word and the process could be so expensive.

IV. MONTE CARLO CONTROL [1]

The active RL named as Monte Carlo Control and RL agent has not any information on reward, policy or utility function to predict best movement in the environment. In some way the Monte Carlo control could be more realistic, since the optimal policy is estimated by the agent who does not know this. Monte Carlo Control method is called Generalized Policy Iteration or GPI [1] and this method is similar as much as what explained at section two about the policy iteration. It consists of two concurrent connected processes:

- First, policy evaluation
- Second, policy Improvement

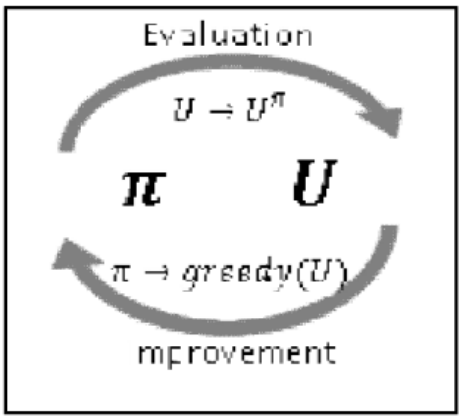

Figure-2 [1]

Policy evaluation section system is checked by current policy (evaluation). After that, under the current utility function second step greedily improvement the policy. After a period, the evaluation and the improvement process reach balance without any changes. The value function and policy are optimal at the equilibrium. Until now we used state-utility (state-value)function ($U\pi(s)$) to estimate value of state s under policy π. Now we have to use action-value function because this function is more sufficient than the state-value function to suggest a policy.

$$Q^{\sigma}(s,a) = E\{\text{Return}_t | s_t = s, a_t = a\} \qquad (4.1)$$

Expected return starting from s taking the actin a thereafter following policy π. Agent moves in the environment trying the different actions and wait its result of the actions until the end. The system update itself after reaching the final state. It means that if it is used on any autonomous equipment for control, the policy will be update after hit the wall inevitably. Because of avoiding this result Temporal Differencing Learning method improved due to expense of policy update in the Monte Carlo control.

V. TEMPORAL DIFFERENCE LEARNING [5]

In the Temporal Difference Learning (TD learning) we could obtain as much same result as Monte Carlo methods since utility function is updated after a single step.

New Estimate← Old Estimate+ Step Size [Target −Old Estimate] [5]

Where the step-size parameter describes the effect-size of changes from time step t to time step t +1. Step size is also called the learning rate (α). [Target −Old Estimate] is the error towards the optimal value Q . The optimal Q-value is guaranteed if Q t→ ∞ = Q . In practice, the learning algorithm stops if Qk is believed to be sufficiently close to Q . One stopping criterion is explained with convergences of Q values. If the difference |Q t (s, a) −Q t−1 (s, a) | is lower than a threshold that could be understand convergence of Q values.

In a single iteration, dynamic programming updates Q-value off-line for every possible state-action. Therefore, the main differences between Dynamic programming and Temporal Difference is the updating Q- value. That is why dynamic programming requires an explicit model of the environment with the probability of moving from any state s to another state s' that is fully defined by the transition function.

Generating the transition that is chosen by the action which is defined by the state transition probability P (s | s, a), and the reward function R (s, a) for the reward (as seen equation 5.1)

$$Q_t(s,a) \leftarrow R(s,a) + \sum_{s'} P(s'|s,a) \max_{a} Q_t(s',a') \qquad (5.1)$$

On the other hand, temporal difference learning, since it is model -free, it is not needed that fully model of the transition function. Some sample episodes of state-action transitions are used by TD, on the contrary getting all possible transitions. Q improved with estimation that is contribution of sampled transitions. The online exploration of sufficiently large number of state -action pairs is used by TD for reducing the error.

$$Q_t(s,a) \leftarrow Q_t(s,a) + \alpha[\underbrace{R(s,a) + Q_t(s',a')}_{\text{TARGET}} - \underbrace{Q_t(s,a)}_{\text{Old Estimate}}] \qquad (5.2)$$

When TD learning implement as an on-policy or off-policy it is named as SARSA and Q-learning respectively. The policy is updated according to actions that taken by the agent for on-policy. On the other hand, off-policy could be learned other policies that is differ by currently followed policy by the agent.

VI. SARSA(fi) [5]

The use of an eligibility trace shows as the λ. Visiting a state or taking of an action is an example of a temporary record of the occurrence of an event is named as eligibility trace. The current reward can be attributed to past states since the trace pointed the memory parameters that is about with the event.

The name SARSA is stands for "State-Action-Reward-State and Action" and explaining of these words one by one that is:

Updating the Q value depends on;

(S) The current state of the agent S_t

(A) The action that the agent choses at

(R) The reward r_{t+1} that the agent gets for choosing this action

(S) The state s_{t+1} that the agent will be in after taking that action

(A) The next action at t_{t+1} that the agent will chose in its new state

These explanation shows below the algorithm of Sarsa.

The exploration -exploitation trade-off is defined by the degree of "greediness" for online policy training. By taking probability ε execute exploration moves at the same time probability (1−ε) uses for learning a t optimal action that is an ε-greedy policy.

Algorithm OfSarsa [5]

Q (s, a) arbitrarily Repeat {for each episode:} Initializes
Choose a from s using policy derived from Q (e.g. ε-greedy) for all steps in the episode do
Take action a, observe r, s
Choose a' from s' using policy derived from Q (e.g. ε-greedy)

$$Q(s, a) \leftarrow Q(s, a) + \alpha[r + \gamma Q(s', a') - Q(s, a)]$$

s←s' ;a←a';
end for
untils is terminal

VII. Q-LEARNING [1]

At 1989 Watkins developed one of the most importing methods in the reinforcement learning was that off-policy TD control algorithm known as

Q-Learning. [1]

The basic of Q-learning as one-step is defined by

$$Q_t(S_t, A_t) \leftarrow Q(S_t, A_t) + \alpha[R_{t+1} + \gamma \max_a Q(S_{t+1}, a) - Q(S_t, A_t)] \quad (7.1)$$

The optimal action-value Q is independent of the followed policy and that directly approximated by the learned action-value function Q. This is make simple the algorithm analysis and enable proof of early convergence. It is determined which state-action pairs are visited and updated by the policy which has effect on them. The Q-Learning algorithm is shown below;

Algorithm Of Q-learning [1]
InitializeQ (s, a); $\forall s \in S, a \in A(s)$; arbitrarily, and Q (terminal-state,·) = 0
Repeat (for each episode):
InitializeS
Repeat (for each step of episode):
Choose A from S using policy derived from Q (e.g., "-greedy)
Take action A, observe R, S0

$$Q(S_t, A_t) \leftarrow Q(S_t, A_t) + \alpha [R_{t+1} + \gamma \max_a Q(S, a) - Q(S, A)]$$

$S \leftarrow S_0$;
untilS is terminal

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Design and Validation of A 28 Ghz Millimeter-Wave Waveguide Filter for Future 5 G Mobile Networks

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ABSTRACT

This paper presents the design, synthesis, and implementation of a WR-34 band iris waveguide filter. It is composed of five resonators and six irises. The Chebyshev response filter operates at 28 GHz with afractional bandwidth of 2.14%. An insertion loss method is used to synthesize the desired S-parameter filter responses. To validate the filter design, a simulation model is developed using the ANSYS High Frequency Structure Simulator (HFSS). The simulated S-parameter responses show good agreement with the theoretical results.

Keywords - Waveguide, Bandpass filter,Millimeter-wave, 5G,Mobile communication, Gigabit-Per-Second (Gbps).

I. INTRODUCTION

Mobile communication is one of the most important and successful technologies in our daily life. It has become an indispensable part of over billions of people around the globe owing to the technology breakthroughs and attractive value propositions. These days, we observed the trend of rapid rise of smart device users, increasing demand in video streaming and increasing popularity in data applications such as online banking, online shopping, gaming and navigation. This scenario has resulted in an unprecedented growth of mobile data traffic. Often, customers are always obsessed with a variety of spectrum based services, thus leading to a global bandwidth shortage. As a result, customers are expected to experience a slower internet service, and network congestion is expected to occur due to imbalance supply and demand. Today, we are using the Ultra High Frequency (UHF) band ranging from 300 MHz to 3 GHz in almost all commercial radio communication channels including TV, satellite communication, cellular, GPS, Zigbee/Bluetooh and AM/FM radio [1, 2]. On the other hand, a large spectrum in the 3-300 GHz range remains underutilized. The spectrum in the range between 3- 30 GHz is generally classified as the Super High Frequency (SHF) band, while 30-300 GHz is classified as the Extremely High Frequency (EHF) band. Since both SHF and EHF bands share similar propagation characteristics and their wavelengths are in the range from 1 to 100mm, the 3-300 GHz frequency spectrum is referred as the millimeter-wave (mm-wave) band [2]. To support the exponential growing demand on the spectrum based services, the underutilized millimeter-wave band is attracting researcher's attention throughout the world and they are motivated to explore on the millimeter-wave frequency band to overcome the global bandwidth shortage[3].A millimeter-wave communication system is capable of accommodating for a larger bandwidth allocation, which can be directly translated into a higher data transfer rate. Often, millimeter-wave communication system is able to offer a fast data transfer rate up to multi-gigabits-per-second [1, 2, 4]. Hence, millimeter-wave communication technique is recognized as a viable technology that can be used as the backbone to satisfy and support the explosive growing demand on the spectrum based services for the next generation of 5G mobile networks.

In this context, filters are one of the key devices that play an important role in millimeter-wave communication. They are used to separate between the wanted and unwanted signals frequencies. The key problem in filter designs is that the passband insertion loss is inversely proportional to the filter bandwidth. Therefore, it is often the case that, in order to realize the design of a sharp filter with a low passband insertion loss for the purpose of very narrow band applications, an extremely high Q resonator factor must be applied. The planner Microstrip filter cannot be used to design a filter at the millimeter-wave band due to its inherent small Q resonator factor, large passband insertion loss, and poor stopband suppression. Similarly, the coaxial filter is not a suitable candidate because it gives a Q resonator factor of at most 5,000, and the cut-off frequency is limited.

The aforementioned problems in the current filter technologies lead to the need for innovation in waveguide filter designs. A air-filled waveguide filter enable an extremely high Q resonator factor up to 20,000. The characteristics of a waveguide filter which offer to achieve a low passband insertion loss and a high suppression requirement to be realized will be a proper technology to be used in future 5G mobile networks.

In this research, a fifth-order Chebyshev response waveguide filter is synthesized by using circular inductive irises. The waveguide filter is composed of five resonators and six irises. The filter design is then validated by constructing a working simulation modelusing the ANSYS High Frequency Structure Simulator(HFSS). The simulated S-parameters responses are analyzed and compared with those of the mathematical model. The organization of this paper is as follows. In Section II, the theoretical principles used to design the filter are explained. The simulation results using the ANSYS HFSS software are presented in Section III. Conclusions and recommendations for future work are presented in Section IV.

II. THEORETICAL PRINCIPLES OF THE FILTER

Waveguide bandpass filters can be developed from uniform lengths of waveguide loaded with shunt discontinuities. The irises in the waveguide act as shunt inductive discontinuities, while the cavity of the waveguide between irises are half wave resonators. The inductive irises that are connected across the broad wall of the guide behave as an impedance inverter over relatively broad bandwidths [5]. Therefore, the physical structure of a waveguide bandpass filter has an equivalent circuit consisting of passband resonators separated by a cascade of frequency dependent inverters. In general, the S-parameters transfer function expressions of a waveguide bandpass filter can be formulated as [5]:

$$|S_{21}(j\omega)|^2 = \frac{1}{1+\varepsilon^2 T_N^2[\alpha(\frac{\lambda_g}{\lambda_{g0}})\sin(\pi\frac{\lambda_{g0}}{\lambda_g})]} \quad (1)$$

where ε is the ripple level constant, λ_g is the guided wavelength; $\lambda_{g0} \approx (\lambda_{g1} + \lambda_{g2})/2$ with λ_{g1} and λ_{g2} are guided wavelength at the upper and lower band-edge frequencies, respectively, $\alpha = [(\lambda_{g1}/\lambda_{g0})\sin(\pi\lambda_{g0}/\lambda_{g1})]^{-1}$; and TN is the Chebyshev polynomial of N degree. For a Chebyshev response filter, the Chebyshev polynomials, TN, can be formulated as [5]:

$$T_{N+1}(\omega) = 2\omega T_N(\omega) - T_{N-1}(\omega) \quad (2)$$

with initial condition $T_0(\omega)=1$ and $T_1(\omega)=\omega$

Fig. 1 illustrates the mathematical model [5] with S- parameter responses for a fifth-order Chebyshev polynomial $T_5(\omega) = 16\omega^5 - 20\omega^3 + 5\omega$ simulated using MATLAB. An insertion loss method is used to synthesize the desired filter response.

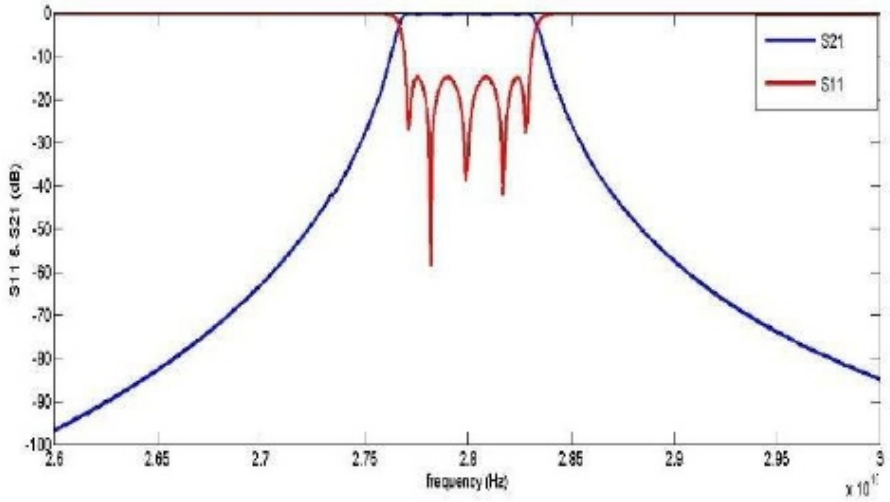

Fig 1: Mathematical model with S-parameter responses for fifth-order Chebyshev response waveguide filter with $T5(\omega) = 16\omega^5 - 20\omega^3 + 5\omega$.

Using a pre-determined filter order, N=5, the approximate initial dimensions for all resonators and irises can be determined, as explained in [5, 6].

III. SIMULATION RESULTS

The standard WR-34 waveguide, with its operating frequency range from 22 GHz to 33 GHz is chosen. Its cutoff frequency is 17.357 GHz and its internal dimensions are 8.64mm × 4.32mm. The designed filter is symmetric in geometry. The designed filter operates at 28 GHz with a return loss level better than 15 dB for the entire passband and a fractional bandwidth of 2.14%. Fig. 2 illustrates the 3D structure of the designed 5-cavity iris waveguide filter, together with its filter parameters. Tuning screws are added to the waveguide filter to tune toward the desired filter responses. Specifically, there are 6 inductive irises and 7 tuning screws. The tuning screws are added to the center of each resonator, including one before and one after the inductive iris from the wave port. Each tuning screw acts like an inductive iris, but it does not have an end- to-end touch of the guide. The final optimized filter parameters, including the tuning screws design parameters are as follows: $d_0 = d_5 = 1.096$mm, $d_1 = d_4 = 2.315$mm, $d_2 = d_3 = 2.436$mm, $l_1 = l5 = 5.557$mm, $l_2 = l4 = 5.616$mm, $l_3 = 5.572$mm, $h_1 = h7 = 0.658$mm, $h_2 = h6 = 0.015$mm, $h_3 = h_5 = 0.262$mm, $h_4 = 0.332$mm, L=45.72mm,D=2.571mm,th=5mm,X=3.054mm,wher e parameter d is the diameter of the irises, lis the length of the resonators, h is the height of the tuning screws, L is the length of the waveguide, D is the diameter of the tuning screws, th represents the thickness of the waveguide and X is the length before and after the first and last inductive post from the wave port. The thickness of the waveguide is kept constant at 5mm for fabrication consideration.

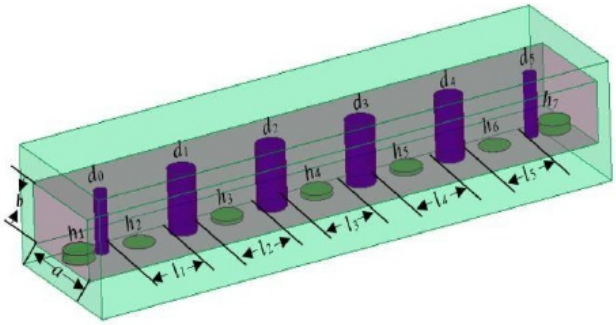

Fig 2: The 3D structure of the fifth-order waveguide filter using circular inductive posts.Design parameters at 28 GHz:

a =8.64mm, b=4.32mm,d_0= d_5=1.096mm, d_1= d4=2.315mm, d_2= d_3=2.436mm, l1= l5=5.557mm, l_2= l4=5.616mm, l_3=5.572mm, h_1= h7=0.658mm, h_2= h_6=0.015mm, h_3= h_5=0.262mm, h_4=0.332mm.

In Fig. 3, the simulated S-parameters responses are compared and analyzed with those of the theoretical responses. The simulated bandwidth and center frequency of the filter show a perfect agreement with the theoretical responses. The simulated return loss level depicts a satisfactory performance, that is better than 8.3405 dB for the entire passband, in contrast with the theoretical results of 15 dB. The S-parameters simulation results also indicate that the filter has an lower and upper stopband insertion loss measurements of-105.18dBand -84.59 dB at 26 GHz and 30 GHz, respectively, which are slightly away from the theoretical response. This filter can achieve a 600 MHz bandwidth with a passband insertion loss level less than 1 dB.

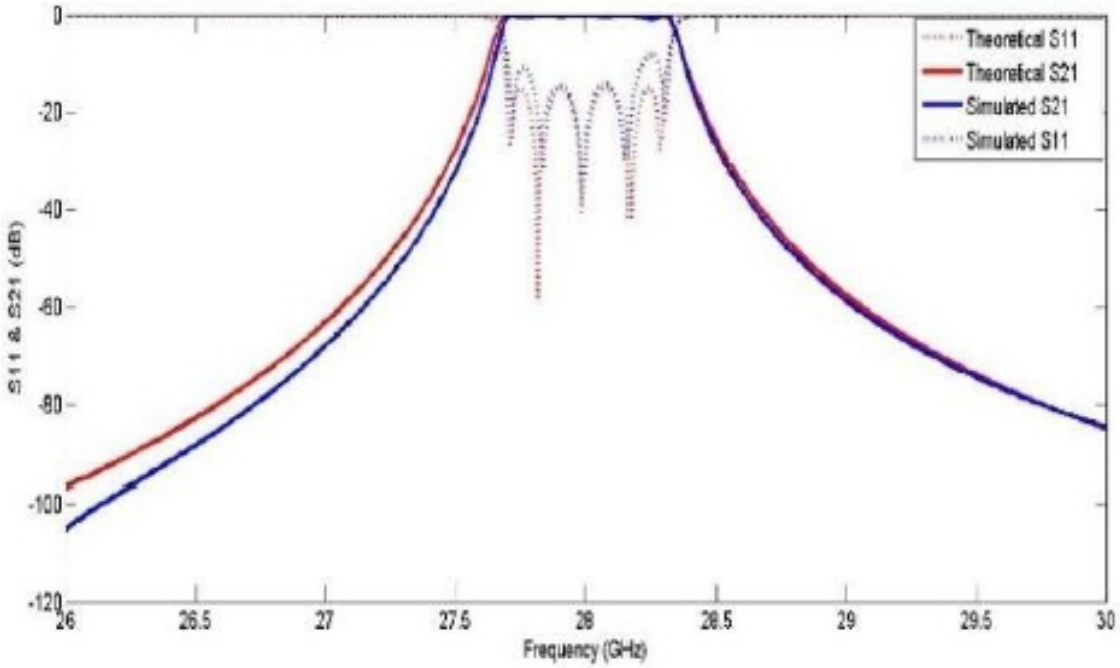

Fig 3: Simulated and theoretical S-parameters responses.

CONCLUSIONS AND RECOMMENDATIONS

The design and validation of a fifth-order millimeter- wave iris waveguide filter using circular inductive irises is presented in this paper. The main contribution of this research is that the designed iris waveguide band pass filter serves as a viable filtering device to exploit the millimeter-wave band, in order to offer a large bandwidth and a fast data transfer rate for satisfying the growing demand of spectrum based services in future 5G mobile networks. The simulation responses of the filter show a good agreement with the results from the theoretical model, which depict a low passband insertion loss and a good return loss level for the entire passband. For further work, fabrication of the waveguide filter will be carried out and measurement results will be analyzed and compared with those of the simulation model.

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