THE INSTITUTION OF ELECTRONICS AND TELECOMMUNICATION ENGINEERS (IETE)

PROCEEDINGS & RECOMMENDATIONS OF IETE APEX FORUM ON "BANDWIDTH MANAGEMENT OF 5G"

Held on

February 20, 2016

at

IETE Professional Activity Centre
Laxmi Institute of Technology, Sarigam

Organized by

THE INSTITUTION OF ELECTRONICS AND TELECOMMUNICATION ENGINEERS

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1. Introduction

The Institution of Electronics and Telecommunication Engineers (IETE) is a leading non-profit professional society devoted to the advancement of Science and Technology of Electronics, Telecommunications and Information Technology. The objectives of IETE focus on emerging electro-technology. The IETE organizes technical seminars, conferences, symposia and exhibitions all over India to reach the unreached, digital divide, advise the regulatory bodies on emerging technology issues. IETE Apex forum is one such event that promotes issues of national interest through a common platform and recommend solutions. IETE also publishes technical journals and provides continuing education to working professionals as well as career advancement opportunities to its members.

IETE Apex Forums

One of the objectives of the IETE Apex Forums is to bring policy makers, policy implementers, academicians, researchers, practicing engineers and industrialists on a common platform for meaningful exchange of ideas and suggestions on the current specific issues of national interest. Meaningful debates and discussions are held; views are exchanged to achieve the aim of the forum. The recommendations outcomes resulting out of the forum are actively pursued for advancement of the profession. This Forum addresses important issues with the participation from Govt. Departments also like Deity, DST, DoT and leading academic institutions.

The following are some of the Round Table Conferences under the Apex Forum held in the recent past:

- **“Internet Governance”** organized on 24 Jul 2015 at IETE, New Delhi.
- **“Smart Cities”** organized on 26 Jul 2014 at India International Centre, New Delhi.
- **"Geo Spatial Technologies"** was organized on 24 May 2014 at Hyderabad Centre at the Mekaster Auditorium of the institution.
- **"Vocation and Skill Development Perspective-Current Scenario**" held on 28 Feb 2014 at IETE HQ, New Delhi.
- **“DRM Technology”** held at IETE HQ on 6 May 2013.
- “**Road Ahead for LTE in India- Opportunities and Challenges**” was held on 11 Sep 2012 at Hyderabad.
- **The Cloud Computing in India** – The Road Ahead” was held on 3 Jul 2012 at IETE HQ, New Delhi.
- **“e-Education Paradigms-Indian Scenario & Challenges**” held on 23 Dec 2011 at IETE HQ, New Delhi.

APEX FORUM ON
"BANDWIDTH MANAGEMENT OF 5G"

Objectives

- Brain storming session on the Bandwidth Management of 5G.

- The Next Generation Mobile Networks Alliance defines the following requirements for 5G networks:
  - Data rates of several tens of megabits per second should be supported for tens of thousands of users
  - One gigabit per second to be offered simultaneously to many workers on the same office floor
  - Several hundreds of thousands of simultaneous connections to be supported for massive sensor deployments
  - Spectral efficiency to be significantly enhanced compared to 4G
  - Signaling efficiency should be enhanced
  - Latency should be reduced significantly compared to LTE-A
  - Lower battery consumption
  - Lower outage probability (better coverage)
  - High bit rates in larger portions of the coverage area
  - Higher number of supported devices
  - Lower infrastructure deployment costs
  - Higher versatility and scalability
  - Higher reliability of communication.

Background Paper
"Bandwidth Management of 5G"

5G is fifth generation of mobile data connectivity that is under formulation to provide unbelievably fast broadband speed between 10Gbps and 100Gbps with varied types of communication capability and capacity. One of the main benefits envisaged of 5G technology over 4G will be its latency. At present, 4G is capable of between 40ms and 60ms, which is low-latency but not enough to provide real-time response. Multiplayer gaming, for example, requires a lower latency than that to ensure that when you hit a button, the remote server responds instantly. The Internet of Things, in which gadgets and objects employ smart, connected features that they have never had before, the strain on bandwidth will continue to grow. It will be more adaptive to user's needs and demands and therefore able to allocate more or less bandwidth based on the application.

5G standards may be introduced approximately in the early 2020s. 3GPP held a conference in September 2015 to plan development of the new standard. Thus the new mobile generations are typically assigned new frequency bands and wider spectral bandwidth per frequency channel (1G up to 30 kHz, 2G up to 200 kHz, 3G up to 5 MHz, and 4G up to 20 MHz), but skeptics argue that there is little room for larger channel bandwidths and new frequency bands suitable for land-mobile radio. The higher frequencies would overlap with K-band transmissions of communication satellites. From users point of view, previous mobile generations have implied substantial increase in peak bitrate (i.e. physical layer net bitrates for short-distance communication), up to 1 gigabit per second to be offered by 4G.

If 5G appears and reflects these prognoses, then the major difference, from a user point of view, between 4G and 5G techniques must be something other than faster speed (increased peak bit rate). For example, higher number of simultaneously connected devices, higher system spectral efficiency (data volume per area unit), lower battery consumption, lower outage probability (better coverage), high bit rates in larger portions of the coverage area, lower latencies, higher number of supported devices, lower infrastructure deployment

costs, higher versatility and scalability, or higher reliability of communication. Those are the objectives in several of the research papers and projects below.

- **A super-efficient mobile network** that delivers a better performing network for lower investment cost. It addresses the mobile network operators' pressing need to see the unit cost of data transport falling at roughly the same rate as the volume of data demand is rising. It would be a leap forward in efficiency based on the IET Demand Attentive Network (DAN) philosophy.
- **A super-fast mobile network** comprising the next generation of small cells densely clustered to give a continuous coverage over at least urban areas and getting the world to the final frontier of true “wide-area mobility." It would require access to spectrum under 4 GHz perhaps via the world's first global implementation of Dynamic Spectrum Access.
- **A converged fiber-wireless network** that uses, for the first time for wireless Internet access, the millimeter wave bands (20 – 60 GHz) so as to allow very wide-bandwidth radio channels able to support data-access speeds of up to 10 Gbit/s. The connection essentially comprises “short” wireless links on the end of local fiber optic cable. It would be more a “nomadic” service (like Wi-Fi) rather than a wide-area “mobile” service.

Radio over fiber:

Radio over fiber (RoF) refers to a technology whereby light is modulated by a radio signal and transmitted over an optical fiber link to facilitate wireless access, such as 3G and Wi-Fi simultaneous from the same antenna. In other words, radio signals are carried over fiber-optic cable. Thus, a single antenna can receive any and all radio signals (3G, Wi-Fi, cell, etc..) carried over a single fiber cable to a central location where equipment then converts the signals; this is opposed to the traditional way where each protocol type (3G, Wi-Fi, cell) requires separate equipment at the location of the antenna.

Although radio transmission over fiber is used for multiple purposes, such as in cable television (CATV) networks and in satellite base stations, the term RoF is usually applied when this is done for wireless access.

In RoF systems, wireless signals are transported in optical form between a central station and a set of base stations before being radiated through the air.

Each base station is adapted to communicate over a radio link with at least one user's mobile station located within the radio range of said base station. The advantage is that the equipment for Wi-Fi, 3G and other protocols can be centralized in one place, with remote antennas attached via fiber optic serving all protocols. It greatly reduces the equipment and maintenance cost of the network RoF transmission systems are usually classified into two main categories:

1. **In RF-over-fiber architecture**, a data-carrying RF (radio frequency) signal with a high frequency is imposed on a light wave signal before being transported over the optical link. Therefore, wireless signals are optically distributed to base stations directly at high frequencies and converted from the optical to electrical domain at the base stations before being amplified and radiated by an antenna. As a result, no frequency up–down conversion is required at the various base stations, thereby resulting in simple and rather cost-effective implementation is enabled at the base stations.

2. **In IF-over-fiber architecture,** an IF (intermediate frequency) radio signal with a lower frequency is used for modulating light before being transported over the optical link. Therefore, before radiation through the air, the signal must be up-converted to RF at the base station.

Advantages

(a) RoF makes use of the concept of a Remote Station (RS)

This station only consists of an optical-to-electrical (O/E) (and an optional frequency up or down converter), amplifiers, and the antenna. This means that the resource management and signal generation circuitry of the base station can be moved to a centralized location and shared between several remote stations, thus simplifying the architecture.

(b) Low Attenuation

It is a well-known fact that signals transmitted on optical fiber attenuate much less than through other media, especially when compared to wireless medium. By using optical fiber, the signal will travel further, reducing the need of repeaters.

(c) Low complexity

RoF makes use of the concept of a remote station (RS). This station only consists of an optical-to-electrical (O/E) (and an optional frequency up or down converter), amplifiers, and the antenna. This means that the resource management and signal generation circuitry of the base station can be moved to a centralized location and shared between several remote stations, thus simplifying the architecture.

(d) Lower cost

Simpler structure of remote base station means lower cost of infrastructure, lower power consumption by devices and simpler maintenance all contributed to lowering the overall installation and maintenance cost. Further reduction can also be made by use of low-cost graded index polymer optical fiber (GIPOF).

Future-proof

Fiber optics are designed to handle gigabits/second speeds which means they will be able to handle speeds offered by future generations of networks for years to come. RoF technology is also protocol and bit-rate transparent, hence, can be employed to use any current and future technologies. New RoF techniques that support MIMO-enabled wireless services, notably 4G/5G mobile and 802.11 WLAN standards, have also been proposed.

The most popular use for RF over fiber is for cable TV systems. It is impossible to run RF signals over copper cable to more than few hundred feet. Content providers may transport their entire CATV channel lineup over a single-fiber optic cable, because this way they can transport the signal for hundreds of km. It works like this: An electrical RF signal usually in the range of 54–870 MHz is converted to modulated light using RF 1310 nm or 1550 nm laser optics. The light travels over single-mode fiber to the fiber optic RF receiver where is converted back to electrical RF. Electrical RF is directly connected to a TV or set-top box. 1550 nm is more popular because it has less losses in the fiber and by using fiber-optic amplifier known as EDFA it is possible to extend the transport distance. 1310 nm is losing about 0.35 db/KM of optical signal, 1550 nm is losing only 0.25 db/km. Optical budget between transmitter and receiver varies, depending on the transmitter power and receiver sensitivity.

Applications:

Access to dead zones

An important application of RoF is its use to provide wireless coverage in the area where wireless backhaul link is not possible. These zones can be areas inside a structure such as a tunnel, areas behind buildings, Mountainous places or secluded areas such as jungles.

FTTA (Fiber to the antenna)

By using an optical connection directly to the antenna, the equipment vendor can gain several advantages like low line losses, immunity to lightning strikes/electric discharges and reduced complexity of base station by attaching lightweight optical-to-electrical (O/E) converter directly to antenna.

The Internet of Things:

By the year 2020, it is predicted by analysts that each person in the UK will own and use 27 internet connected devices. There will be 50 billion connected devices worldwide. These can range from existing technology, such as smartphones, tablets and smart watches, to fridges, cars, augmented reality specs and even smart clothes. Some of these will require significant data to be shifted back and forth, while others might just need tiny packets of information sent and received. The 5G system itself will understand and recognize this and allocate bandwidth respectively, thereby not putting unnecessary strain on individual connection points.

The work has already begun for 4G implementation, but will become even more vital to a 5G future. As part of a “heterogeneous network", the points, or cells, will be used for LTE-A and the technology will be increased and refined to adapt to 5G too. Cells will automatically talk to each device to provide the best and most efficient service no matter where the user is.

Larger cells will be used in the same way as they are now, with broad coverage, but urban areas, for example, will also be covered by multiple smaller cells, fitted in lampposts, on the roofs of shops and homes, and even inside bricks in new buildings. Each of these will ensure that the connection will be regulated and seemingly standard across the board.

Algorithms will even know how fast a device is travelling, so can adapt to which cell it is connected to. For example, a connected car might require

connection to a macro-cell, such as a large network mast, in order to maintain its connection without having to re-establish continuously over distance, while a person's smartphone can connect to smaller cells with less area coverage as the next cell can be picked up easily and automatically in enough time to prevent the user noticing.

4K video streaming:

Capacity will also be important for the future of video streaming. By 2030, EE predicts that 76 per cent of its data traffic will be used streaming video. And a large amount of that will be at 4K or even 8K resolutions.

The data rates of 4G can cope with that – it is expected that a 14Mbps connection should cope with streaming 4K video, 18Mbps for 8K – but if everybody was to do that at the same time, like statistics suggest, the network would have difficulty keeping up with demand.

Other, non-consumer sectors will also be served better with 5G, but as EE itself admits, some of the applications of a low-latency, high capacity network is yet to even be thought of. Your kind-of need the technology in place to figure out much of what to do with it.

And finally, another major benefit to 5G technology is that standards and which spectrum bands will be reserved for its deployment will have been agreed globally, by members during the World Radio Communications Conferences. Your 5G phone in the UK, for example, will work on the exact same system and spectrum band as in the US, South Korea and wherever else.

Today's IETE Apex Forum is a step in this direction to create awareness and discuss a range of band width issues, including reuse at different countries, M2M and D2D communication link monitoring, cyber security, reliability, licensed and unlicensed frequency allocation for the 5G. It is certain that the Apex Forum of the Day will give each one participating in this program a food for thought for joint work on our Indian Scenario.

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IETE – Professional Activity Centre, Sarigam
February, 20, 2016

Sanjeet Kumar Shriwastava
Chairman
IETE PAC, Sarigam

PROCEEDINGS OF THE FORUM

The APEX Forum on **"Bandwidth Management of 5G"** was held at IETE Professional Activity Centre, Laxmi Institute of Technology, Sarigam on the 20th February 2016 (1000 hrs. to 1330 hrs.). **Smt. Smriti Dagur**, President IETE consented to the Chief Guest and **Brig (Dr) V D Abraham, SM (Retd),** Director Laxmi Institute of Technology as the Guest of Honour of the function. **Col Balraj Anand (Retd),** Chairman of Skill Development & Coordination Committee (SD & ICC) Chaired the Forum. **Brig (Dr) V D Abraham, SM (Retd)**, **Col Balraj Anand (Retd), Shri Naresh Kumar Garg** and **Shri Sanjeet Kumar Shriwastava**, were present on the dais.

Welcome Address by Prof. Sanjeet Kumar Shriwastava, Chairman IETE PAC, Sarigam

Good Morning.

On behalf of IETE fraternity, I extend a very warm and hearty welcome to you all in this IETE Apex Forum on an important subject **"Bandwidth Management of 5G".**

At the outset, we are grateful to Madam **Smriti Dagur**, President IETE New Delhi who has been kind enough to accept our invitation to be the Chief Guest for this occasion. But she could not be with us today due to sudden demise of her beloved father. We Share the grief and Pray to almighty for soul to Rest in Peace.

I extend a very warm welcome to **Brig (Dr) V D Abraham, SM (Retd),** Founder IETE sub center Indore and PAC Sarigam and Director Laxmi Institute of Technology who has steered IETE Professional Activity Centre (PAC), Sarigam, strongly in pursuing its activities on various fronts. He has acted as a direct liaison between our Institute & the IETE and provided apt leadership in undertaking professional activities.

I welcome **Col Balraj Anand (Retd)** Chairman SD & ICC IETE for his gracious presence. A special word of thanks for going all out to give recommendation to organize Apex Forum by this newborn PAC.

We are equally thankful to **Shri Naresh Kumar Garg** Chairman IETE Vadodara Centre, **Dr. Upena Dalal** Chairman IETE Surat Sub Centre, who have come from different directions to grace this event.

I welcome all the distinguished speakers who are present here to share their views and knowledge on the theme topic; IETE Members of Vadodara Centre, Surat Sub Centre & Members of IETE PAC, Sarigam, having gathered here in large number; the faculty and staff of Laxmi Institute of Technology, who have come to be benefitted from the event.

I also thank the Trustees of Gajera Trust for providing the required support.

Ladies & Gentlemen,

IETE is a leading professional society devoted to the advancement of Science & Technology in Electronics, Telecommunications, Information Technology, Computer Science and other related disciplines. IETE serves its more than 1.25 Lacs members both individuals and industries/ organizations through its 64 Centers spread all over India including one in Kathmandu (Nepal).

IETE Apex Forums are one such special meeting where domain specialists meet at a common platform to deliberate on key technological aspects of national relevance influencing our society as a whole. Experts from research & development organizations, industry, academia, and user departments share their experiences, ideas and opinions on the theme with an objective to frame-up priority areas, where coordinated work can be taken up by all the concerned stakeholders.

Today's IETE Apex Forum is a step in this direction to create awareness and discuss a range of band width issues, including reuse at different countries, M2M and D2D communication link monitoring, cyber security, reliability, licensed and unlicensed frequency allocation for the 5G.
It is certain that the Apex Forum of the Day will give each one participating in this program a food for thought for joint work on our Indian Scenario.

I am sure this Apex Forum will provide an excellent platform for panelists to present and deliberate on such vital issues of relevance to the modernization of Communication System. This too has been the subject of concern to both Government & society.
I once again welcome you all here and wish this programme a grand success.

Thank you all!

Address by Col Balraj Anand (Retd), Chairman, Skill Development & Industrial Coordination Committee

Respected Brig (Dr) V D Abraham, SM (Retd), Director, Laxmi Institute of Technology, Chairman IETE Vadodara, Chairperson IETE Sub Center Suart, Chairman IETE-PAC, Sarigam , General Manager BSNL Valsad, Our Expert panelists from Academics and Industries, Esteemed members of IETE and LIT, distinguished guests, Students, Ladies and Gentleman. Good Morning to all of you all.

Let me congratulate new born Professional Activity Centre Sarigam for daring to organize a national event of organizing an Apex Forum. I am overwhelmed by the love and affection of Sarigam. I am honored to launch the Web site of IETE PAC Sarigam.
I will be speaking to all after hearing the panelist and wishing the Forum a great success. Jai Hind

Presidential Address by Smt. Smriti Dagur, President, IETE, New Delhi

Brig (Dr) V D Abraham, SM (Retd), Founder IETE-PAC and Director, Laxmi Institute of Technology, **Col Balraj Anand (Retd),** Chairman SD & ICC, **Prof Sanjeet Kumar Shriwastava,** Chairman, IETE-PAC, Our Expert panelists for the day, Esteemed members of IETE and LIT, distinguished guests, Students, Ladies and Gentleman. Good Morning to all of you.

I am extremely happy to see that the IETE-PAC, Sarigam is actively taking lead in progressing the charter of IETE by organizing technical programs in the emerging technologies in the field of Electronics, Telecommunications and IT for

the benefit of professional experts, researchers and students. It gives me immense pleasure to be the Chief Guest and address all of you today on this significant event.

Most of you must be aware that The Institution of Electronics and Telecommunication Engineers was founded in 1953 with the aim and objective of dissemination of knowledge in the field of Electronics, Telecommunication and IT. IETE serves more than 1.25 lakhs members through its 64 Centres, spread all over India and abroad. It is India's leading recognized Professional Society devoted to the advancement of Electronics, Telecommunications, Computers and Information Technology. Developing and improving technical and professional competencies, particularly in the working environment is the greatest challenge that professionals face today. The Institution has distinguished itself by organizing regular conferences, conventions, symposia, seminars, workshops on the topical & current issues of technical advances in the areas of its interest. IETE, as a neutral professional body, promotes the policies that enable convergence of technologies with sharp focus on remote and rural penetration. One of the Committees of IETE, the Technology Regulatory Advisory Committee, which comprises of experts from relevant fields, analyzes the global trend of ICT technologies in an objective manner and recommends to the Govt. and other regulatory bodies, appropriate & necessary technologies and regulatory framework to be introduced and or added or modified, if any.

The Apex Forum is also one such programme which was evolved in the year 1997. Through its medium, over the years, recommendations have been made to various stakeholders on topical subjects of high relevance. The topic for today's Apex Forum is the **"Band Width Management of 5G".**

The world has seen a lot of changes in the realm of telecommunication. Today we no more use landlines. Everyone possesses a mobile phone that functions 24/7. Our handsets not only keep us connected with the world at large but also serve the purpose of entertainment gadget. From 1G to 2.5G and from 3G to 4G this world of telecommunications has seen a number of improvements along with improved performance with every passing day. With the 4G telecommunications systems now already deployed, eyes are looking towards the development of 5th generation or 5G technology and services.

The 5G wireless technology will be even faster, but it's not just about sheer speed. The next major network upgrade will solve one of the most aggravating problems we experience today - searching for a reliable, fast connections. 5G will be about powering much more than just smart phones- it'll be designed to connect smart

watches, fitness bands, and smart household gadgets like the Nest Learning Thermostat among others.

We are living in an era of convergence. Convergence is merging of technologies, domain and discrete IT systems. Basic of convergence lies in Digitization. The digitization of everything is creating a more natural communications experience. Boundaries separating various technologies, engineering practices, functions etc. are dissolving. So tomorrow, our car, our mobile phone, our home security system, our office, all the systems that surround us, will communicate with each other automatically to fill our environment with our preferences and our need to feel connected anywhere, anytime and with anyone, across the world. 5G will bring us perfect real world wireless called "WWWW: World Wide Wireless Web".

The ICT industry has come up with innovation after innovation to satisfy the world's hunger for bandwidth. Greater connectivity and broader bandwidth were achieved with Next-Generation Networks (NGNs), optical broadband and IMT Advanced (4G) mobile-wireless systems. Following NGNs and 4G, Future Networks and IMT-2020 (5G) systems will do the same. With each step forward, the industry finds new ways of supporting an increasing number and diversity of bandwidth-hungry services and applications.

The International Telecommunication Union hasn't revealed the specific requirements and the types of technology that will be incorporated into 5G just yet. Nailing down the correct specifications and setting up infrastructure to deploy these networks is a gradual process. The task involves defining the requirements for 5G and the technology that goes into meeting those requirements, such as achieving a certain speed benchmark and deciding which components and antennas should be added to smart phones to meet those benchmarks.

Very many companies are looking into the technologies that could be used to become part of the system. In addition to this a number of universities have set up 5G research units focused on developing the technologies for 5G. Many professional bodies are also very actively involved world over in defining and developing standards for 5G. Likely to be unfolded between 2020 to 2025, 5G is expected to revolutionize communication reach and capabilities and would truly empower citizens to take full advantage of integrated e-governance initiatives across the board.

I would like to convey my earnest wishes for the success of the Forum and believe that the forum would prove to be an experience-sharing platform, in this upcoming

5G domain. The proceedings of the forum should be compiled and shared with the environment.

Thank you and my best wishes to you all.

Panel of Speakers

The following distinguished speakers spoke on the occasion and expressed their views on the various aspects connected with requirement, framing & freezing the key areas in “Bandwidth Management of 5G”

- Brig (Dr) V D Abraham,SM (Retd), Moderator of Panel discussion
- Shri Hemant R Patel, General manager Bharat Sanchar Nigam Limited, Valsad
- Dr. Upena Dalal, Chairman IETE Surat Sub Centre & Head of Department ECE, SVNIT Surat (Gujarat)
- Dr.Shweta Shah, Honorary Treasurer IETE Surat Sub Centre & Asst Prof ECE, SVNIT Surat (Gujarat)
- Dr Vandana M Rohokale, GISFI & Dean R&D SKNSITS Lonavala
- Mr. Ashwani Jha, Assistant Professor Laxmi Institute of Technology, Sarigam

Panel Discussions

Brig (Dr) V D Abraham, SM (Retd) Founder IETE PAC, Sarigam & Director Laxmi Institute of Technology, Sarigam initiated the discussion and elaborated;

Bandwidth is like the soul - everyone thinks they know what you mean when you discuss it, but they are probably thinking about something entirely different. And that's because, like the soul, bandwidth does not transparently exist in any of the simple ways that we tend to believe.

In computer networks, bandwidth is used as a synonym for data transfer rate, the amount of data that can be carried from one point to another in a given time period (usually a second). Network bandwidth is usually expressed in bits per second (bps); modern networks typically have speeds measured in the millions of bits per second (megabits per second, or Mbps) or billions of bits per second (gigabits per second, or Gbps).

In the field of signal processing, wireless communications, modem data transmission, digital communications, and electronics, bandwidth is the range of frequencies -- the difference between the highest-frequency signal component and the lowest-frequency signal component -- an electronic signal uses on a given transmission medium. Like the frequency of a signal, bandwidth is measured in hertz (cycles per second). This is the original meaning of bandwidth, although it is now used primarily in discussions about cellular networks and the spectrum of frequencies that operator's license from various governments for use in mobile services.

In business, bandwidth is sometimes used as a synonym for capacity or ability. In this sense, bandwidth usually refers to having time or staffing available to tackle something, e.g. "We just don't have the bandwidth to take on mobile app development, and we are already short-staffed on developers."

Before we discuss, we should know the ground reality of digital divide between Urban and rural areas, General Manager BSNL, Valsad who will be the next speaker will deliberate up on.

Evolution to 5G:

Currently we are in the era of deployment of 4G in the global market. Evolution of LTE advanced and closer integrations of LTE and Wi-Fi enables higher data rates. Carrier aggregation is used in LTE-Advanced in order to increase the bandwidth, and thereby increase the bit rate. Advanced radio resource coordination between cells will further improve performance of 4G.

ITU is planning to launch the specifications of 5G (IMT-2020) by 2020.Some of the key network requirements of 5G are Higher Capacity, Low Latency, more number of connected devices, High spectrum efficiency, increased throughput, higher energy efficiency, deeper coverage and higher flexibility. Deployment of new technology for high speed and low latency services has to be carried out. Concepts of spectrum sharing and utilization of unlicensed band for traffic offload will be considered for better spectrum efficiency. Allocation of spectrum in millimeter or centimeter range (above 6 GHz) may be required for dense cell deployments.

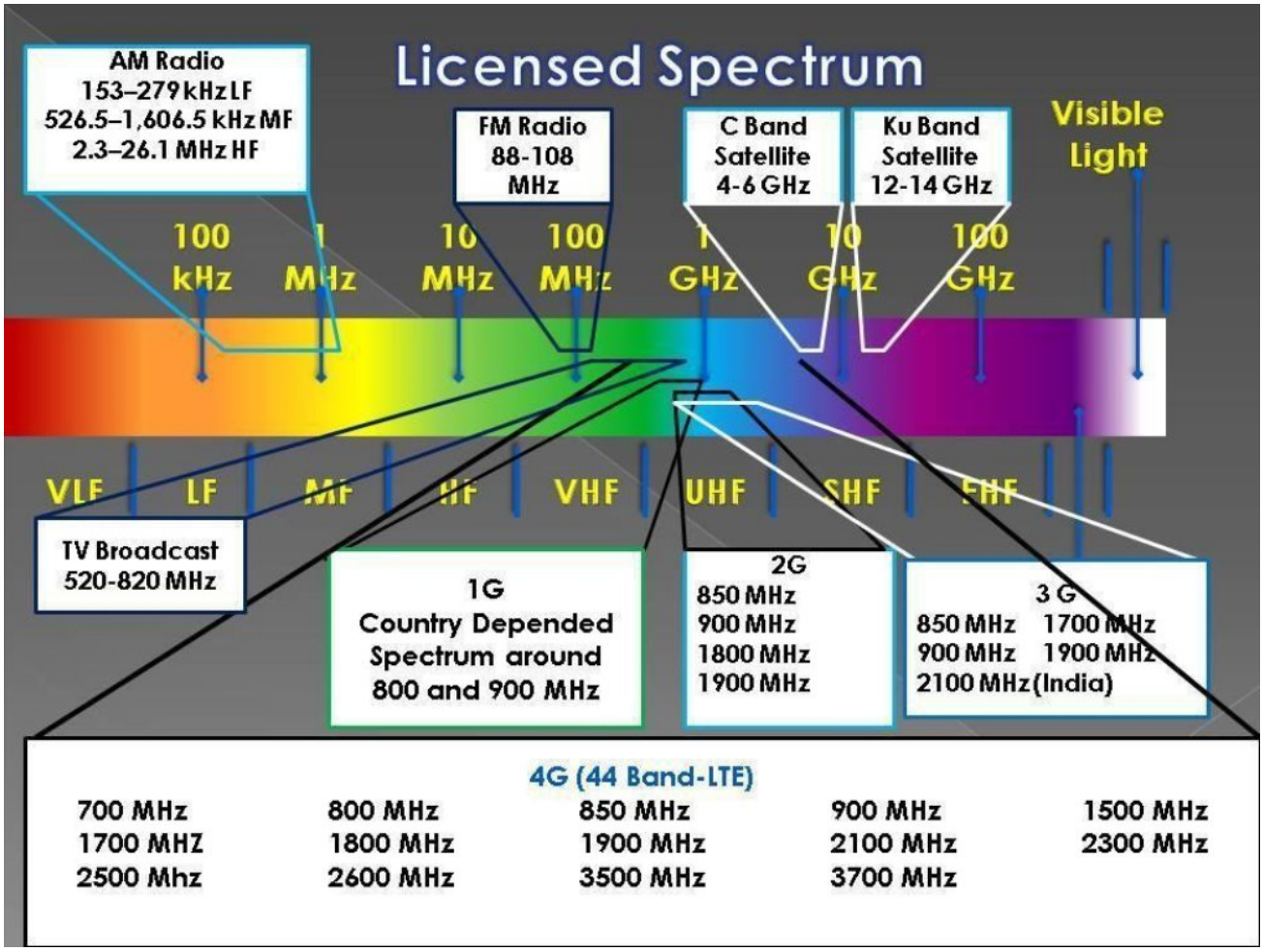
More research is required in the field of Higher order MIMO (Multiple Input Multiple output) for better reception and noise cancellation. Lighter protocols with acceptable security and smoother operations and content delivery will increase the sustainability of network. We can expect Context aware delivery of services for more user satisfaction.

Today our discussions should be centered around the spectrum, let recapitulate the spectrum usage.

Spectrum

We are using frequencies form ranging from kHz to GHz. Some of the frequencies are unlicensed, also termed as ISM band, are free to use for everyone with some restrictions of maximum radiated power.

In unlicensed band we have 26 MHz of Spectrum from 902MHz to 928 MHz, 83.5 MHz spectrum from 2.4-2.483 GHz, and in 5 GHz range. In licensed frequencies we have many spectrum bands for different Telecommunication regions given by ITU.



Globally the countries are grouped into three regions;

Region 1: Europe, Middle East, Africa, the former Soviet Union, including Siberia; and Mongolia

Region 2: North and South America and Pacific (East of the International Date Line)

Region 3: Asia, Australia and the Pacific Rim (West of the International Date Line)

Even though the frequency does not limit to the boundaries of these regions, the standardization can plan reuse of bandwidth globally. We will recapitulate with the present allocation and usage.

Bandwidth of Various Technologies

Technology/Generation	Bandwidth Per Channel
AM	10 kHz
FM	200 kHz
Bluetooth	1 MHz
Wi-Fi (2.4 and 5 GHz)	20 MHz, 40 MHz, 80 MHz, 160 MHz
TV Channel Broadcast	6 to 8 MHz
1G (Analog Mobile)	30 kHz
2G	200 kHz
3G	5 MHz
4G	5 to 20 MHz (40 MHz Optional)
5G	?

Telecom Frequency Bands in India

India has currently deployed operations or has future plans to deploy telecom operations in a total of 8 radio frequency bands as of now.

Band No	Type	Up link(MHz)	Downlink (MHz)	Bandwidth
1	Paired	1939-1979	2129-2169	40X2
3	Paired	1710-1765	1805-1860	55X2
5	Paired	824-844	869-889	20X2
7	Paired	2500-2570	2620-2690	70X2
8	Paired	890-915	935-960	25X2
28	Paired	703-748	758-803	45X2
40	Unpaired	2300-2400	100	
41	Unpaired	2496-2690	194	

I draw the attention to the Digital Dividend in which digitizing the Cable TV transmission and utilize, which India has already done in Band No.28

In this apex forum, we would like to find out answers to some questions like:

1. Is it Possible to use unlicensed band for 5G?
2. While utilizing the Mille metric wavelength, how one can economize infrastructure cost using Array matrix in Antennas?
3. How can we do global re-use and dynamic allocation of idle frequencies of Bandwidth?
4. What role MIMO can play in the Bandwidth Management?
5. GISFI- contribution in global Spectrum/Bandwidth allocation?

Thank you, Jai Hind

Shri Hemant R Patel, General Manager Bharat Sanchar Nigam Limited, Valsad, represented Government and gave out the ground realities:

Respected Brig (Dr) V D Abraham, SM (Retd), Director, Laxmi Institute of Technology, Col Balraj Anand, Chairman of SD&ICC, Chairman, IETE Vadodara, Chairperson IETE Sub Center, Chairman, IETE-PAC, Our Expert panelists from Academy and Industries, Esteemed members of IETE and LIT, distinguished guests, Students, Ladies and Gentleman. Good Morning to all of you all.

We are still struggling to fill the void of Digital Divide of rural and urban areas. Presently the existing Technology has not yet matured. There are many takers with the government agencies, our commitments should be to the mass society. Optimum utility of Bandwidth is ideal, but the transmission power should be within the safe limit of human survival. Accountability of maintaining the standards should be adhered by the service providers.

My view point from the government agency and service provider is that existing infrastructure should be made use and should be compatible with technologies up to 4G. Thank you and wish the Apex forum all the success.

Prof (Dr.) Upena Dalal, Chairman IETE Sub Centre Surat & HoD, ECE Dept, SVNIT Surat (Gujarat)

Dr Upena Dalal is of the opinion that LTE evolution offers most of the key foundation technologies for 5G;

- OFDM based multicarrier modulation technique, which is having high speed wireless communication capability
- MIMO support with pre coding in downlinks
- Cellular infrastructure for mobility
- Integration of Macro, micro, Pico and femto cell environments and heterogeneous network architecture support
- Cognitive and carrier aggregation features

- Coordinated Multipoint transmission and reception
- Multi-Radio Access Technology with self-optimization in hetnet
- Enhancements like Machine Type Communication (MTC)

Presently the Global target is efficient utilization of spectrum for high speed communication by bandwidth management and by increasing spectral efficiency. LTE may become the Global Cellular Standard uniting all Wireless Industries. 5G will be designed to integrate with LTE networks and many 5G features to for as LTE Advanced. Internet of Things poised for massive adoption.

Evolution of LTE in Release 13 for more resources LTE in unlicensed spectrum

While licensed spectrum remains 3GPP operators' top priority to deliver advanced services and user experience, the opportunistic use of unlicensed spectrum is becoming an important complement to meet the growing traffic demand.

Licensed-Assisted Access will give operators the option to make use of unlicensed spectrum with a unified network, offering potential operational cost saving, improved spectral efficiency and a better user experience

The focus of the Release 13 work is on the aggregation of a primary cell, operating in licensed spectrum to deliver critical information and guaranteed quality of service, with a secondary cell operating in unlicensed spectrum to opportunistically boost data rate. A key objective of the project is to ensure fair coexistence between LTE AA and Wi-Fi.

Carrier Aggregation enhancements

The LTE CA framework was standardized in Release 10, with the protocol allowing aggregation of up to 5 Component Carriers (CCs) in downlink and uplink.

As operators have planned for deployments with the aggregation of more and more carriers, it has become necessary to expand the LTE CA framework to be able to aggregate more than 5 CCs.

The goal in Release 13 is to expand LTE CA up to 32 CCs and hence provide a major leap in the achievable data rates for LTE as well as in the flexibility to aggregate large numbers of carriers in different bands. But the enhanced framework will also be useful for LAA operation in unlicensed spectrum where large blocks of spectrum are available.

Elevation Beam forming / Full-Dimension MIMO

Beam forming and MIMO have been identified as key technologies to address the future capacity demand. But so far 3GPP evaluations for these features have mostly considered antenna arrays that exploit the azimuth dimension.

So 3GPP RAN is now studying how two-dimensional antenna arrays can further improve the LTE spectral efficiency by also exploiting the vertical dimension for beam forming and MIMO operations.

Also, while the standard currently supports MIMO systems with up to 8 antenna ports, the new study will look into high-order MIMO systems with up to 64 antenna ports at the eNB, to become more relevant to the use of higher frequencies in the future.

Enhanced multi-user transmission techniques

The goal of the project is to study downlink multi-user transmissions using superposition coding to see if such techniques can increase spectral efficiency of the LTE system.

Superposition Coding (SC), a multiuser transmission scheme based on library of off the-shelf point-to-point channel codes. It deliberately introduces interference among user signals at the transmitter.

Indoor positioning

The study will first determine the performance of already specified positioning methods in indoor environments, and later evaluate potential improvements to the existing methods or new positioning methods in order to achieve better positioning accuracy.

While initially driven by the FCC request to improve the positioning accuracy in indoor environments for emergency calls, the work can further expand the capability of the LTE platform allowing operators to address the growing market of indoor positioning.

Dr. Shweta Shah, Asst. Prof ECE Dept, SVNIT Surat (Gujarat), talked on;

The fifth generation of mobile technology (5G) is positioned to address the demands and business contexts of 2020 and beyond.
It is expected to enable a fully mobile and connected society and to empower socio-economic in countless ways many of which are unimagined today, including those for productivity, sustainability and well-being .

Suggested Solution

• 5G should include design embedded flexibility to optimize the network usage

• Should include modular network functions i.e. deployed and scaled on demand

• Should include a wide range of use cases, business and partnership models

• It anticipates the need for new radio interface

5G: Vision

5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models.

She also highlighted the 5G characterization, 5G Requirements, 5G Technology, 5G Architecture, & 5G Spectrum. The 5G requirements cover end to end considerations including user, system, enhanced service, management and operation, device and business model requirement. It is particularly important to keep improvements in the areas like Network capability, Consistent customer experience, Flexibility, Efficiency, innovation

Dr Vandana M Rohokale, GISFI Representative &
Dean R & D SKNSITS Lonavala on
“Bandwidth Management of 5G”

Ever increasing evolution and dense popularization of mobile computing devices and services demand for technological convergence. Convergence is nothing but collaboration of two or more distinct entities or phenomena for a common cause. Presently we are living in a world where we are surrounded by numerous heterogeneous wireless devices and technologies. Television white spaces and /or other spectrum white spaces can be efficiently utilized for today’s emerging spectrum need. That day is not a far when the television spectrum white spaces

can be utilized for the broadband Internet access or so due to advances in mobile communication field. User centric mobile generation is knocking our doors and the mobile users are eager to welcome the qualitative and rich communication experience technology named as fifth generation mobile communication (5G). 5G will be an extended version of Global Information Multimedia Communication Village (GIMCV) and Wireless Innovative System for Dynamically Operating Mega-communications (WISDOM) concepts envisioned

The converged visualization of 5G mobile wireless is shown in Figure 2.

Converged 5G mobile wireless system will be the integration of almost all wired and wireless, old and newly evolved networks and supporting technologies. Wireless Sensor Networks (WSNs), Internet of Things (IOT) , WLAN, Wi-Fi, Light Fidelity (Li-Fi) with Visible light Communication (VLC), Cellular Networks, Infra-structured networks like PSTN, Cognitive Radio Networks (CRN) with Software Defined Radios (SDR) and Software Defined Networks (SDN),

Vehicular Adhoc Networks (VANETs), Smart Grids, Optical Fiber Communication, Cloud Computing, Tele-healthcare systems, Cooperative Multiuser MIMO with Smart Antennas, millimeter wave communications, satellite communications, etc. will have to work in collaboration and cognition with every other network to bring 5G into reality. In user centric approach of 5G, Quality of Life (QoL), Quality of Experience (QoE) by user and quality of Service (QoS) by service providers will have to walk hand in hand.

With Internet of Things (IoT) and Machine to machine communication (M2M), 5th generation services will need dynamic access to spectrum in a variety of heterogeneous bands to support various use cases in reality. 5G ecosystem demands variety of channels for fulfilling the increasing traffic capacity demands. 5G technical requirements are very critical like very high data rates greater than 10 Gbps, very low latency less than 1 millisecond and very high throughput with great user experience. For 5G to be user centric, we need to take into account two things like Effective bandwidth management and Spectral Efficiency Improvement. The spectrum used by mobile communication systems today is becoming congested. One novel idea is to use visible light bands, where light-emitting diodes (LEDs) can be both a source of illumination and a hot spot. The very high spectrum bands (such as 28 or 60 GHz) have enormous potential because they can provide wider bandwidth and support higher data rates. Also, the use of unlicensed spectrum around 2.4 and 5 GHz, as well as re-farming the 900 and 1800 MHz bands, could also increase the spectrum available for broadband data. Furthermore, it is expected that new bands will become available

after the World Radio communication Conferences. But new spectrum bands alone will not be sufficient.

India - National Frequency Allocation Plan

(Source: Spectrum Requirements for 5G- Dr. Ashok Chandra, 2015)

- **59.3 – 64 Ghz**
  - Fixed
  - Inter – Satellite
  - Mobile
  - Radio Location
- **64 – 65 Ghz**
  - Fixed
  - Inter – Satellite
  - Mobile Except Aeronautical Mobile
- **65 – 66 Ghz**
  - Earth Exploration Satellite
  - Inter – Satellite
  - Mobile Except Aeronautical Mobile
  - Space Research

Highlights of her talk include-

- The speaker touched upon the objectives of the, 5G and Its Requirements, the global trends, Dynamic Spectrum allocation.
- Bandwidth Management Techniques
- Challenges due to upcoming Services like Internet of Things, Visible Light Communication, Intelligent Transportation System, etc.

Mr. Ashwani Jha, Asst Prof, CSE Dept., LIT, Sarigam deliberated

Three main criteria for the 5G standard have been established:

1. It should be capable of delivering a 1Gbps downlink to start with and multi-gigabits in future.
2. Latency must be brought under one millisecond.
3. It should be more energy efficient than its predecessors (though there's no agreement yet on just how much more) Spectrum Management

- Strict rules are necessary to prevent one type of transmission from interfering with the next.
- Governments must oversee appropriate licensing of this valuable resource to facilitate use in all bands.
- Governments spend a considerable amount of time allocating particular frequencies for particular services, so that one service does not interfere with another.
- These allocations are agreed internationally, so that interference across borders, as well as between services, is minimized.

Top Solution in Spectrum Allocation and Implementation

- One solution to the spectrum crunch could be to look beyond the lower-frequency spectrum between 700MHz and 2.6GHz used by most carriers today, and move towards higher spectrum bands such as 6GHz, 28GHz, and 38GHz.
- At the top end, beyond 30GHz, these extremely high frequency bands are known as millimeter wave. Bringing those bands into use is both one of the most exciting, and least guaranteed, areas of 5G development.
- Using traditional spectrum allows you to transmit data over a longer distance but at lower capacity, but millimeter wave offers greater bandwidth, but the signal won't reach as far. Millimeter wave also bring with it the possibility of beam forming — rather than broadcasting or receiving signals in all directions, they're sent directly where they need to go, be that a handset, a router, or a base station.

The new risks with 5G

- 5G makes all sorts of technologies possible - but also raises the stakes. If your car is being operated via a cloud-based autonomous driving system over 5G, you don't want to lose the signal right at the precise moment it's about to tell your vehicle to slam on the brakes.
- Operators and technology companies know that (and are perhaps considering the insurance implications).

Prof. Nandlal Dhandhukia, HoD, ECE Dept,LIT Sarigam spoke on "Key Challenges for the 5G Infrastructure PPP"

Key Points of his inputs

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
- Saving up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network
- Reducing the average service creation time cycle from 90 hours to 90 minutes
- Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision
- Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
- Ensuring for everyone and everywhere the access to a wider panel of services and applications at lower cost

Recommendations

- Proposes new Radio over Fiber (RoF) techniques that support MIMO enabled wireless services, notably 4G/5G mobile and 802.11 WLAN standards
- Efficiency based on Demand Attentive Network (DAN) philosophy in which idle slot or bandwidth should dynamically distributed GLobal implementation of Dynamic Spectrum Access.
- The millimeter wave bands (20 – 60 GHz) so as to allow very-wide bandwidth radio channels able to support data-access speeds of up to 10 Gbit/s.
- Data-carrying RF (radio frequency) signal with a high frequency is imposed on a light wave signal before being transported over the optical link
- Light wave can be used for Line of Sight WiFi usages in public places like Airport, Railway Stations, Bus stations etc,
- RoF makes use of the concept of a Remote Station (RS) in which it only consists of an optical-to-electrical (O/E) (and an optional frequency up or down converter), amplifiers, and the antenna. The resource

management and signal generation circuitry of the base station can be moved to a centralized location and shared between several remote stations, thus simplifying the architecture

- “Heterogeneous network", the points, or cells, to be used for LTE-A and the technology has to be refined to adapt to 5G
- Television white spaces and other general white spaces in the spectrum can be utilized for advanced wireless applications
- For Indoor applications and IoT, visible light spectrum can be a good option
- Spectral efficiency can be improved with the cognitive radio networks and software defined radios
- Appropriate bandwidth management is the basic building block for the success of converged 5G services

Conclusion

Col Balraj Anand (Retd) Chairman SD & ICC IETE, while summing up the forum congratulated the fruitful outcome of panel discussion on regulation aspects of Bandwidth Management of 5G. The governance issues and the regulation issues were adequately covered in depth by the expert speakers.

The Apex Forum had detailed discussions on different aspects such as: technology development, application areas, maintenance aspect, Spectrum Management, Frequency allocation etc. Various experts representing research, academic (SVNIT Surat, Laxmi Institute of Technology ,Sarigam) industry representatives, professional bodies like IETE, expressed their ideas which can be crystallized the recommendations The forum ended with vote of thanks by **Shri Nandlal Dhandhukia** Vice Chairman IETE Professional Activity, Centre Sarigam. Contributions made by all is deeply appreciated and acknowledged

IETE APEX FORUM-2016

List of Participants –"A"

List of Participants

S.No.	Name	Designation	Contact No.	E-mail Id
1.	Brig (Dr) V.D. Abraham,SM (Retd)	Guest of Honour	9714844898	vdabraham@gmail.com
2.	Col B. Anand (Retd)	Chairman SD & ICC IETE	9811648030	b_anand6@rediffmail.com
3.	Shri Sanjeet Kumar Shriwastava	Chairman IETE PAC, Sarigam	7043793882	Sanjeetballia@gmail.com
4.	Shri Naresh Kumar Garg	Chairman IETE Vadodara Centre	9426574470	nkgarg3@gmail.com
5.	Dr. Upena Dalal	Chairman IETE Surat Sub Centre	9898057727	upena_dalal@yahoo.com
6.	Shri Hemant R Patel	General Manager BSNL Valsad	9426000707	hemits98@gmail.com
7.	Dr. Vandana Rohokale	GISFI Representative	9689922524	vmr.301075@gmail.com
8.	Dr. Shweta Shah	Hony. Treasurer IETE, Surat Sub Center	9925458497	snshah@eced.svnit.ac.in
9.	Wg.Cdr. Sanat Vasavada	Past Chairman IETE Vadodara Centre	9426386921	wgcdrvasavada@hotmail.com
10.	Shri Tushar B. Kher	Honorary Secretary Vadodara Centre	9428007646	tusharkher@yahoo.co.in
11.	Dr. Shilpi Gupta	Honorary Secretary Surat Sub Centre	9737011973	sgupta@eced.svnit.ac.in
12.	Shri Nandlal Dhandhukia	Vice Chairman IETE PAC Sarigam	8905848891	nand111188@gmail.com
13.	Mrs. Sita Singh	Honorary Secretary IETE PAC ,Sarigam	7096708500	sitasingh200711@gmail.com
14.	Shri Neeraj Paliwal	Hony.Treasurer IETE PAC,Sarigam	9425993523	npneerajpaliwal@gmail.com
15.	Shri Karan H. Bhagat	CEO, Allied Infosoft Vapi	8905233344	karan@alliedinfosoft.com
16.	Shri Jay Nayak	BDM Shree Net Vapi	9033588357	jaynayak1992@gmail.com
17.	Shri Paraesh Malankar	Head Network Engineer, Shree Net Vapi	8866784980	pm2799@gmail.com
18.	Shri Jigar Patel	CEO , Softyoug Vapi	8511170666	jigar@softyoug.com
19.	Shri Ashish Parekh	CEO, Chips and Bytes Vapi	9898029116	ashish@chipsandbytes.in
20.	Shri Ashwani Jha	Member IETE PAC, Sarigam	9693634512	ashwanijha@email.com

21.	Mrs. Suchita Borkar	Member IETE PAC, Sarigam	9998119553	msunil5@rediffmail.com
22.	Mr. Hitesh Kamani	Member IETE PAC, Sarigam	9974158939	hiteshk.lit@lvs.co.in
23.	Mr. MiteshNakrani	Member IETE PAC,Sarigam	7567013538	miteshn.lit@lvs.co.in
24.	Ms. NipaModi	Member IETE PAC,Sarigam	9727536502	nipa.lit@lvs.co.in
25.	Ms. Siddhi Desai	Member IETE PAC,Sarigam	9737136698	siddhi.desai.lit@lvs.co.in
26.	Ms. Priyanka Patel	Member IETE PAC,Sarigam	9974053578	priyanka.s.lit@lvs.co.in
27.	Mrs. Anjana R	Member IETE PAC,Sarigam	9638027905	anjana.lit@lvs.co.in
28	Mr. Narendra Bhilwala	Member IETE PAC,Sarigam	8469404384	narendra.lit@lvs.co.in
29	Mr. Biraja Prasad	Member IETE PAC,Sarigam	8156081887	biraja.lit@lvs.co.in
30.	Mr. Kannan S	Member IETE PAC,Sarigam	7201923035	engineerskannan@gmail.com
31.	Mr. Ravi Krishna Pandey	Member IETE PAC,Sarigam	9904904209	ravikrishna.lit@lvs.co.in
32.	Mr. Abinash	Member IETE PAC,Sarigam	8511252940	abhinash709@gmail.com
33.	Mr. Viral Prajapati	Asst. Prof. LIT Sarigam	9725210025	Viralkumar.lit@lvs.co.in
34.	Mr. Amrat Patel	Principal LIT,Sarigam	9725210099	Amrat.lit@lvs.co.in
35.	Mr. Keval Patel	Asst. Prof. LIT Sarigam	9898136037	Kevel.lit@lvs.co.in
36.	Ms. Rashmi Patel	Asst. Prof. LIT Sarigam	9824418876	Rashmi.lit@lvs.co.in
37.	Ms.Nikita Panchal	Asst. Prof. LIT Sarigam		Nikita.lit@lvs.co.in
38.	Mr. Nirmal Vijay	Asst. Prof. LIT Sarigam	9426980015	Nirmal.lit@lvs.co.in
39.	Mr/ Hariprasad K. Patel	Asst. Prof. LIT Sarigam	9909877115	hariockey@gmail.com
40.	Mr. Ketan Vyas	Asst. Prof. LIT Sarigam	9898154370	Ketan.lit@lvs.co.in
41.	Mr.Shailendra Prajapati	Asst. Prof. LIT Sarigam	7359924377	Shailendra.lit@lvs.co.in
42.	Mr. Bhavesh K. Patel	Asst. Prof. LIT Sarigam	9725210041	Bhavesh.lit@lvs.co.in
43.	Ms. Kavita Joshi	Asst. Prof. LIT Sarigam	9377856212	Kavita.lit@lvs.co.in
44.	Ms. Rajvi Patel	Asst. Prof. LIT Sarigam	9879757927	Rajvi.lit@lvs.co.in
45.	Ms. Ditya Patel	Asst. Prof. LIT Sarigam	9726054871	Ditya.lit@lvs.co.in
46.	Ms. HemaliVansia	Asst. Prof. LIT Sarigam	9574830661	Hemali.lit@lvs.co.in
47.	Ms.Farzin Shaikh	Asst. Prof. LIT Sarigam	8153806069	Farzin.lit@lvs.co.in
48.	Ms. Hiral Desai	Asst. Prof. LIT Sarigam	9724250698	Hiral.lit@lvs.co.in
49.	Ms. Harshila B. Patel	Asst. Prof. LIT Sarigam	9712903280	Ksvpatel5626@gmail.com
50.	Ms. Varunda J. Patel	Asst. Prof. LIT Sarigam	7227000903	Vrunda88@gmail.com

51.	MS. RinkalPrajapati	Asst. Prof. LIT Sarigam	9904358383	Rinkal10feb@gmail.com
52.	Ms. Shanthini Akbar	Asst. Prof. LIT Sarigam	7227898195	Shanthini.lit@lvs.co.in
53.	Ms. Rama Maliya	Asst. Prof. LIT Sarigam	9979273876	Malyarama126@gmail.com
54.	Ms. SaritaYadav	Asst. Prof. LIT Sarigam	9574601429	Sarita.lit@lvs.co.in
55.	Mr. DarpanBulsara	Asst. Prof. LIT Sarigam	8154799002	darpanbulsara@lvs.co.in
56.	Mr.Tushar Patel	Asst. Prof. LIT Sarigam	9879443484	Pateltushar4152@gmail.com
57.	Mr. Sagar Mistry	Asst. Prof. LIT Sarigam	7359661866	Sagar.lit@lvs.co.in
58.	Ms. Amir Hamza	Asst. Prof. LIT Sarigam	9573338969	Amir.lit@lvs.co.in
59.	Mr. KrunalDhaval	Asst. Prof. LIT Sarigam	9725105335	Krunald.lit@lvs.co.in
60.	Mr. Shrikant Mishra	Lab instructor, LIT Sarigam	9303054868	Shrikant.lit@lvs.co.in
61.	Mr. Jinesh Mistry	Lab instructor, LIT Sarigam	9558316221	Jignesh.lit@lvs.co.in