UNLEASHING THE POWER OF AI

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FOREWORD

The PGdepartmentof commerceof KorambayilAhamedHajiMemorial UnityWomen'sCollege, Manjeri takes much privilege in bringing out a Journal for the reference of academiccommunity and also aiming at many other stakeholders such as students, Research Scholars,Industrial community etc. The publication covers almost all significant areas of technology suchas networking, IoT, etc. I am very much sure that this effort will bean investing asset for the accomplishment of higher education dreams. Wishing all the successtothis smallendeavour.

Mr. Rahib B

Head & Assistant Professor

PGDepartment ofComputer Science

PREFACE

Welcome to the world of software projects and technologies. The book serves as a comprehensive Guide that explores the dynamic and ever – evolving landscape of software development, providing valuable insights and practical knowledge to both seasoned professionals and enthusiasts.

The field of software project and technologies has an integral part of our lives, transforming industries,Revolutionizing communication, and driving innovation across the globe.The structure of this book is organized in a logical and progressive manner. Each chapter focuses on a Specific aspect of software project and technologies, building upon the foundation established in thePreceding chapters.Whether you are a seasoned professional seeking to expand your knowledgeOr a student starting your journey in the world of software projects and technologies, thisBook caters your needs.

I would like to express sincere gratitude to the mentors, colleagues, and reviewers who have

Contributed their expertise and insights to the development of this book. Their invaluable input And support have played a pivotal role in its creation.

Iwouldliketo putonrecordadebtofdeepsenseofgratitudetoDr.MuhammedBasheerUmmathur,ourbelovedPrincipal,for his valuable guidance. I express my sincere thanks to Mr. Rahib B, Head andAssistant Professor, PG Department of Computer science, for his wholehearted encouragement incompleting the publishing work. Besides, I would like to shower my sincere gratitude to allfacultymembersofPGDepartmentofComputer scienceforttheirinspiration,guidanceandsuggestions.IwouldbefailinginobligationsifIdonotmentionmygratitudetoeveryonewho hascontributedtheirarticles tothisbook.

-The Editor

SEMINAR ARTICLES

ABSTRACT

This paper focused on the analysis of the development of hands-free interface between human and computer. The computer vision technology is intended to replace the conventional computer screen pointing devices for the use of disabled or a new way to interact with mouse using their face and eye movement. Some people who do not have hands cannot use computer, due to their inability to control mouse and keyword operations. By introducing them to technology and make them computer compatible will create them to learn and do some work. Several efforts are made by professionals to assist the disabled in providing them a tool to interact with the computers using signals such as electroencephalography(EEG) from the brain, facial muscle signals(EMG), which require the use of attachments and electrodes that makes them impractical. The method described in this paper does not use any of this expensive equipment. It just needs a computer with a webcam making it easy and uncomplicated method. By taking real-time images of the user, the program is designed to evaluate these images using a face detection algorithm. By using different expressions of a face using computer vision and matching it with already stored expression and execute actions as per the move. After detecting the face, the position of eyes and mouth is captured for controlling the mouse functions such as o left-click, right-click, scroll up and down, move the cursor up, down, left, right. This method doesn't require any special hardware and sensors.

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Chapter 1

INTRODUCTION

Eyes and their movements are important in expressing a person's desires, needs and emotional states. The significance of eye movements with regards to the perception of and attention to the visual world is certainly acknowledged since it is the means by which the information needed to identify the characteristics of the visual world is gathered for processing in the human brain. Computers are readily usable to persons who have hands to control mouse and keyboard and eyes to see what is on the monitor. Now even blind can use the computer using the text to speech option which pronounces the content on the screen. But people who do not have hands cannot use it due to their inability to control mouse and keyword operations. In today's competitive environment everybody needs to be equipped with different sets of skills so as get a job. Knowledge and usage of computers being a necessity nowadays. So this causes them to live a miserable life. Computer vision technology is intended to replace the conventional computer screen pointing devices for the use of disabled or a new way to interact with mouse using their face and eye movement. Several efforts are made by professionals to assist the disabled in providing them a tool to interact with the computers using signals such as electroencephalography (EEG) from the brain, facial muscle signals (EMG), and electrooculogram (EOG). Also, methods like limbus, pupil, and eye or eyelid tracking, contact lens method, corneal, pupil reflection relationship have also been implemented. These methods require the use of attachments and electrodes means some physical connection is needed to the head, which makes them impractical. The method described in this paper does not use any of this expensive equipment. It just needs a computer with a webcam making it easy and cheap and uncomplicated method. By taking real-time images of the user the program is designed to evaluate these images and identify the type of action to be performed by taking a match against the previously stored expressions to identify the operation to be performed and take parameter if needed in case of moving the cursor the change in the relative position of eyes concerning the central position tells about the direction to move the cursor. The implementation of this method would open a wide range of options for people who don't have hands. It will enable them to go to school and learn through the computer with the mouse being controlled by their head movement. It would also give them job opportunities in the service to earn them a job.

This research describes the transformation of a commercial eye-tracker for use as an alternative peripheral device in human-computer interactions, implementing a pointer that only needs the eye movements of a user facing a computer screen, thus replacing the need to control the software by hand movements.

0.1 GENERAL BACKGROUND

When computer vision started to take shape as a field in the 1960s, its aim was to try and mimic human vision systems and ask computers to tell us what they see, automating the process of image analysis. Inspired by human perception, the basic mechanisms of computer vision are straightforward and have not evolved much since the early years—the idea is to first extract meaningful features from the raw pixels, and then match these features to known, labeled ones in order to achieve recognition. In the 90s, features based on statistical analysis, such as principal component analysis (PCA), were successfully applied for the first time to complex recognition problems such as face classification. A classic example is the Eigenface method introduced by Matthew Turk and Alex Pentland . Given a database of face images, the mean image and the eigenvectors/images (also known as characteristic vectors/images) were computed through PCA. This small set of eigenimages can theoretically be linearly combined to reconstruct any face in the original dataset, or beyondThis kind of technology is the precursor to artificially intelligent image recognition. Just like animals, computers "see" the world differently from us humans: basically, they count the number of pixels, try to discern borders between objects by measuring shades of color, and estimate spatial relations between objects. As computer vision evolved, algorithms started to be programmed to solve individual challenges, and they become better at doing the job the more they repeat the task. By detecting the face regions and using the landmark information in the face, a camera is also able to detect blinking eyes, red-eye effects, or smiling and signal the users accordingly. Some applications go one step further by recognizing the faces.

Eye tracking research has been around for a long time. In general, the application of eye traversal consists of two categories : diagnostic and interactive. In diagnostic purpose, the eye tracking provides an evaluation over a user reaction to a given stimulant. In the other hand, the inter-active counterpart uses eye-gaze movement as an input to a system. Several attempts have been made to apply eye movement detection in a real world application. Iwata and Ebisawa combined pupil, eyelids, and head pose detection to mimics a mouse operation. A combination of pupil movement, eyelids opening and closing, and head movement allows a user to move pointer, click, and drag. A virtual on screen keyboard selected by a cursor controlled by eyeball movement make it possible for disabled person to provide text entry to a computer. Eye tracker is also efficient to help people who suffer paralysis to partially restore their mobility ability, by providing a control function for wheelchair.

Chapter 2

COMPUTER VISION TECHNOLOGY

Humans and most animals have eyes. We use our eyes and our brains to see and visually sense the world around us. Visual perception is the most important sense. A large proportion of our brain is used for processing visual information. Computer vision is a field of artificial intelligence that trains computers to interpret and understand the visual world. Using digital images from cameras and videos and deep learning models, machines can accurately identify and classify objects and then react to what they "see." Computer vision is concerned with the automatic extraction, analysis and understanding of useful information from a single image or a sequence of images. It involves the development of a theoretical and algorithmic basis to achieve automatic visual understanding. The goal of computer vision is to develop algorithms that allow computer to "see".It is a multidisciplinary field that could broadly be called a subfield of artificial intelligence and machine learning, which may involve the use of specialized methods and make use of general learning algorithms.

0.2 COMPUTER VISION APPROACHES

0.2.1 Typical task of computer vision

Computer vision tasks include methods for acquiring, processing, analyzing and understanding digital images, and extraction of high-dimensional data from the real world in order to produce numerical or symbolic information, e.g., in the forms of decisions. Understanding in this context means the transformation of visual images (the input of the retina) into descriptions of the world that can interface with other thought processes and elicit appropriate action. This image understanding can be seen as the disentangling of symbolic information from image data using models constructed with the aid of geometry, physics, statistics, and learning theory.

Recognition

The classical problem in computer vision, image processing, and machine vision is that of determining whether or not the image data contains some specific object, feature, or activity.

- Object recognition (also called object classification) – one or several pre-specified or learned objects or object classes can be recognized, usually together with their 2D positions in the image or 3D poses in the scene. Blippar, Google Goggles and LikeThat provide stand-alone programs that illustrate this functionality.

- Identification – an individual instance of an object is recognized. Examples include identification of a specific person's face or fingerprint, identification of handwritten digits, or identification of a specific vehicle.

- Detection – the image data are scanned for a specific condition. Examples include detection of possible abnormal cells or tissues in medical images or detection of a vehicle in an automatic road toll system. Detection based on relatively simple and fast computations is sometimes used for finding smaller regions of interesting image data which can be further analyzed by more computationally demanding techniques to produce a correct interpretation.

- Content-based image retrieval – finding all images in a larger set of images which have a specific content. The content can be specified in different ways, for example in terms of similarity relative a target image (give me all images similar to image X), or in terms of high-level search criteria given as text input (give me all images which contain many houses, are taken during winter, and have no cars in them).

- Pose estimation – estimating the position or orientation of a specific object relative to the camera. An example application for this technique would be assisting a robot arm in retrieving objects from a conveyor belt in an assembly line situation or picking parts from a bin.

- Optical character recognition (OCR) – identifying characters in images of printed or handwritten text, usually with a view to encoding the text in a format more amenable to editing or indexing (e.g. ASCII).

- Facial recognition- facial recognition system is a technology capable of identifying or verifying a person from a digital image or a video frame from a video source. There are multiple methods in which facial recognition systems work, but in general, they work by comparing selected facial features from given image with faces within a database.

Motion analysis

Several tasks relate to motion estimation where an image sequence is processed to produce an estimate of the velocity either at each points in the image or in the 3D scene, or even of the camera that produces the images . Examples of such tasks are:

- Egomotion – determining the 3D rigid motion (rotation and translation) of the camera from an image sequence produced by the camera.
- Tracking – following the movements of a (usually) smaller set of interest points or objects (e.g., vehicles, humans or other organisms[28]) in the image sequence.
- Optical flow – to determine, for each point in the image, how that point is moving relative to the image plane, i.e., its apparent motion. This motion is a result both of how the corresponding 3D point is moving in the scene and how the camera is moving relative to the scene.

Scene reconstruction

Scene reconstruction aims at computing a 3D model of the scene. In the simplest case the model can be a set of 3D points. More sophisticated methods produce a complete 3D surface model. The advent of 3D imaging not requiring motion or scanning, and related processing algorithms is enabling rapid advances in this field. Grid-based 3D sensing can be used to acquire 3D images from multiple angles. Algorithms are now available to stitch multiple 3D images together into point clouds and 3D models.

Image restoration

The aim of image restoration is the removal of noise (sensor noise, motion blur, etc.) from images. The simplest possible approach for noise removal is various types of filters such as low-pass filters or median filters. More sophisticated methods assume a model of how the local image structures look, to distinguish them from noise. By first analysing the image data in terms of the local image structures, such as lines or edges, and then controlling the filtering based on local information from the analysis step, a better level of noise removal is usually obtained compared to the simpler approaches.

0.2.2 System Methods

The organization of a computer vision system is highly application-dependent. Some systems are stand-alone applications that solve a specific measurement or detection problem, while others constitute a sub-system of a larger design which, for example, also contains sub-systems for control of mechanical actuators, planning, information databases, man-machine interfaces, etc. The specific implementation of a computer vision system also depends on whether its functionality is pre-specified or if some part of it can be learned or modified during operation. Many functions are unique to the application. There are, however, typical functions that are found in many computer vision systems.

Image acquisition

A digital image is produced by one or several image sensors, which, besides various types of light-sensitive cameras, include range sensors, tomography devices, radar, ultra-sonic cameras, etc. Depending on the type of sensor, the resulting image data is an ordinary 2D image, a 3D volume, or an image sequence. The pixel values typically correspond to light intensity in one or several spectral bands (gray images or colour images), but can also be related to various physical measures, such as depth, absorption or reflectance of sonic or electromagnetic waves, or nuclear magnetic resonance.

Pre-processing

Before a computer vision method can be applied to image data in order to extract some specific piece of information, it is usually necessary to process the data in order to assure that it satisfies certain assumptions implied by the method. Examples are :Re-sampling to assure that the image coordinate system is correct, noise reduction to assure that sensor noise does not introduce false information, contrast enhancement to assure that relevant information can be detected.

Feature extraction

Image features at various levels of complexity are extracted from the image data. Typical examples of such features are:Lines, edges and ridges, localized interest points such as corners, blobs or points.

Detection/segmentation

At some point in the processing a decision is made about which image points or regions of the image are relevant for further processing. Segmentation of one or multiple image regions that contain a specific object of interest. In this method, Segmentation of one or multiple videos into a series of per-frame foreground masks, while maintaining its temporal semantic continuity.

Decision making

The decision making include the final decision required for the application, for example: Pass/fail on automatic inspection applications, Match/no-match in recognition applications.

Chapter 3

EVALUATION OF AN EYE-POINTER INTERACTION DEVICE FOR HUMAN-COMPUTER INTERACTION

The eye-tracking concept refers to a set of technologies and procedures that make it possible to monitor and register the way in which a person fixes his/her visual attention on a given scene or image. Advances in eye-tracking technology have led to better human-computer interaction, and involve controlling a computer without any kind of physical contact. This research describes the transformation of a commercial eye-tracker for use as an alternative peripheral device in human-computer interactions, implementing a pointer that only needs the eye movements of a user facing a computer screen, thus replacing the need to control the software by hand movements. it is important to distinguish two main approaches in performing the observation: those that measure the position of the eye with respect to the head; and those that measure the orientation of the eyes in space. The latter is known as the “point of regard”. Several efforts are made by professionals to assist the disabled in providing them a tool to interact with the computers using signals such as electroencephalography (EEG) from the brain, facial muscle signals (EMG), and electrooculogram (EOG). Also, methods like limbus, pupil, and eye/eyelid tracking, contact lens method, corneal, pupil reflection relationship have also been implemented.

0.3 ELECTROOCULOGRAM

Electrooculography is a method for sensing eye movement and is based on recording the standing corneal retinal potential arising from hyperpolarizations and depolarizations existing between the cornea and the retina; this is commonly known as an electrooculogram (EOG).This potential can be considered as a steady electrical dipole with a negative pole at the fundus (retina) and a positive pole at the cornea. Therefore, a human eyeball can be assumable as a spherical battery that the centre of cornea is positive and the retina is negative. It is possible to regard that the battery like this is embedded in an eye socket and rotates around the torsional centre of eye. Consequently, the micro-currents flow radially from the positive pole to the negative pole of the battery through the conductive tissue in the orbit. These currents generate the standing potentials around the eye. The standing potentials in the eye can thus be estimated by measuring the voltage induced across a system of electrodes placed around the eyes as the eye-gaze changes. The EOG signal is a result of a number of factors, including eyeball rotation and movement, eyelid movement, different sources of artifact such as EEG, electrode placement, head movements etc.

0.4 ELECTROMYOGRAPHY

Electromyography is the study of muscle function through monitoring of the electrical signals generated by the muscle. The system uses electromyogram (EMG) signals from facial muscles to produce five distinct cursor actions, namely: left, right, up, down and left-click. EMG is recorded by using a small wearable device that acquires signals from the sensors on a headband. A surface electrode placed on the skin above a superficial muscle will receive electrical signals emanating from several muscle fibers associated with different motor units. The spatio-temporal summation of these electrical signals results in what is called an EMG signal. The classification algorithm can be determine if a facial muscle contraction had occurred and if so, which specific muscle was the source of this contraction. The power spectral dencity (PSD) indicated how the power of an EMG signal was distributed over a frequency range of 0 Hz – 600 Hz.

0.5 DETECTION BASED ON THE PUPIL AND CORNEAL REFLECTION

Operations of eye-tracking systems are achieved by means of a series of sequential operations. First, an infrared LED near to the observer irradiates the eye, and the reflected image is captured by a nearby camera. The infrared LED allows the device to distinguish between the pupil and iris regions. At the same time, the camera also captures the corneal reflection; here, an application may use a predefined threshold to increase precision. The center of the pupil and the position of the corneal reflection are detected using segmentation algorithms. For each user, the system creates a transformation function that corresponds to every movement first, with respect to central vision, and second, relative to the observed image. This transformation takes place through a calibration process that is independent for each observer. After defining and applying the appropriate transformation function, the eye-tracker system can record every eye movement for the scene or image.

Chapter 4

PROPOSED SYSTEM ARCHITECTURE

This section depicts the overview of the proposed system and introduces an algorithm to carry out the functions of a mouse by providing a hands-free interaction between humans and computers. The algorithm starts to detect a face of a person using a face detection algorithm. After detecting the face, the position of eyes and mouth is captured for controlling the mouse functions such as left-click, right-click, and cursor movement. This method doesn't require any special hardware and sensors. It is a hands-free system that is useful for handicapped. First, we have to activate the mouse control mode by opening the mouth. For moving the mouse cursor left or right we simply have to move our head in the intended direction of movement of a cursor. For enabling the scroll mode, we have to squint our eyes into the camera and on initiation, it will show scroll mode is on. Now you can move your head up for scrolling the up and similarly down to scroll the page down.

0.6 SYSTEM ARCHITECTURE

Human-Computer Interaction (HCI) application in Python (3.6) Version will allow us to control the mouse cursor with the facial expressions; it works with the regular built-in webcam in the Laptop. No wearable gadgets or sensors are needed. The Actions that include the facial expressions are:

- Winking of eyes
- Squinch eyes (To peep/ look with the eyes partially closed, similar to as looking too bright sunlight.
- Moving Head Around (Pitch and Yaw)
- Opening the mouth (To Activate and Deactivate the Cursor movement)

0.7 METHODOLOGY

The method for mouse movement by pupil and mouth movement was achieved using the following process.

0.7.1 Face detection

To represent a clean and accurate image, the user should face parallel to the webcam position. The image of the person is captured by webcam preinstalled in the system using OpenCV and processed using python. Dlib has a pre-trained dataset iBUG 300-W which has 68 coordinates that mapped to the face of a person. The facial detector detects key landmarks on the face of a person and tracks them. Figure 1 shows 68 facial coordinates.

Figure 1: Facial coordinate point

0.7.2 Eye detection

In terms of blink detection, we are only interested in two sets of facial structures — the eyes. Each eye is represented by 6 (x, y)-coordinates, starting at the left-corner of the eye (as if you were looking at the person), and then working clockwise around the remainder of the region as shown in figure 2.

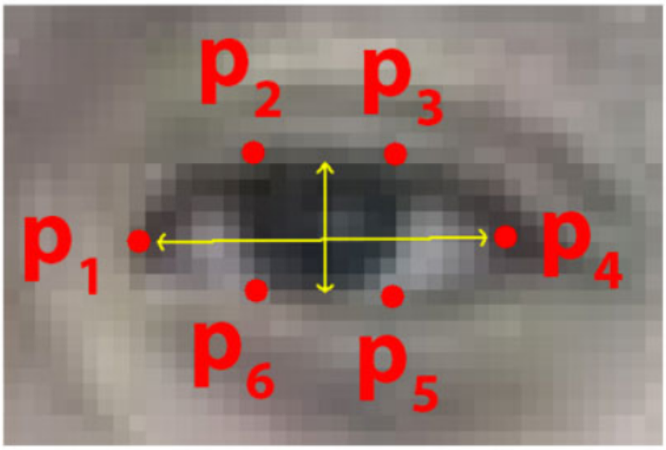


Figure 2: The 6 facial landmarks associated with the eye.

For eye detection, we use Eye-Aspect-Ratio (EAR). It was used to observe if the person's eye is flickering or not in the video frame. Each Eye is expressed as 6 coordinated (p1-p6), p1 is the coordinate of the left part of the eye and then p2-p6 is located accordingly when we travel in the clockwise direction. The eye aspect ratio is approximately constant while the eye is open, but will rapidly fall to zero when a blink is taking place.

$$EAR = \frac{(P2 - P6) + (P3 - P5)}{2(P1 - P4)} \quad (1)$$

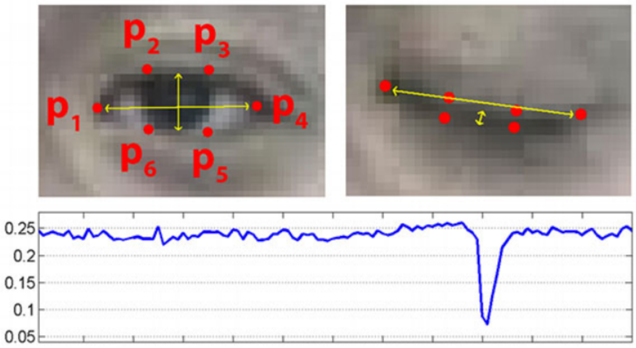


Figure 3: Top-left: Eye is open. Top-right: Eye is closed. Bottom: Plotting the Eye-Aspect-Ratio over time.

On the top-left eye that is fully open — the eye aspect ratio here would be large(r) and relatively constant over time. However, once the person blinks (top-right) the eye aspect ratio decreases dramatically, approaching zero. The bottom figure plots a graph of the eye aspect ratio over time for a video clip. As we can see, the eye aspect ratio is constant, then rapidly drops close to zero, then increases again, indicating a single blink has taken place.

0.7.3 Mouth detection

Same as eye-aspect-ratio, we have mouth-aspect -ratio(MAR), which is used to identify whether the mouth is open or not.

$$MAR = \frac{\|p2 - P8\| + \|p3 - P7\| + \|p4 - P6\|}{2\|p1 - P5\|} \quad (2)$$

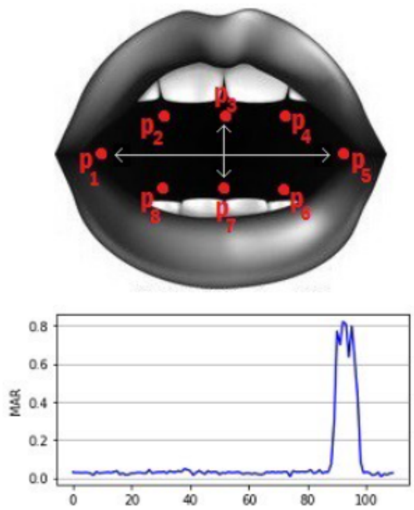


Figure 4: Mouth-Aspect-Ratio for mouth detection

Chapter 5

CODE REQUIREMENTS

These are all the packages available in python.

- NumPy - 1.13.3
- OpenCV - 3.2.0
- PyAutoGUI - 0.9.36
- Dlib - 19.4.0
- Imutils - 0.4.6

0.8 NUMPY

NumPy is the major bundle for logical processing with Python. NumPy Consists of an amazing N-dimensional cluster object, Sophisticated (broadcasting) capacities, Tools for coordinating C/C++ and Fortran code, Useful direct polynomial math, Fourier change and irregular number abilities. Other than its conspicuous logical uses, NumPy can likewise be utilized as a productive multi-dimensional compartment of conventional information. Subjective information types can be characterized. This permits NumPy to consistently and rapidly coordinate with a wide assortment of databases.

0.9 OPENCV

OpenCV (Open Source Computer Vision Library) is written in C/C++, for real time computer vision. It takes advantage of multi-core processing and hardware acceleration.OpenCV presents another arrangement of instructional exercises that will control you through different functions accessible in OpenCV-Python. OpenCV-Python is the Python Programming interface for OpenCV, consolidating the best characteristics of the OpenCV, C++ Programming interface and the Python language. And is accessible on various stages including Windows, Linux, operating system X, Android, and iOS. Interfaces for fast GPU tasks dependent on CUDA and OpenCL are additionally under dynamic improvement. Applications of OpenCV includes egomotion estimation, gesture recognition, facial recognition system, and artificial neural networks.

0.10 PYAUTOGUI

The reason for PyAutoGUI is to give a cross-stage Python module for GUI mechanization for people. The Programming interface is intended to be as basic as conceivable with reasonable defaults. PyAutoGUI can recreate moving the mouse, tapping the mouse, hauling with the mouse, squeezing keys, squeezing and holding keys.

0.11 DLIB

Dlib is a broadly useful cross-stage programming library written in the programming language C++. Its structure is vigorously affected by thoughts from a plan by agreement and segment based programming designing. Subsequently, it is, as a matter of first importance, a lot of autonomous programming parts. PyAutoGUI has no conditions (other than a cushion and some different modules, which are introduced by pip alongside PyAutoGUI). It needn't bother with the pywin32 module introduced since it utilizes Python's own C type's module.

0.12 IMUTILS

A progression of accommodation capacities to make essential picture handling capacities, for example, interpretation, pivot, resizing, skeletonization, and showing Matplotlib pictures simpler with OpenCV and both Python 2.7 and Python 3.6. This resize function of imutils maintains the aspect ratio and provides the keyword arguments width and height so the image can be resized to the intended width/height while maintaining aspect ratio. Skeletonization is the process of constructing the "topological skeleton" of an object in an image, where the object is presumed to be white on a black background.

Chapter 6

ALGORITHM AND WORKING OF SYSTEM

0.13 ALGORITHM

The algorithm starts to detect a face of a person using a face detection algorithm. For activating or deactivate mouse control we have to open mouth continuously for some time. If the user blinks their left eye it will act as a left click. If the user blinks their right eye it will act as a right-click. for some time it will activate or deactivate scrolling when the user squints his or her eye. Head will be used for cursor movements and scrolling up or down. The algorithm used can be depicted by the flowchart shown in Figure 6.1

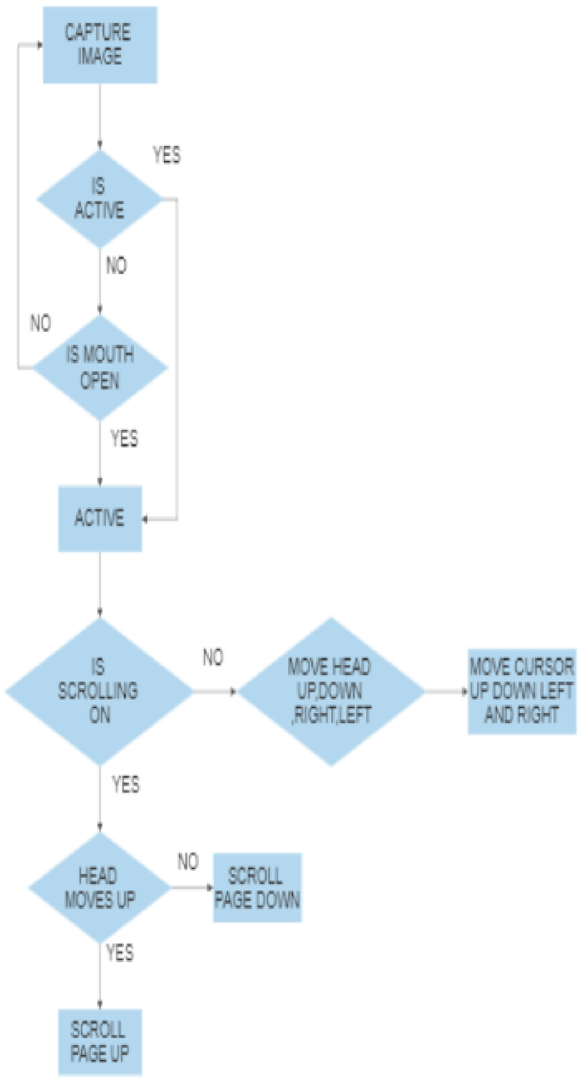


Figure 5: Flowchart of the algorithm

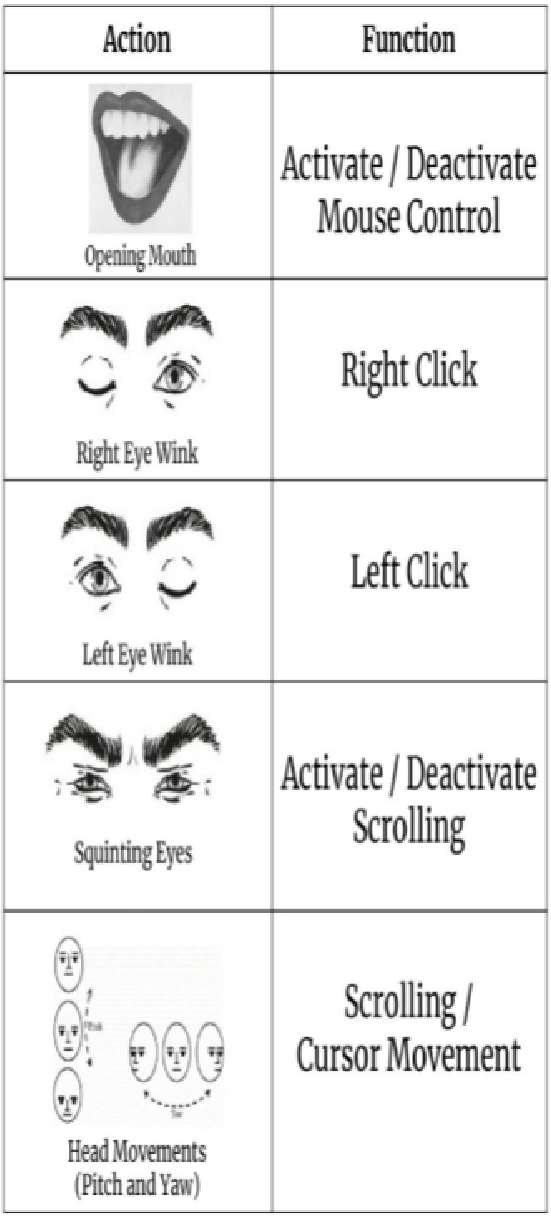
- The camera keeps looking for pictures at the rate of 30 frames per second. If it can detect a face then it checks whether the face control function is on or off.
- Then if it is enabled it captures frames for different instructions by the user through the movement of his face as per the directions given.
- If he wants to turn the scroll mode on he/she has to squint both eyes and then move his face up or down for scrolling.

- To simply move the cursor user will simply move his head.
- For click, he will squint one of his eyes as per the side of the mouse he wants to press.
- To disable the mouse control, he has to again open his mouse open.

0.14 WORKING

This project is deeply centered around predicting the facial landmarks of a given face. We can accomplish a lot of things using these landmarks. From detecting eye-blinks in a video to predicting emotions of the subject. The applications, outcomes, and possibilities of facial landmarks are immense and intriguing. Dlib's prebuilt model, which is essentially an implementation and not only does a fast face-detection but also allows us to accurately predict 68 2D facial landmarks. Using these predicted landmarks of the face, we can build appropriate features that will further allow us to detect certain actions, like using the eye-aspect-ratio to detect a blink or a wink. The EAR value drops whenever the eye closes. Using the mouth-aspect-ratio to detect a yawn etc or maybe even a pout. Similar to EAR, MAR's price goes up once the mouth opens.

The formula for automatic detection of voluntary eye movements was utilized within the development of a program. The Hough model is a feature extraction technique utilized in image analysis, and digital image processing. The aim of the technique is to search out imperfect instances of objects among a definite category of shapes by a picked procedure In this project, these actions are programmed as triggers to control the mouse cursor. PyAutoGUI library was used to move the cursor around.



Action	Function
Opening Mouth	Activate / Deactivate Mouse Control
Right Eye Wink	Right Click
Left Eye Wink	Left Click
Squinting Eyes	Activate / Deactivate Scrolling
Head Movements (Pitch and Yaw)	Scrolling / Cursor Movement

Figure 6: Action and their respective functions

Chapter 7

CONCLUSION

A system that enables a disabled person to interact with the computer was successfully developed and tested. It has an easy and wide application. Easy mouse cursor movement using face and switching between modes using eyes to enable or disable scrolling. Blinking to click. It has a wide range of applications. The system can be adapted to be used by individuals suffering from complete paralysis, to operate and control a weelchair. The proposed methodology is very simple and efficient on controlling the cursor movement in an efficient manner. It can be used for physically disabled people in their education as this would empower them to type instead of writing without hand. This will lead to job opportunities for disabled people. The eye mouse can be used in vehicles to observe the laziness of the driver by detecting the drowsiness symptoms, so it prevent vehicle accidents. It can also be used in gaming and the Internet of Things domain. The system also have enough intelligent in acquiring the users image from web camera. By taking real-time images of the user, the program is designed to evaluate these images and identify the type of action to be performed by taking a match against the previously stored expressions to identify the operation.This system will replace the use of conventional head movement based PC control by physically challenged people. This paper does not use any of this expensive equipment. It just needs a computer with a webcam making it easy and cheap and uncomplicated method.

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ABSTRACT

IoT is an extension of typical computer based Internet model to a geographically distributed, heterogeneous and constrained model of connected things. The "things" in IoT can be computers, sensors, actuators and processes. IoT applications offer value to the users by combining data sets from various IoT devices in-order to generate complex and interconnected business rules. These business rules then actuate IoT devices to automate the process. Effective business rules generation requires interoperability; Interoperability is the ability of equipment and systems from different vendors to operate together. Interoperability of the IoT Devices is hence becoming more and more important to build a scalable, adaptable and a seamless IoT Device networks. Which is not an easy feat because of multiple vendors problem and legacy system issues, because of that we say interoperability is one of the challenges facing the IoT. While the emergence of many IoT protocols promises Internet connectivity to a large number of devices, it also leads to an inevitable fragmentation that hinders the IoT adoption. It focuses deal of protocol multiplicity and eliminates the root cause of fragmentation. The concept of RINA (Recursive InterNetwork Architecture) using to design the IoT and to reduce above mentioned complexities. RINA refers; it is a computer network architecture that combines the distributed computing and telecommunications. RINA's fundamental principle is that computer networking is just Inter-Process Communication (IPC). It reconstructs the overall structure of the Internet and forming a model that comprises a single repeating layer. Also i investigate the benefits of RINA such as reducing protocol complexity, improving standardization, and enhancing security.

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Chapter 1

INTRODUCTION

Internet of Things (IoT) is an extension of typical computer based Internet model to a geographically distributed, heterogeneous and constrained model of connected things. The "things" in IoT can be computers, sensors, actuators and processes. The Internet of Things (IoT) is defined as a paradigm in which objects equipped with sensors, actuators, and processors communicate with each other to serve a meaningful purpose.

There are no single consensus on architecture for IoT, which is agreed universally. Different architectures have been proposed by different researchers, like; Three-and five layer architecture, Cloud and Fog based architecture, Edge computing architecture, Hybrid Cloud-Fog-Edge computing architecture, Mist computing architecture etc.

IoT applications offer value to the users by combining data sets from various IoT devices in-order to generate complex and interconnected business rules. These business rules then actuate IoT devices to automate the process. Effective business rules generation requires interoperability; Interoperability is the ability of equipment and systems from different vendors to operate together. Interoperability of the IoT Devices is hence becoming more and more important to build a scalable, adaptable and a seamless IoT Device network. Which is not an easy feat because of multiple vendors problem and legacy system issues. Because of that we say interoperability is one of the challenges facing the IoT. Fragmentation, Cost, Connectivity, managebility, security are the other major challenges is faced by IoT.

IoT Network protocols, HTTP, LoRaWan (Long RangeWide Area Network), ZigBee, IoT Data Protocols, MQTT (Message Queue Telemetry Transport), CoAP (Constrained Application Protocol) etc. While the emergence of these IoT protocols promises Internet connectivity to a large number of devices, it also leads to an inevitable fragmentation that hinders the IoT adoption. It focuses deal of protocol multiplicity and eliminates the root cause of fragmentation.

This paper deals with the concept RINA (Recursive InterNetwork Architecture) to design the IoT architecture and to eliminate the above mentioned complexities.

RINA (Recursive InterNetwork Architecture) is a computer network architecture that combines the distributed computing and telecommunications. RINA's fundamental principle is that computer networking is just Inter-Process Communication (IPC). It reconstructs the overall structure of the Internet and forming a model that comprises a single repeating layer. In details, RINA is based on the fundamental principle that networking is Inter-Process Communication (IPC). RINA recurses the IPC service over different scopes. Specifically, a scope defines a Distributed IPC Facility (DIF) comprised of the set of IPC processes, possibly running on different machines, that collaboratively provide a set of well-defined flow services to upper application processes. The mechanisms within each IPC process are the same but each DIF layer is instantiated using a possibly different set of policies.

The main concept of this paper is designing the IoT architecture using RINA. In this procedure, it consist of two elements IoT device and an IoT sub-manager. The IoT device has two DAPs- one is part of the IoT DAF and other is part of the DIFs. The aim of the IoT sub manager is to translate the Non RINA IoT protocol to a common RINA protocol CDAP. Using these two, RINA concept is applied on the IoT architecture.

Disadvantages of IoT is security, privacy, complexity etc. By using the RINA concept to design IoT architecture, it provide various advantages like; Reduced protocol complexity, Improved standardization and reduced time-to-market, Improved security.

Several trends in networking such as SDN or network virtualization are naturally supported by RINA, meeting requirements for 5G networks, IoT and customized private clouds. Such as Recursive congestion management, Securing RINA networks, RINA for converged operator networks in 5G scenarios, RINASim: OMNeT++ RINA simulator IRATI: A programmable RINA implementation for Linux/OS.

1.1 Objective

The main objective of this seminar is to simplify IoT by design based on the Recursive InterNetwork Architecture (RINA) and explores RINA's benefits such as reducing protocol complexity, improving standardization, and enhancing security.

Chapter 2

IoT(INTERNET OF THINGS)

2.1 Internet of Things

IoT is an extension of typical computer based Internet model to a geographically distributed, heterogeneous and constrained model of connected things. The "things" in IoT can be computers, sensors, actuators and processes. The Internet of Things (IoT) is defined as a paradigm in which objects equipped with sensors, actuators, and processors communicate with each other to serve a meaningful purpose. These devices range from ordinary household objects to sophisticated industrial tools. With more than 7 billion connected IoT devices today, experts are expecting this number to grow to 10 billion by 2020 and 22 billion by 2025.

The internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. A thing in the internet of things can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low or any other natural or man-made object that can be assigned an Internet Protocol (IP) address and is able to transfer data over a network. Increasingly, organizations in a variety of industries are using IoT to operate more efficiently, better understand customers to deliver enhanced customer service, improve decision-making and increase the value of the business.

2.2 What is IoT?

Internet of Things (IoT) is a network of devices which can sense, accumulate and transfer data over the internet without any human intervention. What makes living things alive? They can sense and communicate with each other, can't they? Whether inanimate objects could sense and interact with each other without any human intervention?

This is pretty much the underlying concept of Internet of Things.

Figure 2.1: Concept of internet of things

2.3 How IoT works

An IoT ecosystem consists of web-enabled smart devices that use embedded systems, such as processors, sensors and communication hardware, to collect, send and act on data they acquire from their environments. IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices – for instance, to set them up, give them instructions or access the data. The connectivity, networking and communication protocols used with these web-enabled devices largely depend on the specific IoT applications deployed. IoT can also make use of artificial intelligence (AI) and machine learning to aid in making data collecting processes easier and more dynamic.

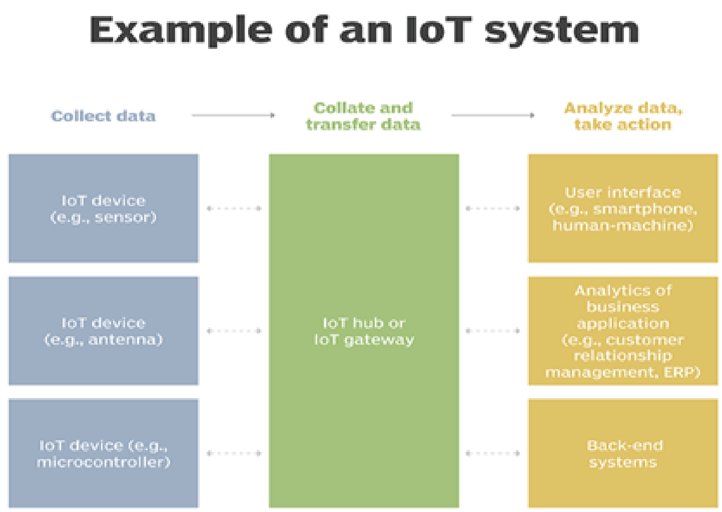

Figure 2.2: Example of an iot system

2.4 Why Is IoT so Important?

Over the past few years, IoT has become one of the most important technologies of the 21st century. Now that we can connect everyday objects—kitchen appliances, cars, thermostats, baby monitors—to the internet via embedded devices, seamless communication is possible between people, processes, and things. By means of low-cost computing, the cloud, big data, analytics, and mobile technologies, physical things can share and collect data with minimal human intervention. In this hyper connected world, digital systems can record, monitor, and adjust each interaction between connected things. The physical world meets the digital world and they cooperate. The internet of things (IoT) helps people live and work smarter, as well as gain complete control over their lives. In addition to offering smart devices to automate homes, IoT is essential to business. IoT provides businesses with a real-time look into how their systems really work, delivering insights into everything from the performance of machines to supply chain and logistics operations. IoT enables companies to automate processes and reduce labor costs. It also cuts down on waste and improves service delivery, making it less expensive to manufacture and deliver goods, as well as offering transparency into customer transactions. As such, IoT is one of the most important technologies of everyday life, and it will continue to pick up steam as more businesses realize the potential of connected devices to keep them competitive.

2.5 Internet of Things (IoT) characteristics

The fundamental characteristics of the IoT as defined as follows:

Interconnectivity - With regard to the IoT, anything can be interconnected with the global information and communication infrastructure.

Things- related services - The IoT is capable of providing thing-related services within the constraints of things, such as privacy protection and semantic consistency between physical things and their associated virtual things. In order to provide thing-related services within the constraints of things, both the technologies in physical world and information world will change.

Heterogeneity - The devices in the IoT are heterogeneous as based on different hardware platforms and networks.

Dynamic changes - The state of devices change dynamically, e.g., sleeping and waking up, connected and/or disconnected as well as the context of devices including location and speed. Moreover, the number of devices can change dynamically.

2.6 IoT Architecture

IoT is not just Internet-connected consumer devices. In fact, IoT is the technology that builds systems capable of autonomously sensing and responding to stimuli from the real world without human intervention. Therefore need to develop a process flow for a definite framework over which an IoT solution is built. There is no single consensus on architecture for IoT, which is agreed universally. Different architectures have been proposed by different researchers are; Three- and Five-Layer Architectures, Cloud and Fog Based Architectures, Edge Computing Architecture, Hybrid Cloud-Fog-Edge Architecture, Mist Computing Architecture. The IoT Architecture generally comprises of these 4 stages:

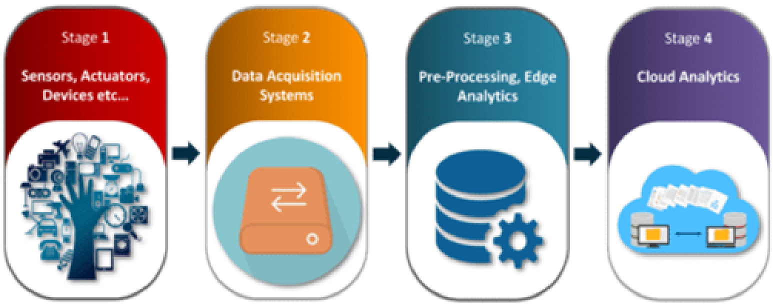

Figure 2.3: Fours stages of IoT architecture

Stage 1 (Sensors/Actuators): A thing in the context of "Internet of Things", should be equipped with sensors and actuators thus giving the ability to emit, accept and process signals.

Stage 2 (Data Acquisition Systems): The data from the sensors starts in analogue form which needs to be aggregated and converted into digital streams for further processing. Data acquisition systems perform these data aggregation and conversion functions.

Stage 3 (Edge Analytics): Once IoT data has been digitized and aggregated, it may require further processing before it enters the data center, this is where Edge Analytics comes in.

Stage 4 (Cloud Analytics): Data that needs more in-depth processing gets forwarded to physical data centers or cloud-based systems.

2.7 Advantages of IoT

2.7.1 Define what you'd like to learn from sensors:

Over the next three years, a majority of the devices purchased will have sensors and many existing items can be retrofitted with sensors. This will produce a wide range of new data sources for people and systems to use to improve their lives and existing business processes. Within a business setting, IT must define what types of information can be obtained from these sensors and work with business leaders to define which business processes can be improved with this new IoT information

2.7.2 Connected Infrastructure:

Connected Infrastructure combines industry-leading customer advocacy, design, and support teams, for a comprehensive approach to the network. Connected Infrastructure delivers maximum performance, time savings, space optimization, superior customer experience and sustainability by design, to address challenges.

2.7.3 Automation And Control:

Due to physical objects getting connected and controlled digitally and centrally with wireless infrastructure, there is a large amount of automation and control in the workings. Without human intervention, the machines are able to communicate with each other leading to faster and timely output.

2.7.4 Connected Transportation:

Using IoT in aviation, maritime, rail and roadways can improve safety, lower cost for greater scale, make transportation more secure and enable smart choices. IoT helps to monitor things in the real-time. We can know the availability of things instantly and track them whatever and whenever we want.

2.8 Challenges of IoT

2.8.1 Connectivity

Connectivity is an important component of IoT because it plays a vital role in the transport of data from the sensors and transmission of instruction to the actuators. In the context of IoT, connectivity can be evaluated at various levels from frequency bands at physical layer to MAC protocols at link layer, network protocols and mobility at network layer, transport protocols at transport layer and application protocols at application layer.

2.8.2 Interoperability

IoT applications offer value to the users by combining data sets from various IoT devices in-order to generate complex and interconnected business rules. These business rules then actuate IoT devices to automate the process. Effective business rules generation requires interoperability, which is not an easy feat because of multiple vendors. The first challenge in IoT is to build a middleware that is capable of supporting all kinds of devices and IoT applications. However, creating such a unified middleware that will be used across the industry has proven to be an impossible task so far due to a combination of factors such as market interests and lack of standardization. For example, industry players tend to create their own IoT platforms with their own technology stacks and abstractions. While the underlying protocols are the same, the implementation details can be different. This not only creates interoperability problems but also limits the choice in making comparisons and deciding which platform to use.

2.8.3 Fragmentation

The primary source of fragmentation in IoT is the use of different data transfer protocols. Fragmentation using different application protocols contributes even more to creating barriers and locking in customers as well. This creates a translation problem. Translating between application protocols requires translating the semantics of the operations and of the object models. It can be very difficult to capture (and preserve) all of the variation of the semantics, which are never well-specified. Here a standard application protocol can have a major effect by eliminating the need for translation, which would also eliminate unforeseen effects when the translation failed to capture some variation of the semantics.

2.8.4 Cost

From the point of view IoT platform provider, connecting new device types that have different protocols takes implementation time and efforts. which is true for standard protocols and even more for proprietary ones. In order to integrate a new IoT protocol, we have to deal with two major steps. First of all, it is needed to implement the low-level communication details of the protocol and secondly, the devices have to be represented in a unified way. The unified representation should be common for different types of protocols. It is typically implemented in the form of a device abstraction that extract the main protocol functionalities so that devices can be managed in the same way irrespective of the underlying protocols they support. All of these activities come at a certain cost for development. Another aspect of the cost is to ensure support for the newer versions of the underlying protocols. What is more, there are numerous devices by different manufacturers that may introduce behavior that is not fully compliant with the protocol specifications. In addition, if a protocol becomes popular temporarily, but eventually its use does not become widespread in the long term, the efforts for implementing its support into the IoT platform may become completely wasted. At the same time, the IoT platform provider may still be tempted to provide support for it – even if only a relatively small number of companies are using it – expecting that it will eventually become popular again.

2.8.5 Security

Security in IoT is fundamentally linked to the ability of users to trust their environment. If people don't believe their connected devices and their information are reasonably secure from misuse or harm, the resulting erosion of trust causes a reluctance to use the Internet. This has global consequences to electronic commerce, technical innovation, free speech, and practically every other aspect of online activities. Indeed, ensuring security in IoT products and services should be considered a top priority for the sector. The first issue is, the Internet as a whole, are actually related to the TCP/IP model. The protocols of the TCP/IP suite were developed without security considerations. Securing the TCP/IP itself has been largely an after-thought rather than providing solutions from within the TCP/IP architecture. IoT naturally inherits those issues as the current IoT architectures are based on TCP/IP. The second issue is, it is difficult to achieve end-to-end security in the IoT environment. The information travels through different hops in a network, protocol translations at intermediary nodes might not work with the existing security solutions for two reasons: first, the information relevant for translation is sent in encrypted form and might not be available to the nodes, and second, the changes made at the gateways might invalidate the end-to-end data integrity protection

Chapter 3

RINA(Recursive InterNetwork Architecture)

3.1 Introduction

The Internet is changing and evolving rapidly. Nowadays, more and more applications are created continuously and due to the requirements of the networks, the Internet has become an architectural patchwork with increased complexity. Thus, new architectures are being proposed to solve the weaknesses of the current Internet. RINA is a new network architecture, which was developed from scratch as an alternative to TCP/IP. John Day, the originator of this idea, claims that there are some networking principles which are independent of technology and when applied, lead to a much simpler implementation and a unified theory of networking. Thus, he focuses on the fundamentals of networking and argues that in order to get a deeper understanding of architecture, abstractions have to be used. The outcome is a simplified and a more easily managed model. RINA is based on inter-process communication and capitalizes on repeating patterns and structures as well as on the separation of mechanisms from policies. The hierarchical model in which layers can be stacked on top of each other recursively, is also embraced by the architecture of SDN. RINA attempts to solve the problems of TCP/IP like mobility, multihoming and addressing by providing a secure and configurable environment which is similar to the SDN trend. The simplicity and the features of this architecture, make RINA a topic worthwhile to be examined.

3.2 RINA Structure and Mechanisms

On the contrary to the other network stacks, RINA recourses the same layer which is called DIF. The lowest layer, shim DIF, operates over any lower layer, which could be physical, or other protocols such as TCP or UDP. DIFs are usually numbered from 1 (e.g. 1-DIF, 2-DIF) as the lowest, and N-DIF refers to the current layer one focuses on. In Fig. 3.1, a sample arrangement of two layers of DIFs between two end-nodes and two routers is shown. An IPC Process (IPCP) is an instance of the same code managing IPC in each layer at each node. The internal structure of every IPCP is the same, and it consists of the following mechanisms which operate at different timescales;

- **Data Transfer:** handles packet transmission including:

  – Delimiting: a mechanism for encoding Service Data Units (SDUs) coming from the upper layer/DIF within PDUs.

  – Error and Flow-Control Protocol (EFCP): is composed of two sub-protocols, Data Transfer Protocol (DTP) and Data Transfer Control Protocol (DTCP), which handle data transmission.

  – Relaying and Multiplexing Task (RMT): routes packets to output ports of the DIF or upwards.

  – SDU Protection: intended for encryption, compression, error-code and TTL.

- **Data Transfer Control:** handles error, flow, and retransmission control.

- **Layer Management:** includes

  – Routing

  – Common Distributed Application Protocol (CDAP): operates on configuration objects, and layer management

  – Resource and flow allocation

  – Locating applications

– Security management, access control,

– Enrollment, and authentication.

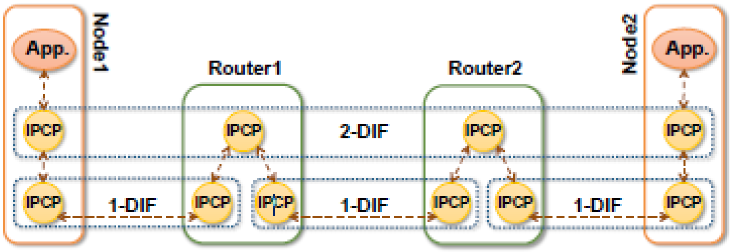

Figure 3.1: A sample RINA topology with two end-nodes and two routers

3.3 Unique Features of RINA

3.3.1 Secure DIFs

"DIF is a secure container". RINA secures layers instead of protocols. Every PDU leaving N-DIF towards an (N-1)-DIF can be protected by the SDU protection module meaning that RINA protects NDIF PDUs in their entirety as they cross the N-1 DIF boundary. Even control information (addresses, flow-ids, etc.) can be protected from the layer below. This solves the PEP problems with breaking secure connections by intermediate nodes.

3.3.2 Divide and Conquer

Through DIFs and recursion, the problem of securing a wide scope (e.g. as wide as the Internet scale) will be divided to the problem of securing smaller scopes. Compromising the protection of some DIFs does not compromise the whole network.

3.3.3 QoS

Every connection in RINA is established after the source represents its QoS requirements which include maximum requested bandwidth. Deviating from those, e.g. in

DoS attacks by congesting the network, can result in dropping its packets at the first routing node, which is some form of DoS prevention.

3.3.4 Mobility

Mobility management in RINA is smoothly performed since every IPCP at every DIF can seamlessly join/leave DIFs without losing its name in its own DIF. It just needs some local routing updates at lower DIFs, without any side-effects on security. In addition to mobility, RINA can also improve multi-homing.

3.3.5 Authentication

Every IPCP should be authenticated first before joining a DIF. This is performed before connection management through the enrollment process, and enrollment does include access control. This means that attackers have to join a DIF to be able to address IPCPs in that DIF which requires authentication first.

3.3.6 Firewall

Every router will naturally play as a firewall in RINA. Security modules in IPCPs can provide firewall functionalities.

3.3.7 Programmable DIFs

Any new functionality, which might address some security, privacy, or performance issue, can be simply developed as a policy and plugged into existing mechanisms. This reduces functional redundancies in protocols and the risk of causing new vulnerabilities by reducing required efforts.

3.3.8 Access Control

Authorization in RINA is performed by the Access Control module in IPCP, and uses CDAP as the signaling protocol. This mechanism determines if a requesting entity is allowed to access a given resource.

3.3.9 Synchronization-Independent Port Allocation

RINA decouples port allocation from the synchronization process happening in protocols such as TCP, which reduces the chance of intercepting a connection and makes attacks harder to mount.

Chapter 4

IOT BASED ON RINA

4.1 Introduction

This paper deals with the concept RINA (Recursive InterNetwork Architecture) to design the IoT architecture and to eliminate the above mentioned complexities. One of the top trends impacting the Internet of Things (IoT) is that the number of things, or devices, that connect to the Internet grows at a tremendous rate. According to Gartner, there are 14.2 billion connected things in use in 2019 with an estimated increase of up to 25 billion by 2021. This opens a remarkable potential to create enormous business value and to reshape entire industries. A report by McKinsey predicts that the IoT can generate a global economic value of up to 11.1 trillion a year by 2025. With that in mind, it becomes crucial to design an IoT architecture that will ensure that things are connected in a seamless and interoperable way. The current architectures face challenges due to the existence of a plethora of connectivity protocols. A device that supports one protocol and is used in one IoT system can be difficult to be readily used in another IoT system that supports the same protocol due to potential differences in middleware and proliferation of "standards." Despite the fact that these protocols share commonalities, they are different from each other from an applications and networking perspective. Translating between application protocols can be especially challenging as it requires translating both the semantics of the operations and of the object models. As a result, using different technologies to achieve identical use cases can lead to fragmentation and barriers to entry, factors that can negatively affect interoperability and significantly increase the cost.

Identifies middleware as a key technology for the development of IoT applications. The purpose of IoT middleware is to hide the underlying details of the low-level communication protocols. This helps reduce the cost and time for development along with having the capability to bridge across different types of devices.

One of the most important roles of IoT is to connect heterogeneous networks using various communication technologies and protocols. Architecture standardization as a factor that will foster market competition based on creating quality products, but at the same time claims the architecture requires new protocols between heterogeneous devices – this fragments the market, reducing quality.

Using RINA's single recursive layer, our purpose is to model an architecture of what should be the "ideal" case that will provide interoperability by design and that will inherently reduce protocol complexity. An IoT architecture with RINA is based on a single layer that makes a clear delineation between transmission mechanisms and transmission policies. While transmission mechanisms are fixed, transmission policies can be adjusted.

4.2 Iot Based Approach to RINA

This section presents the fundamentals of RINA, gives an overview of the main RINA elements, and proposes a novel RINA-based approach for designing the architecture of IoT.

4.2.1 RINA: A Different Kind of Networking

The proposed in the pioneering work of the RINA as a network architecture that is based on the principle that networking is inter-process communication (IPC). RINA takes an alternative approach to networking compared to the mainstream TCP/IP model. In TCP/IP, it assumes a different set of dedicated layered functions. Instead of that, RINA builds on the premise that there is a single layer responsible for IPC that recurses over different scopes. In TCP/IP the numbers of layers are fixed. In RINA the numbers of layers not fixed and layers can be stacked on top of each other depending on the application or networking needs. The traditional network architecture attempts in one layer to effectively provide and manage traffic over multiple orders of magnitude. This is an unreasonable expectation. RINA uses layers of repeating functionality configured to provide and manage a given range of operation (e.g. capacity, QoS and scale). By using divide and conquer the great range is more effectively addressed.

4.2.2 Main Concepts in RINA

As per requirement for designing an IoT architecture based on RINA, the following RINA concepts will be introduced: Distributed Application Facility (DAF), Distributed Application Process (DAP), Application Process (AP), Distributed IPC Facility (DIF), IPC Process (IPCP), Error and Flow Control Protocol (EFCP), and Common Distributed Application Protocol (CDAP).

A DAF consists of individual processes, called DAPs, cooperating across one or more processing systems that exchange information using IPC and maintain a shared state. Each DAP has tasks that manage distributed resource allocation, storage, and IPC within the DAF as well as the tasks specific to the distributed application.

A DIF is a specialization of a DAF. It is a collection of two or more APs that cooperate to provide IPC services to applications or upper layers. The elements unique to a DIF are delimiting, EFCP, and the flow allocation. An AP is a program instantiation that is intended to accomplish a specific purpose, while an IPCP is a special AP within a DIF that delivers IPC services.

A distinguishing feature of RINA is that a DIF provides a clear separation between mechanisms and policies. While all DIFs are independent of each other, each DIF provides the same set of fixed mechanisms such as data transfer, routing, congestion control, etc. What is different is that these mechanisms can be configured differently for different use cases, i.e. using different policies. In RINA, if an application makes a request to allocate networking resources, then this common RINA layer determines the mechanisms and policies that will satisfy the application's request.

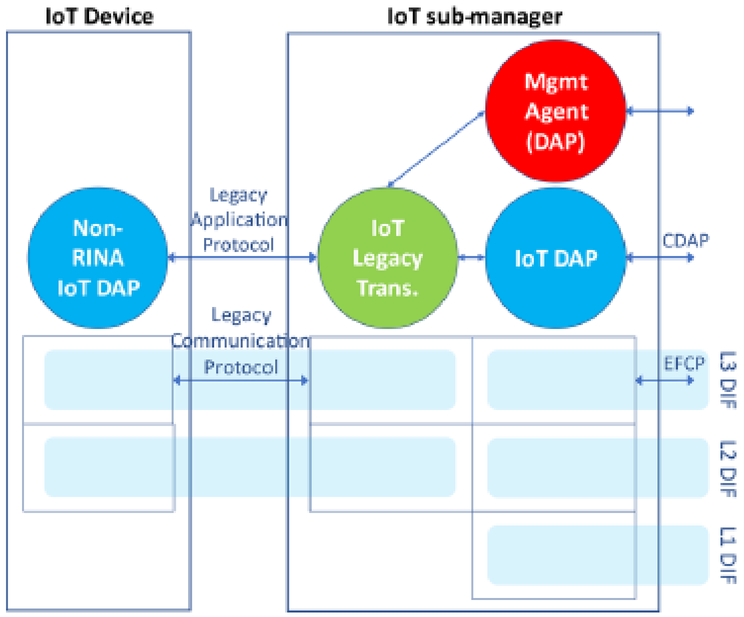

Figure 4.1: A RINA-based representation of an IoT device and an IoT submanager

The tasks unique to a DIF are Flow Allocation, Delimiting, Relaying, and EFCP. EFCP deals with maintaining an IPC instance within a DIF. EFCP is a data transfer protocol that ensures reliability, order, and flow control. On the other hand, CDAP enables distributed applications to deal with communications at an object level, rather than forcing applications to explicitly deal with serialization and input/output operations. It helps sharing data over a network without having to create specialized protocols and thus can be used to construct arbitrary distributed applications.

4.2.3 Design of IoT Architecture Using RINA

The IoT architecture is the same as the architecture of network management. The network management is one kind of IoT.IoT consists of devices of all kinds such as sensors and actuators that are connected to the Internet using different protocols. If we are ignoring the device type or supported protocol, the function of an IoT device is to provide an analog-to-digital (A-to-D) interface between the analog and digital worlds that is accessed by an IoT Agent (IoTA). An IoTA is an application in IoT. The A-to-D interface resides in the device's operating system. An IoT device may have one or more A-to-D interfaces that are accessed by one or more IoTAs, and one Network Management Agent (NMA), used to manage the DIFs in the IoT device. The IoTAs belong to an IoT DAF that is managed by an IoT Application Manager.An IoT network may consist of different systems, and every system has its own NMA. The NMAs belong to the Network Management DAF (NMA DAF). These agents report to a Distributed Management System (DMS) that aggregates and processes sensed data to make it available to the users of the IoT network. The DMS is the IoT Management Application. DMS is distributed across IoT managers that process DMS data for different regions of devices. DMS also includes IoT sub-managers that have the task to translate legacy application protocols to a common protocol as well as preprocess DMS data for sub-regions of devices.Translation is needed as IoT devices use different application and communication protocols.

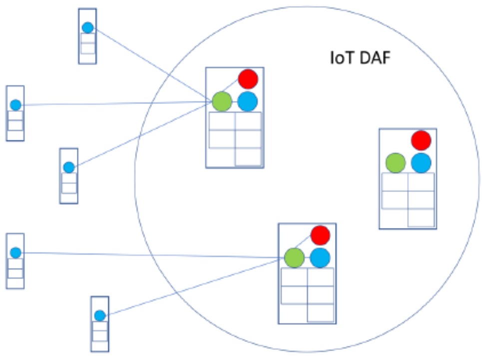

Figure 4.2: IoT DAF

Fig 4.1 gives the main constituent element of a RINA based architecture for IoT. It includes an IoT device and an IoT sub-manager. An IoT device has two DAPs: one DAP is part of the IoT DAF, and the other DAP that is part of the NMA DAF. An IoT device may employ two or more types of DIFs: one type of DIF interfaces to each instance of the physical medium (different media may require a differently configured media DIF). The other DIF which is over the media DIFs, is concerned with managing resource allocation across the different instances of physical media. The main purpose of the IoT sub-manager is to translate a legacy (non-RINA) IoT protocol to a common RINA protocol – CDAP. CDAP achieves commonality by taking advantage of what has been known in the networking industry since the late 1980s – namely, that application protocols modify state external to the protocol, and the only operations that can be performed remotely are read/write, create/delete, and start/stop on object models. (CDAP is based on the experience with CMIP, HEMS, and even SNMP). As noted earlier, these simple operators ensure that the focus is on the definition of the object models, i.e. the application, where it belongs. Clearly, there can be a wide range of object models, which are not part of the protocol. Hence the number of application protocols is actually quite small. This approach is a major advantage to development and shortening time to market. It is much easier to add new object models than to modify an existing protocol. Given that CDAP is independent of the object models, arbitrary application protocols (e.g. Z-Wave or ZigBee) can be translated using an identical underlying methodology since they are mostly concerned with operations such as read/write, create/delete, and start/stop.

The Legacy Application Protocol communicates with the IoT Legacy Translation DAP using the Legacy Communication Protocol. The Legacy Communication Protocol carries the data from the IoT device to the top layer (3rd level DIF) of the IoT sub-manager, which in turn delivers the data to the IoT Legacy Translation DAP. The IoT Legacy Translation DAP passes the result to the IoT DAP which uses EFCP as a common communication protocol to transmit data to other parts of the IoT network. While undoubtedly a necessary evil initially, the advantage to the customer (the owner of an IoT installation) to eliminate these translations cannot be overstressed. They are not only unnecessary overhead but also hold the potential for unforeseen (and potentially catastrophic) behavior.

Every IoT network needs to have at least two DAFs: one DAF to manage the communications and another DAF for the IoT applications. The purpose of the first DAF is to manage the IoT network; there are three cases that can be listed in this context: a) IoT devices may be purely end systems connected to media level routers (bridges), b) forward data to other IoT devices in its network, or c) be directly connected in a star configuration to an IoT submanager as shown on Fig 4.1. On the other hand, the purpose of the second DAF is to manage the IoT application.

Depending on the problem domain, more than one IoT device type may be managed by one IoT management application. The commonality RINA brings to these DAFs is again another major advantage.

Fig 4.2 represents the IoT DAF. The IoT DAF only includes IoT sub-managers because they are operating within the RINA model. While the IoT devices do not belong to the IoT DAF, they can become part of it by introducing a RINA DIF that will replace the need for protocol translation. After moving to commonality with such a DIF, the entire network would be within the same DAF and primary IoT DAPs could have direct access to the sensors. The IoT DAF has its own DIFs with policies that support its communication requirements. By distinguishing the IoT manager and network manager, it is possible for a single network manager to support multiple IoT applications, or for the two to have different entities (organizations) responsible for them.

4.3 Benefits of RINA In IOT

The section discusses why RINA leads to a better architecture for the IoT and what are the possible advantages for the industry.

4.3.1 Reduced Protocol Complexity

RINA has the potential to simplify IoT; that is it can reduce the number of protocols and the complexity of network management. As indicated in Fig. 1, the IoT sub-manager deals with translation between various legacy IoT protocols and the IoT DAP. Translation can be problematic in itself as it is hard to implement and may create indeterminate delays.However, translation can be used as a first step to achieve commonality as the main goal is to eliminate the IoT submanagers. A complete move to commonality would be to introduce a RINA DIF in the architecture, then push the DIFs down to the physical layer, and at the appropriate time replace the legacy IoT protocols. This would also allow moving to common (standard) object models. Commonality across IoT is a major advantage for IoT customers who should demand it. It is not in the self-interest of the vendors. It cannot be stressed enough that while IoT is very important to the vendor of IoT devices, IoT is not important to the customer. The customers have a use of IoT that benefits their business. They are not in the IoT business. They just want it to work and do not only what they need but also what they need to do next. Maximizing commonality is of primary importance to the customer. Commonality (plug and play, interchangeable parts) keeps the customers' options open and avoids their capture by a vendor. As a comprehensive theory of networks, operating systems, and distributed applications, RINA would provide commonality beyond the narrow focus of IoT, which would also be the best basis for driving the commonality. Furthermore, the architecture in Fig. 1 proposes how RINA can be used to solve current problems in the industry, thus challenging the misconception that RINA requires "throwing everything away".

4.3.2 Improved Standardization and Reduced Time-to-Market

The RINA-based standardization will ensure a common interoperable IoT architecture in which the IoT providers would compete on factors such as cost, functionality, usability and quality of service rather than creating barriers to entry. This will effectively reduce or completely eliminate today's problem with fragmentation in IoT. Instead of building their own IoT platforms, industry companies will focus on what brings value –services and applications. Without commonality in the architecture, it would be expensive to create innovative services and applications, while at the same time having to build the underlying architecture. RINA can also help reduce the time-to-market by eliminating a significant part of the cost needed to build a common architecture, and instead help focus the efforts on developing services and applications that bring the business value in IoT.

4.3.3 Improved Security

RINA comes with inherent security advantages over the mainstream TCP/IP model. Due to RINA's architecture specifies, security is not only a second thought. The recursion of the single layer provides security isolation in itself and end-to-end security is provided from within the architecture. RINA can resist a number of security attacks faced by TCP/IP even without using cryptographic techniques like Simple Codes, Symmetric Encryption, Asymmetric Encryption, Steganography, and Hashing. RINA security features are that it requires explicit enrollment of IPCPs when joining DIFs, it has addresses that are internal to a DIF (unlike TCP/IP's global addressing space which allows systems to freely connect to each other), and the applications in RINA are accessed by their application name (while in TCP/IP they listen to a well-known port). IoT can readily leverage these features that RINA possesses inherently in its networking model.

Chapter 5

FUTURE PROOF OF RINA

Several trends in networking such as SDN or network virtualization are naturally supported by RINA, meeting requirements for 5G networks, IoT and customized private clouds. Such as Recursive congestion management, Securing RINA networks, RINA for converged operator networks in 5G scenarios, RINASim: OMNeT++ RINA simulator , IRATI: A programmable RINA implementation for Linux/OS. Here discuss three topics such as Recursive congestion management, Securing RINA networks, RINA for converged operator networks in 5G scenarios.

5.1 Proof of RINA

5.1.1 Recursive congestion management

Using RINA, allow layers to react sooner and respond more effectively to temporary congestion than in today's Internet. In RINA, congestion management is a per-¬layer function. Therefore, the network designer can size each layer to bind the time to detect and react to congestion. Moreover, each layer can deploy the congestion management scheme that is better suited to its operational environment, maximizing the efficiency of the reaction to congestion. Lower layers can apply selective backpressure to upper layers, slowing down the flows that are congesting one or more of the layer's resources.

5.1.2 Securing RINA networks

Different design principles that make RINA inherently more secure than the current Internet and at a much lower cost: securing layers instead of protocols, recursion allows for isolation and layers of smaller scope, separation of mechanism and policy, decoupling of port allocation from synchronization and the use of a complete naming and addressing scheme and also the usual mechanisms of authentication, access control, and confidentiality can be used to protect a layer.

5.1.3 RINA for converged operator networks in 5G scenarios

One of the main challenges to achieve the 5G (and beyond) vision is to design converged operator networks that can effectively support heterogeneous access technologies and address a differentiated set of application requirements (delay, loss, capacity) using the same infrastructure. The clean, repeating building blocks of RINA and the programmability of its functions position this architecture as an ideal framework to attack the 7 / 8 problem.

Chapter 6

CONCLUSION

The Internet of Things (IoT) is defined as a paradigm in which objects equipped with sensors, actuators, and processors communicate with each other to serve a meaningful purpose.IoT applications offer value to the users by combining data sets from various IoT devices in-order to generate complex and interconnected business rules. These business rules then actuate IoT devices to automate the process. Effective business rules generation requires interoperability; Interoperability is the ability of equipment and systems from different vendors to operate together. Interoperability of the IoT Devices is hence becoming more and more important to build a scalable, adaptable and a seamless IoT Device network. Which is not an easy feat because of multiple vendors problem and legacy system issues. Because of that we say interoperability is one of the challenges facing the IoT. Fragmentation, Cost, Connectivity, managebility, security are the other major challenges is faced by IoT.Using RINA's single recursive layer, our purpose is to model an architecture of what should be the "ideal" case that will provide interoperability by design and that will inherently reduce protocol complexity. An IoT architecture with RINA is based on a single layer that makes a clear delineation between transmission mechanisms and transmission policies. While transmission mechanisms are fixed, transmission policies can be adjusted.This seminar clearly describe about IoT , RINA and the architecture of IoT designed by using the concept RINA.

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ABSTRACT

Smart wearable, bands, fitness trackers are all part of human lives these days. The recent wearable Ad lines tells that the device is sweat proof. Then comes the idea of powering the fitness device or smart wearable devices with the most common bio-fuel that can be ever found in human. ie, the sweat. By powering those devices with sweat will reduce or avoid the usage of a chemical battery in a wearable.

The power needed to operate these kind of wearable devices vary from 1 milliwatt for a basic step counter to tens of milliwatts for most advanced smart watches. When using small centimeter sized batteries, capacity of 10 to 300 milliampere hours, this results in the less battery lifetime. Sweat contains trace amounts of a wide variety of minerals and other substances like glucose and lactate. These substances, called metabolites, are by-products of the chemical processes that constantly go on inside living beings, and they make attractive bio-fuels. We are particularly interested in lactate, because its concentration in sweat rises with exertion.

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Chapter 1

INTRODUCTION

In the modern era, our energy sources or stock of energy resources to the remaining reserve lifetime. The term energy includes every type including heat energy, potential energy, kinetic energy, chemical energy and electrical energy. Major causes for energy and resource depletion are growth in population, nature degradation and deforestation etc.

We should now think for ways to conserve these existing energy resources and also the methods to find new type of energies which the human lives, electronic devices and day-to-day devices works on. We should take the effort to reduce the consumption of energy by using less of an energy service. It can be achieved by using energy sources more efficiently or by reducing the amount of resource used. Energy have the capacity to be transformed into another useful forms or other energy types with the help of any external forces. Energy can be conserved just by adjusting many of our daily life activities and behaviours. According to the recent studies, the energy resources or fuels which are used to control the world will be exhausted in around 200 years.

1.1 OVERVIEW

It is important to find or invent another source of energy to sustain in this world. Every devices including our smart watches and fitness trackers needs the power to operate. The energy use has been increased a lot in these days. Researchers start doing research on the energy sources that won't exhaust till the ending of the world. They firstly tried the solar resources believed that they won't exhaust, but they had limitations at night time and also at the winter or rainy season where sun is not visible.

The later researches was to find an energy source from the human body which will last forever till the end of human era. Firstly, they tried to create energy by transforming the body temperature to heat energy. These can be converted to source of energy. but this had a disadvantage of winter season and the person sitting in a air conditioned cold room. They try more biofuels from the human body. At last, researchers is now trying on producing electrical energy from the human fluid or the sweat. Human sweat is high in chemicals which enhances the transformation process of the minerals into electrical energy and store it for further use.

Chapter 2

SMART WEARABLES

Everyone believes that smart devices or electronic gadgets makes human more smart. These smart devices includes the smartphones, smartwatches, fitness trackers etc. The most common in this generation is smartwatches and mobile devices. Recently, smart watches are introduced with the human body sensors such as testing of ECG from the wrist and also can know the oxygen level in the blood. These devices have improved a lot in the modern age.

2.1 SMART WATCHES

A smartwatch is a wearable computer in the form of a watch; modern smartwatches provide a local touchscreen interface for daily use, while an associated smartphone app provides for management and telemetry (such as long-term biomonitoring). While early models could perform basic tasks, such as calculations, digital time telling, translations, and game-playing, recent smartwatches have more general functionality closer to smartphones, including mobile apps, a mobile operating system and LTE/WiFi/Bluetooth connectivity.

Measure your blood oxygen level with a revolutionary new sensor and app. Take an ECG anytime, anywhere. See your fitness metrics at a glance with the enhanced Always-On Retina display. With the new watch introduced few weeks back. A healthier, more active, more connected life is within reach.

Figure 2.1: Recently released smart watch

2.2 FITNESS TRACKERS

An activity tracker, also known as a fitness tracker, is a device or application for monitoring and tracking fitness-related metrics such as distance walked or run, calorie consumption, and in some cases heartbeat. It is a type of wearable computer. The term is now primarily used for smartwatches that are synced, in many cases wirelessly, to a computer or smartphone for long-term data tracking. There are also independent mobile and Facebook apps. Some evidence has found that the use of these type of devices results in less weight loss rather than more. Sleep tracker devices have a tendency to underdetect wakefulness.

Figure 2.2: Recently released fitness tracker

Chapter 3

SMART WEARABLES BATTERY

Smart devices or wearables like smartwatches and fitness trackers has now been a common in human life now. Most of the people uses smart wearables for their fitness activities and personal reminders or official matters. According to a research, 20.1 million smart watches were sold in last year and almost 61% of people on world uses smart wearables. Smart wearables are not just on wrist for checking time. As per user survey, most of the people uses it for tracking health, finding their smart phones and keys, receiving notifications instantly like calls, message etc. without peeping to their mobile phones, view social media push notifications etc.

3.1 BATTERY TYPE

Recently, most smart wearables have a rechargeable battery made of lithium-ion. Ordinary liquid lithium batteries was used in smart wearables at the beginning of smart watch era just like an ordinary wrist watch. Since 2013, these batteries was gradually replaced by lithium-ion battery.

3.2 BATTERY CAPACITY

Smart wearables are still difficult to meet the needs of ordinary users. Smart watch batteries comes with a minimum battery capacity of 380mAh. Activity tracker or fitness tracker is released with a minimum battery capacity of 36mAh to around 200mAh.

3.3 BATTERY LIFE

Since smart watches uses a lot of tasks than a fitness tracker, it's battery drains more faster. Optimal battery life for a smartwatch is around 1 to 2 days. Even top selling and top-ranking smartwatch brands are struggling to improve the life of batteries.

Figure 3.1: Smart watch battery

Since Fitness or Activity trackers don’t get used much as smart watches and as they don’t have much functionalities, the tracker’s batteries lasts almost 5 to 6 days minimum. The most popular and top rated companies tries to improve it upto few weeks.

Figure 3.2: Fitness tracker battery

Chapter 4

POWERING WEARABLES

Smart wearables such as smart watches and fitness & activity trackers needs to be charged well before using. Charging time may vary according to the devices and battery capacity. Mostly, two types of charging methods are using usb charger and using wireless chargers. Fitness trackers takes almost 1 to 2 hours to charge completely. Smart watches takes approximately about 4 to 5 hours to get charged completely depending on the model.

4.1 USB CHARGERS

The most common and traditional method to charge a wearable is to use an usb charger. Fitness tracker and watches comes with charging port variants as micro-usb, direct usb and also c-type usb. USB charging is more efficient than charging using the wireless adapters because Wireless adapters are commonly shared by other devices and using wireless charging may result in the heating of watch surface.

4.2 WIRELESS CHARGING

Smart wearables can be also charged using the wireless chargers and adapters available for the smart wearables. There is a small platter fixed on the back of wearables which transfers the energy to the battery.

4.3 LIMITATIONS

There are a lot of limitations while using these wearables. People always keeps on travelling to do their stuffs,work etc. and will only get a few time for charging the devices. This will drain the batteries of wearables faster and they may not be able to charge it on the go. At the actual usage time or at the time of exercise or fitness training, these may lie dead without any use.

Batteries are also harmful for the environment, they can damage the bio-system. They are also harmful to human skin if a wearable battery breaks and skin comes to direct contact with the toxic battery fluids. The newly developed batteries can replace the existing battery system in upcoming days.

Figure 4.1: Wireless charging

Figure 4.2: Charging fitness tracker

Chapter 5

HARVESTING HUMAN ENERGY

Harvesting human energy from the human body and surroundings in not a new idea. An average human being generates upto 100 Watts of power. According to a study, human can sustain 300-400 watts of power for a short time of few minutes. In the case of sprinting or small exercises, we can harvest energy output over 2,000 watts. The human body generates more bioelectricity than a 120-volt battery and over 25,000 BTUs of body heat. Combined with a form of fusion, the machines had found all the energy they would ever need. There is a total of 70 trillion volts to a value of 3.5 trillion volts.

Self-winding watches was the first experiment with the energy from human body. These watches use the natural motion of the human body to generate power. In the first devices, a small weight inside the watch would wind the mechanism. Later watch versions have a magnetic weights which passed through a coil, which generates electricity enough to charge a battery. Modern self-winding watches use piezoelectric materials, crystalline substances that release an electric charge when bent or squeezed. This was not a success experiment since it has limitations while under clothes.

Scavenging light is done with fingernail-size photovoltaic cells, which have been used to power calculators for decades. Most are rigid, but researchers in our center are developing solar cells that are flexible and even stretchable, to better conform to the human body.

5.1 BODY HEAT

Body heat is a third energy-scavenging approach. In most climates and settings, the temperature of the human body is well above ambient temperature. Tiny thermoelectric generators exploit this differential. The body-heat scavenger used on the PowerWatch, which is a fairly basic smart watch, fits on the skin-facing side of the device.

Unfortunately, few of these tried-and-true energy-harvesting methods have been able to supply sufficient power for a small, flexible, useful wearable. Motion harvesters are fine for watches, but there's not enough motion to harvest in the areas where the newest wearables are worn, such as on the chest or in the ear. Thermoelectric generators can scavenge energy effectively only when their design includes a large heat sink, typically made from aluminum, to collect the body's heat and transfer it to the device. And thermoelectric generators and solar cells don't work well if the wearable is worn under clothing. A thermoelectric generator (TEG) can be used to harvest electrical energy from human body heat for the purpose of powering wearable electronics. The TEG was further fabricated into a T-shirt and the power was recorded for different human activities.

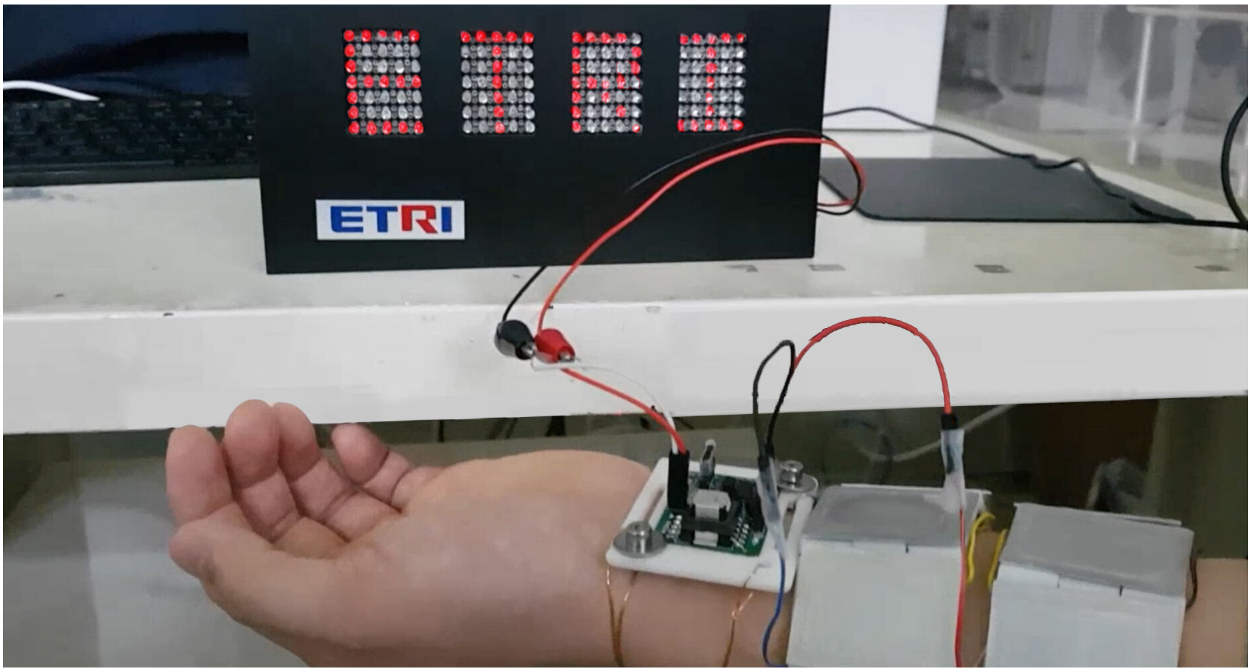

Figure 5.1: thermoelectric generators harversting human energy

Chapter 6

HUMAN SWEAT AS POWER

Sweating is the production of fluids secreted by the sweat glands in the skin of mammals. Two types of sweat glands can be found in human body. They are eccrine glands and apocrine glands. Sweat is generated when the body temperature rises up from exercise, heat, stress or hormone shifts. sweating helps to keep the body's internal temperature at normal range which is 37 degree celsius. An exercise physiologist at Henry ford health system stated that Sweating helps in releasing heat, which helps to maintain optimal body temperature. Sweating is known as the human body's natural way of regulating body temperature. This is done by releasing water and salt, which evaporates to help cool you. Sweating itself doesn't burn a measurable amount of calories, but sweating out enough liquid will cause you to lose water weight.

In humans, sweating is primarily a means of thermoregulation, which is achieved by the water-rich secretion of the eccrine glands. Maximum sweat rates of an adult can be up to 2–4 liters per hour or 10–14 liters per day (10–15 g/min·m2), but is less in children prior to puberty.Humans have approximately 2–3 million eccrine sweat glands and this number is fixed by approximately 2–3 years of age.

6.1 CHEMICAL COMPOSITION

Sweat consists primarily of water and electrolytes. The primary electrolytes contained in sweat are sodium and chloride. Potassium, urea, lactate, amino acids, bicarbonate and calcium are also found. Dissolved in the water are trace amounts of minerals, lactic acid, and urea. Although the mineral content varies, some measured concentrations are: sodium (0.9 gram/liter), potassium (0.2 g/L), calcium (0.015 g/L), and magnesium (0.0013 g/L). The main electrolytes of sweat are sodium and chloride, though the amount is small enough to make sweat hypotonic at the skin surface.

Eccrine sweat is clear, odorless, and is composed of 98–99% water; it also contains NaCl, fatty acids, lactic acid, citric acid, ascorbic acid, urea, and uric acid. Also the concentration of urea in the sweat is 22.2 mmol/L, which is 3.6 times that in serum. The results indicate that sweat uric acid concentration is quite minimal, and the estimated total uric acid excretion per day in normal physiological range is insignificant.

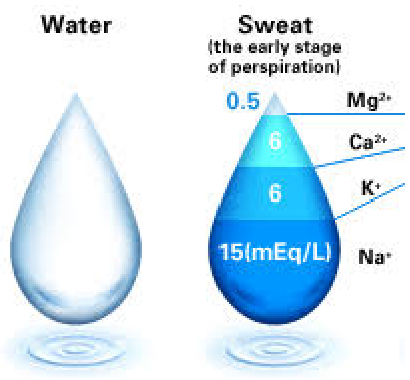

Figure 6.1: Chemical composition of sweat

6.2 SWEAT INTO ENERGY

Certain chemicals found in human sweat can be used as fuel in wearable-size fuel cells. These biofuel cells could offer high power densities in a more practical, wearable form than is possible with any of the existing energy-scavenging approaches. Our team has already developed prototype wearables that generate power from sweat.

The Welsh scientist William Robert Grove first worked out the process in 1839; he used hydrogen as the fuel and oxygen as the catalyst to generate water and electrical current.

Chapter 7

BIOFUEL CELL

7.1 DESIGN

To make fuel cells that works with the human sweat for the wearables, anodes and cathodes are fixed as a series of islands connected by serpentine coils. The coils unwind under stress, allowing the structure to flex and stretch. Anodes and cathodes are capped with carbon nanotubes, which creates 3D pellets to increase the effective surface area of the electrodes.

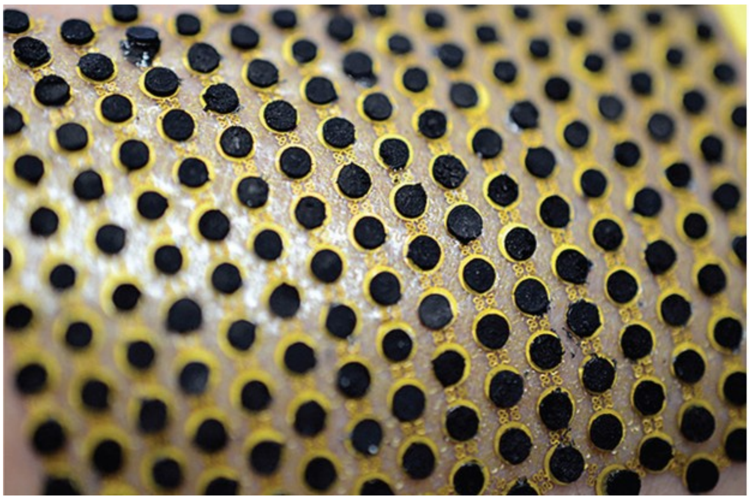

Figure 7.1: Design of biofuel cell

7.2 WORKING

A fuel cell consists of two electrodes—an anode and a cathode—with an electrolyte between them. The fuel goes into the anode, where a catalyst separates its molecules into electrons and protons. The protons pass through a membrane to the cathode, while the electrons flow into a circuit. The Welsh scientist William Robert Grove first worked out the process in 1839; he used hydrogen as the fuel and oxygen as the catalyst to generate water and electrical current.

Hydrogen is impractical for a wearable fuel cell because it's highly flammable. Sweat, on the other hand, is easily acquired and abundant, particularly when a person is exercising or playing sports. And, given that athletes embraced all sorts of wearables early and widely, they represent an attractive early market for sweat-powered devices.

Sweat isn't just water. It contains trace amounts of a wide variety of minerals and other substances like glucose and lactate. These substances, called metabolites, are by-products of the chemical processes that constantly go on inside living beings, and they make attractive biofuels. We are particularly interested in lactate, because its concentration in sweat rises with exertion. In our sweat biofuel cells, we create a layer of enzymes that reacts with the lactate in sweat to split the electrons and protons and create an electrical current.

This is not the first time to think of using body fluids as fuel. Some of the original pacemaker and cochlear implants proposed in the 1970s were intended to use glucose biofuel cells for power. Given the abundance of biofuels inside the body, using them for implantable devices was a logical choice. The main drawback was that the enzymes used to catalyze the fuel cell reaction would degrade, and the electrode would stop functioning within a few days. The only way to restore the fuel cell's operation was to surgically remove the implant, which was obviously impractical.

To avoid the enzyme-depletion issue, instead we has focused on developing disposable wearables worn outside the body. We demonstrated our first biofuel cells in 2014. The lactate biofuel cells were screen-printed onto a fabric headband and a wrist-worn sweat guard.

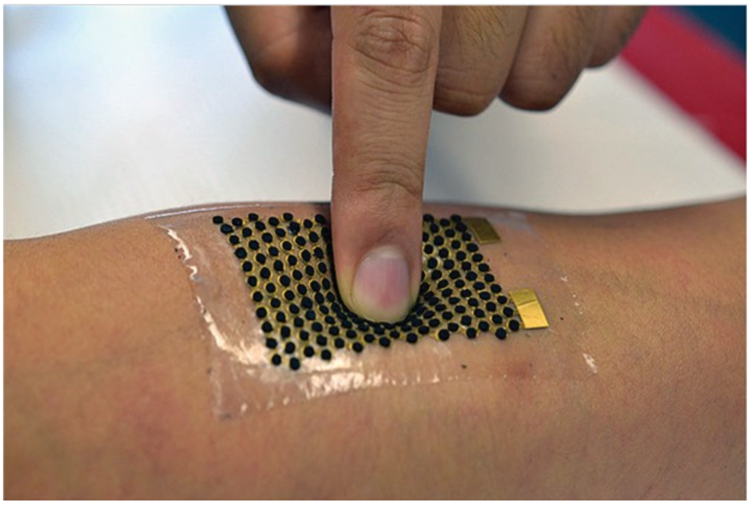

Figure 7.2: biofuel cell on hand

Our test subjects each wore a headband and a sweat guard while riding an exercise bike. We'd hooked up each biofuel cell to a small DC-DC converter. The converter raised the voltage generated by the perspiring bike riders to the levels necessary to light up a microwatt-level LED and power a digital wristwatch. In the experiment, the biofuel cells generated up to 100 microwatts per square centimeter, enough to power both the LED and the watch. That's a greater power density than would be possible with a thermoelectric generator paired with a small, wearable-size heat sink, and somewhat greater than the power density of a solar cell operating in normal indoor lighting.

To our knowledge, this was the first demonstration of a printable, wearable biofuel cell powering an everyday object. What's more, because the biofuel cell was printed onto a flexible textile, the design was reasonably comfortable to wear, and it continued to function even after repeated bending. However, it didn't generate quite enough power to operate a sophisticated activity tracker or a full smart watch. It also didn't conform to the skin as comfortably as we would have liked.

7.3 INSIDE STORY

To turn sweat into power for a digital watch or other wearable devices, a fuel cell uses a layer of enzymes that react with the lactate in sweat to split the electrons and protons. The protons pass through a membrane to the cathode, while the electrons flow into a circuit, powering the device.

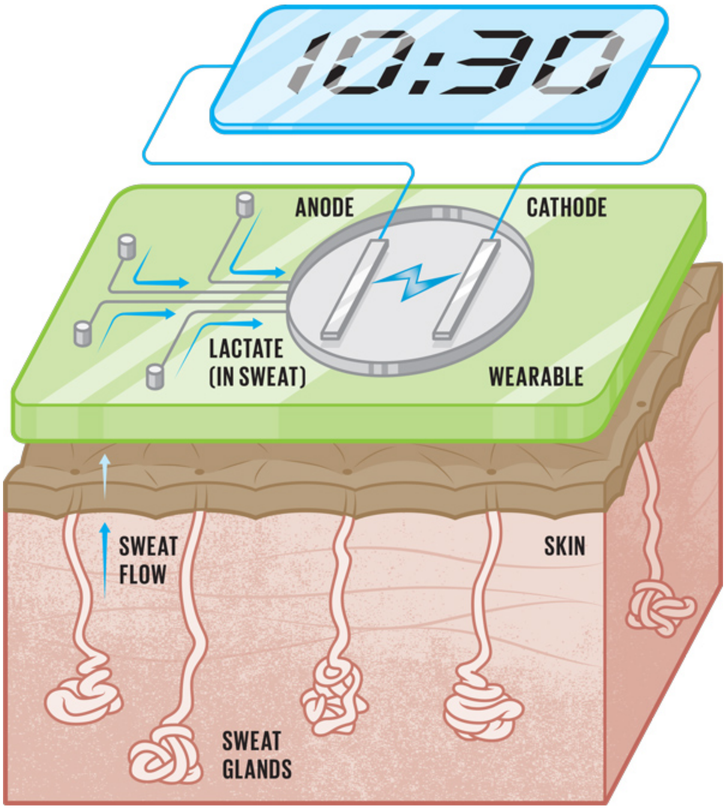

Figure 7.3: working of fuel cell

Chapter 8

DESIGN REVIEW

Of course, truly useful wearables have more components than a digital watch does. Even the simplest activity tracker includes an accelerometer, memory, and a Bluetooth radio. Together, these items consume about a milliwatt or two, about 10 times as much as what we generated in our 2014 demonstration. Indeed, boosting the power density of wearable biofuel cells is one of our biggest challenges. If the cells can't generate much more power than alternative technologies can, they won't make it into real products.

8.1 REVIEW

In reviewing our fuel cell's design, we realized that the surface of the anode was relatively flat. That meant the anode was exposed to only the molecules resting directly below it, which greatly limited the amount of biofuel the cell could catalyze. In 2017, in collaboration with our UC San Diego colleague Sheng Xu and his team, we came up with a 3D carbon-nanotube structure in the form of pellets that could be attached to the top of the anode and the cathode. These pellets increased the electrodes' effective surface area without increasing the actual area of the device. Although using this 3D structure meant our cell was no longer fully printable, it allowed us to load each electrode with more of the catalyst, giving access to more fuel and enabling each cell to generate much more power.

Increasing the cell's effective surface area and making additional improvements in the chemical composition of our catalyst enabled us to boost the power density by a factor of 10, to 1 milliwatt per square centimeter. That power density approaches that of a small solar cell in direct sunlight.

Chapter 9

TESTING

To test this design, we built a circuit board that included a Bluetooth radio, typically the most power-hungry component of a wearable device. Our prototype lactate fuel cell generated around a milliwatt, enough to successfully power the radio, a small microprocessor, and peripheral components, including a temperature sensor and voltage converter.

9.1 FLEXIBILITY ISSUE

The 3D electrodes we used in this design weren't flexible. Ultimately, we want a fuel cell that's not just flexible but also stretchable. The human body is bumpy and curvy, so flexibility alone isn't sufficient to ensure that the fuel cell will conform smoothly to a user's skin—think of trying to wrap a sheet of paper around your wrist. Something stretchy like nylon or cling wrap would be much better.

To create flexibility and stretch, we again turned to carbon nanotubes, using an "island bridge" structure developed by Xu's group. This biofuel cell is dotted with rows of "islands," each one of which is a 3D electrode. Half of the islands make up the anode, and the other half form the cathode. The islands are connected by stretchy "bridges" made of thin, spring-shaped wires that can stretch and bend. However, the electrodes themselves don't stretch, so over time, the mechanical mismatch can create a lot of strain and cause the fuel cell to fail.

Chapter 10

IMPLEMENTATION

10.1 PROBLEMS

There's one more hurdle to bringing sweat power to wearables: In most situations, people don't sweat constantly—or at least not heavily enough to generate much power. If you're not sweating, your fuel cell will run dry and stop producing power. This may not be an issue in applications like exercise and athletics, but it's a big deal in most other cases.

There are three ways to work around this limitation. We could use the scavengers only for applications where the availability of sweat is guaranteed. Or we could add an energy-storage element to the wearable. Or, finally, we could add a complementary, nonbiofuel energy scavenger to the wearable.

10.2 SOLUTION

For wearables that need a constant supply of energy—for example, smart watches—an obvious solution is adding a battery or an ultracapacitor to act as an energy buffer. If the fuel cell has a high power density but the availability of power is intermittent, then the wearable device will charge its battery when power is available and discharge the battery when the biofuel cell stops producing power.

This energy buffer needs to have the same general physical properties as the rest of the wearable. It doesn't make sense to have a biofuel cell that's small, soft, and stretchable if the battery on top is large and rigid.

Increased likelihood of successful energy harvesting and therefore decrease the demands on the energy buffer, we're also looking at using multiple types of energy scavenging to power a single wearable. Users may not necessarily sweat all the time, but if their wearable combines a biofuel cell with a solar cell and a thermoelectric generator, then the chances of any one of these devices generating power at a particular time is going to be higher than with one of them acting alone.

Of course, integrating several scavenging technologies needs to happen without compromising the wearer's comfort. As with the biofuel cell–energy buffer combination, we have to make these gadgets small, soft, and stretchy. Researchers have lately been considering how to redesign energy-scavenging devices for better integration into what we like to call an energy sandwich—that is, a collection of energy scavengers stacked in a single small, stretchable device. In 2018 we developed a small circuit that can simultaneously extract energy from multiple sources and send it to multiple wearables and a battery simultaneously.

Chapter 11

REPLACING TRADITIONAL BATTERIES

So far, we've been talking about using biofuel cells to replace traditional batteries in wearables. UC San Diego researchers are also making progress on printable batteries that are smaller, cheaper, and more flexible than traditional batteries. These, along with supercapacitors, will eventually be useful for briefly storing the energy harvested by wearable biofuel cells.

11.1 BIOFUEL AS SENSORS

And here's the real magic of biofuel cells: They can act as sensors. That's something no battery can do. The sensing is possible because the output power of a biofuel cell is usually proportional to the underlying concentration of metabolites being used as fuel. We can exploit this phenomenon to build self-powered sensors—devices that perform sensing and energy harvesting at the same time.

Our team has developed self-powered biosensors to detect changes in the lactate or glucose concentration of sweat while using that same lactate or glucose to generate the power the sensor needs to operate. Lactate is a good marker of exertion, and knowing one's level is useful for athletes and also for people fighting illness. Glucose is a marker for nutrition as well as for blood sugar levels. Custom low-power microelectronic circuits in the device—powered by the biofuel—read the sensor data, convert it to a digital format, and wirelessly transmit the reading to a smart watch or phone. We believe this is the first practical demonstration of a noninvasive, integrated, self-powered chemical biosensing system with a wireless readout.

Chapter 12

CONCLUSION

Sweat power is a new technology, and many challenges remain. For one thing, not everybody sweats in the same amounts; we have to make sure our systems can adapt to varying conditions. We also need to do a better job of integrating these biofuel cells with other harvesters, energy sources, and electronics to create useful wearables.

And finally, the longevity of our biofuel cells needs improvement. Right now, most of our prototypes are designed for use in disposable devices, as easy to put on and take off as a Band-Aid. These biofuel cells might go into wearables meant to be worn for a day at most, for use by athletes trying to optimize training, people fighting illness who need to monitor temperature and hydration, or those just interested in tracking their general well-being. While we feel this approach is reasonable for many applications, we'd still like to try to extend the devices' longevity a bit further.

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ABSTRACT

This paper discusses about layer concerns of traffic shaping. At present there are so many papers discussing about applying traffic shaping in protocol stack layers. Here discussing is it possible or okay to apply traffic shaping in data link layer,means the higher layer of protocol stack. So many traffic mechanisms are there.

Consider credit based shaping (CBS) mechanism to analyze various interpretations in layers. Regarding the layering concerns traffic shaping is referred to as packet shaping. The CBS mechanism is completely based on increasing and decreasing credit behaviours. When applying traffic mechanisms to higher layer protocol stack layer ,may occur different interpretations.

The paper discuss how the interpretations influence the traffic shaping in higher layers. And also a remedy for future investigations cross check the analysis for higher layer interpretations by using “independent WCRT analysis for individual priority classes in Ethernet” . Every interpretations have their own limitations in many aspects such as easy to analyze, easy to maintain etc

The main concern of this paper is that , is the existing analysis are still valid for the different interpretations or not. Data analysis and data interpretations are fast becoming more valuable with increase in the importance of digital communication. According to the WEF s report accumulated digital universe of data is set to reach 44ZB in 2020.

Contents

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Chapter 1

INTRODUCTION

IEEE 802.1 working group is an standard association group. It ensures network management in all aspects according to IEEE 802 standards. IEEE 802 are Ethernet standards. Few important IEEE 802.1 tasks are design and implementing standards for improving network management, network traffic management and provide different services etc

Time Sensitive Networking (TSN) is a set of standards define in the IEEE 802.1 task group. Mainly tsn aims to standardize features in the second layer of OSI reference model. That is data link layer. Time sensitive networking standards are used for reliable real-time communication. Time Sensitive Networking is an solution for time critical frame transmission in data link layer. For ensuring reliability TSN provides so many methos like Audio/Video Bridging(AVB), Credit Based Shaping(CBS) methods. Here mainly discuss about crediy based shaping and what are the interpretations may occur when applying credit based shaping in data link layer of protocol stack. Traffic shaping also referred to as packet shaping, it is one of the most important technique to ensure high quality services.

Credit Based Shaping is a queuing discipline is intended to be used by time sensitive networking. It is completely based on the term "credits". In general, say that if the data stream is waiting for transmission only the data queue with positive credits can undergo transmission. During the transmission the credits are spent. In credit based shaping decrease and increase in credits are termed as 'sendslpoe' and 'idlesloe'. Before transmission credits are accumulated to data streams.

In early there were so many analysis are performed to analyse what are the interpretations and issues may occur if traffic shaping is applied to various layers, like "start of frame transmission" and "end of frame transmission". Some of the analysis are busy period analysis and eligible interval analysis. Eligible analysis is more advanced than busy period analysis.

But don't know that is the existing analysis are still valid for future investigation. To get the answer for the question we have to revisit the "INDEPENDENT WCRT ANALYSIS FOR INDIVIDUAL PRIORITY CLASSES IN ETHERNET". Already mention that everything is based on credits and according to credits priority are assigned. services are based on priority . Worst Case Response Time eligible intervals do not rely on interfering priority classes. The transmission of frames in Ethernet AVB is scheduled in to high priority classes. there are several priority classes are possible, but mainly consider or extend the medium priority class of WCRT. So WCRT analysis class medium prevents the starvation of low priority classes.The main challenge is lies on influence of multiple high priority classes

1.1 OBJECTIVE

The main objective is to understand the layering concepts based on credit based shaping in the IEEE 802.1 time sensitive networking and what are the network traffic issues may arise . At present various analysis techniques are performed, but still have to conclude that , is this analysis techniques are still valid for future

Chapter 2

IEEE 802 ETHERNET

2.1 ETHERNET

Ethernet is a family of networking technologies commonly used in Local Area Networks(LAN),Metropolitan Area Networks(MAN),Wide Area Networks(WAN). It was introduced in 1980 and first standardized in 1983 as IEEE 802.3. The main idea behind this is multiple computers can connect each other and can access and send data at any time. Ethernet can go at different speeds

IEEE 802 is a family of IEEE standards ,and the IEEE 802 standards are restricted for the networks carrying data packets.The number"802" has no particular importance, it may be a next number that can be assign to the next standard project.The services and protocols defined in IEEE 802 are meant for data link layer and physical layer of OSI(Open System Interconnection) reference model.IEEE 802 divides the data link layer in to two, Logical Link Control(LLC) and Media Access Control(MAC).

IEEE 802.1Q is an independent standard that represent Ethernet frame.

2.2 What IS IEEE 802 TASK GROUP

IEEE 802.1 working group is an IEEE standard association group that ensures the network management and monitoring capabilities in network developed. The important IEEE 802.1 tasks are design and implementing standards for high quality services of networks. IEEE 802.1 comprises of four groups. They are, Inter networking, Audio Video Bridging, Data center bridging and finally security.

Chapter 3

TIME SENSITIVE NETWORKING

3.1 TIME SENSITIVE NETWORKING

Time sensitive networking is a set of standards specified by IEEE 802. Time sensitive networking task group is a part of IEEE 802.1 working group. The aim of time sensitive technology is to standardise features of second layer of osi(open system interconnection)reference model,that is data link layer. TSN standards are used for reliable and real-time communication.TSN technology ensures reliability through guaranteeing transmission of data packets with low bounded latency, low packet delay and low packet loss. Time sensitive networking technology is an attractive solution for time critical frame transmission in the data link layer. To acieve low bounded latency two methods namely traffic shaping and traffic scheduling are considered. The base standards for TSN are given below.

. **IEEE 802.1Q-2018**

. **IEEE 802.1AB-2016**

. **IEEE 802.1AS-2020**

. **IEEE 802.1AX-2020**

. **IEEE 802.1BA-2011**

. **IEEE 802.1CB-2017**

. **IEEE 802.1CM-2018**

3.2 IMPORTANCE OF TIME SENSITIVE NETWORKING IN FUTURE

Time sensitive technology is an growing technology for future inventions. Now we live in a world of self-driving cars, reusable self landing rockets, robots etc...Time sensitive technology is the factor that behind these extraordinary inventions.Time sensitive networking provides the three essential element of precise timing: bounded jitter, bounded latency and guaranteed bandwidth.

The TSN/AVB(Audio Video Bridging)standards are completed in 2011. To achieve low latency IEEE 802.1Qbv defines Time Aware Shaper(TAS) that act as a traffic gate or stop light for different priority traffic that crossing over the switch. So we can simply say that Time Sensitive Netwoking is an growing technology..

3.3 ADVANTAGES OF TSN OVER TRADITIONAL ETHERNET

Time Sensitive Networking have some advantages over traditional Ethernet.

Guarantees latency times.

It support both critical and non-critical data traffic transmission over the network.

Higher level protocol layers can share a common network infrastructure.

No vendor dependencies.

3.4 INTRODUCTION TO DATA LINK LAYER

Data link layer is the layer two of osi reference model. This layer is the protocol layer and transmits data across the physical layer(layer 1 of osi reference model).Data link layer is the most complicated layer and has complex functionalities. It recieves data from the physical layer and split in to frames and then transfer the frames in to the upperlayer. Data link layer has two sublayers

Logical Link Control(LLC)

Media Access Contro(MAC)

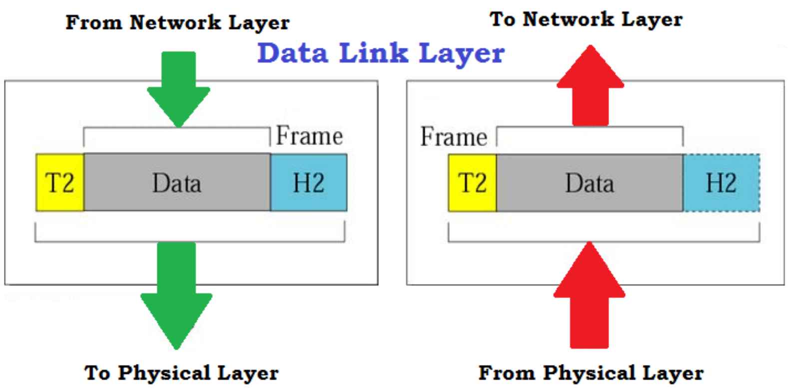

Figure 3.1: data link layer of osi reference model

Chapter 4

TRAFFIC SHAPING CONCEPT RELATED TO NETWORKING

4.1 TRAFFIC SHAPING

Traffic shaping and traffic scheduling in time sensitive networking aims to achieve low bounded latency and zero congestion loss. Traffic shaping is an important technique to ensure high quality of services and also it is an important requirement for network firewall.

Traffic shaping is also referred to as packet shaping, generally it is a bandwidth management technique that delays certain type of packets in order to ensure network performance and to provide high quality services. Most common type of traffic shaping is the application based traffic shaping. If applying traffic shaping to the higher layers of the protocol stack(data link layer and physical layer) what will happen? what are the interpretations may occur when applying traffic shaping in these layers or how the interpretations influence the traffic shaping are going to be discussed. The two important traffic shaping are Audio Video Bridging and Cedit Based Shaping.

One of the disadvantage of traffic shaping is that the throughput of network traffic is fixed it wont make use of additional bandwidth if it is available. Applying traffic shaping to improve network performance can be a cheaper solution than upgrading a network's hardware.

4.2 AUDIO VIDEO BRIDGING

Audio Video Bridging is a common name for the technical standards that are developed by AVB task group of the IEEE 802.1 standard committee. AVB standards provide reliability and low latency for Ethernet networks. The transmission of frames in Ethernet AVB is scheduled in a high prioritized manner. Frames from different sources are distributed over FIFO out put queues depending on the corresponding priority classes. In Ethernet AVB different priority classes are possible, but consider high,medium,low and best effort(BE) priority classes.

AVB is a growing up technology in several automation domain. AVB offers several benefits such as open specification and real time support and offers advantages in frame of high bandwidth.

The standard IEEE 802.1BA represents the audio video system.

MINIMUM LATENCY: 0.25ms.

MAXIMUM SAMPLING RATE: 192KHZ.

MAXIMUM BIT DEPTH: 32 bit floating point.

DEVELOPMENT DATE: September 2011

MANUFACTURER: IEEE Avnu.

4.3 CREDIT BASED SHAPING

Credit based shaping is one of the traffic shaping mechanism. It is a queuing discipline is intended to be used by time sensitive networking. Credit based shaping is completely based on a term is called "credits".Credits are accumulated to the data queue as they wait for transmission. Only the data queue with positive credits are eligible to service and the credits are spent by the data queue while they are in transmitting. If frames are waiting for service the credits are accumulated or raised. If all the transmission from that queue is finished the credits is reset to zero. The rate at which the credits are increased and decreased are expressed in terms known as "idleslope" and "sendslope".

already discuss that in time sensitive networking many priority classes are possible like AVB A , AVB B and BE. BE is the best effort traffic. In best effort traffic there are no guarantee regarding the delivery of packets or frames. Best effort is a network service to deliver messages or data packets to the desired destination but a disadvantage is that it does not provide any special features like retransmitting corrupted packet or lost packet.

The class AVB A has higher priority and is used for audio traffic and the class AVB B has a medium priority and is used for video traffic and finally best effort traffic obtain the remaining bandwidth. It indicates that best effort traffic has low priority. These classes are originates from Ethernet AVB standards. TSN provides a time aware shaper that act as a traffic gate and it allows higher priority queues to transmit and can undergo credit based shaping.

Now let us discuss what happened when credit based shaping is applied in the physical layer and data link layer of the protocol stack and what are the interpretations occurs.

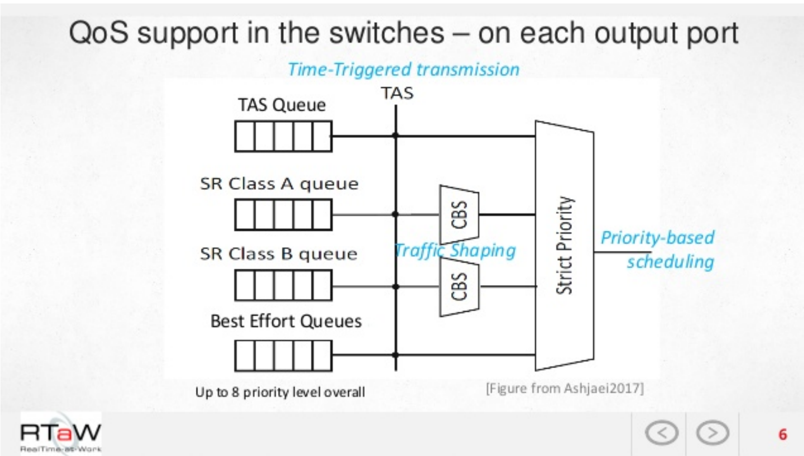

Figure 4.1: output port of a Ethernet switch

4.4 IEEE 802.1Qav CREDIT BASED SHAPER

- IEEE 802.Qav: Forwarding and queuing enhancement for time sensitive streams.
- IEEE 802.1Qbv: Enhancement for scheduled traffic. IEEE 802.1Qbu IEEE 802.3br: Frame preemption.
- IEEE 802.1Qca: Path control and reservation.
- IEEE 802.1Qcc: Stream reservation protocol(SRP) enhancement and performance improvement.
- IEEE 802.1CB: Frame replication.

4.5 IEEE 802.1Qav - TIME AWARE SCHEDULER

The basic function of the time aware scheduler is to create equal cycles(time periods).These time slots then assigned to the traffic classes. Time aware scheduler provide a fixed time table for the different traffic classes. This scheduler requires synchronization.

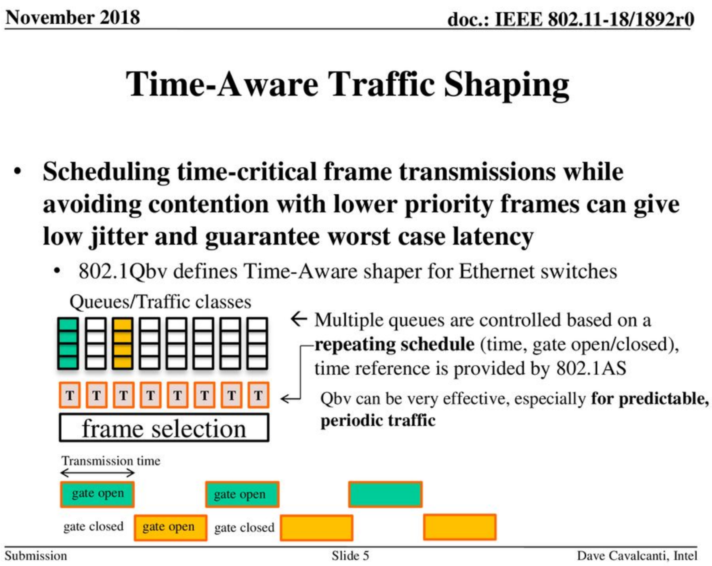

Figure 4.2: time aware traffic shaping

Chapter 5

DATA INTERPRETATIONS

Data interpretation and data analysis are fast becoming important with the increasing of digital communication. Huge amount of data get accumulated day by day. For managing huge amount of data more efficiently and effectively data interpretation and data analysis are important and also to ensure the security of data.

Data analysis is the first step towards data interpretations. Data interpretation is the process of reviewing the data through some processes to assign some meaning to the data that are analysed and by studying the result they can arrive at a definite conclusion.

When applying credit based shaping in layers it may cause some kind of interpretations. In general, say that physical layer interpretations and data link layer interpretations. The interpretations may occur due to some criteria called "start of frame transmission" and "end of a frame transmission". Mainly these interpretations are based on the inter packet gap(IPG) between the Ethernet messages.

5.1 INTER PACKET GAP(IPG)

"Start of a frame transmission" is defined as the starting of a frame and "end of a frame transmission" is defined as the end of a transmission of packet or the end of a inter packet gap.

inter packet gap is the minimum pause between the network packets or network frames generally 9.6 microsecond inter frame gap. The purpose of inter packet gap is to allow enough time for the Ethernet devices to recover. If the inter packet gap between the data packets are too small proper clean up wont be performed. According to IEEE 802.3 standards a data link layer must allow a minimum amount of time to sent another packet for transmission.

The main purpose of inter packet gap is to clean up and reallocate the resources used by previous transmission. If the inter frame gap is too small it will lead to the incoming new packets to utilize the resources allocated for the previous packet transmission. So any new connection get refused. The main reason for the 9.6 microsecond inter frame gap is to allow the station to back to the receive mode from the transmitting mode. With out inter frame gap there is possibility for losing frames or packets. This may arise interpretations.

Chapter 6

ANALYSIS TECHNIQUES

6.1 WORST CASE RESPONSE TIME ANALYSIS

Worst case response time of a message is defined as the longest time to receive a message that was initialized by a sender. A message is said to be schedulable if and only if it's worst case response time is less than or equal to the deadline. Worst case response time (WCRT) is must for controller area network(CAN) messages. Controller area networks is currently the most widely used technology in the field of autompbiles.

6.2 SCHEDULABILITY ANALYSIS OF ETHERNET AUDIO BRIDGING NETWORK WITH SCHEDULED TRAFFIC SHAPING

In the schedulability analysis an improvement to the AVB protocol called AVB ST(scheduled traffic) is proposed. AVB ST meant for supporting scheduled traffic. Schedulability analysis is mainly presented for the real time traffic that crossing through AVB ST networks. Here defines two stream reservation classes , SR class A and SR class B and a credit based shaper is added. The class with higher bpriority can undergo credit based shaping . Time aware shaper allow transmission according to the schedule. When an scheduled traffic message pass through the network some elements influence the delay of messages. This analysis do not lead to a schedulable result in most of the cases.

Here the element or the factor that cause delay in message is the "bandwidth".Bandwidth is the major factor that effects the efficiency of packet transmission through network channel. Bandwidth is the maximum amount of data transmitted over the internet in a given amount of time. Bandwidth reservation guarantees high quality of services for different types media like audio, video. A solution to increase the bandwidth of the traffic classes is known as "bandwidth over-reservation". This is a solution for obtaining minimized bandwidth over reservation. Bandwidth reservation is beneficial only when the number of users asking for guaranteed bandwidth is relatively smaller than other users . So the solution can be used for both AVB and AVB ST networks.

6.3 INDEPENDENT WCRT ANALYSIS FOR INDIVIDUAL PRIORITY CLASSES IN ETHERNET AVB

6.3.1 BUSY PERIOD ANALYSIS

In the automotive industry bandwidth consideration and standardization are two important factors for considering Ethernet is an alternative solution for the real time communication . Initial method to guarantee latency for Ethernet AVB depended on traditional busy period analysis. The worst case response time of a frame transmission can be bound using traditional busy period analysis. This analysis is performed to estimate the maximum amount of influences from which a transmission may suffer. By performing traditional busy period analysis a desired independence not achieved. As a solution for the interferences occured eligible interval analysis is performed.

6.4 ELIGIBLE INTERVAL ANALYSIS

Eligible interval analysis is an independent real time analysis . By introducing the eligible interval analysis instead of busy period analysis that can manage the analysis quite simply. The new analysis that is eligible interval analysis is independent of interpriority interferences other than the assumptions enforced by the Ethernet AVB standards. In eligible interval analysis only one low priority frame can interfere during an eligible interval. The main challenge of eligible interval analysis is rely in the influence of multiple high priority classes. Because the eligible interval analysis is tight in the case of a single high priority stream.

In cases of multiple higher priority classes provides strict conditions. As a solution to the influence of multiple higher priority classes and multiple low priority classes extend the worst case response time of a medium priority class. So this division prevents the starvation of low priority classes so can guarantee the latency of a priority class effectively.

Chapter 7

CONCLUSION

In this paper discuss about the layering concerns for the analysis of credit based shaping in IEEE 802.1 time sensitive networking. Already discuss that time sensitive networking is a growing technology. Here point out the various interpretations may occur when credit based shaping is applied to the data link layer rather than the physical layer of the protocol stack. Each of these interpretations has it's own advantages and disadvantages. Here a question is arised that whether the existing analysis are still valid to solve these kind of interpretations. So mainly adapt the independent WCRT eligible interval analysis for future studies.

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