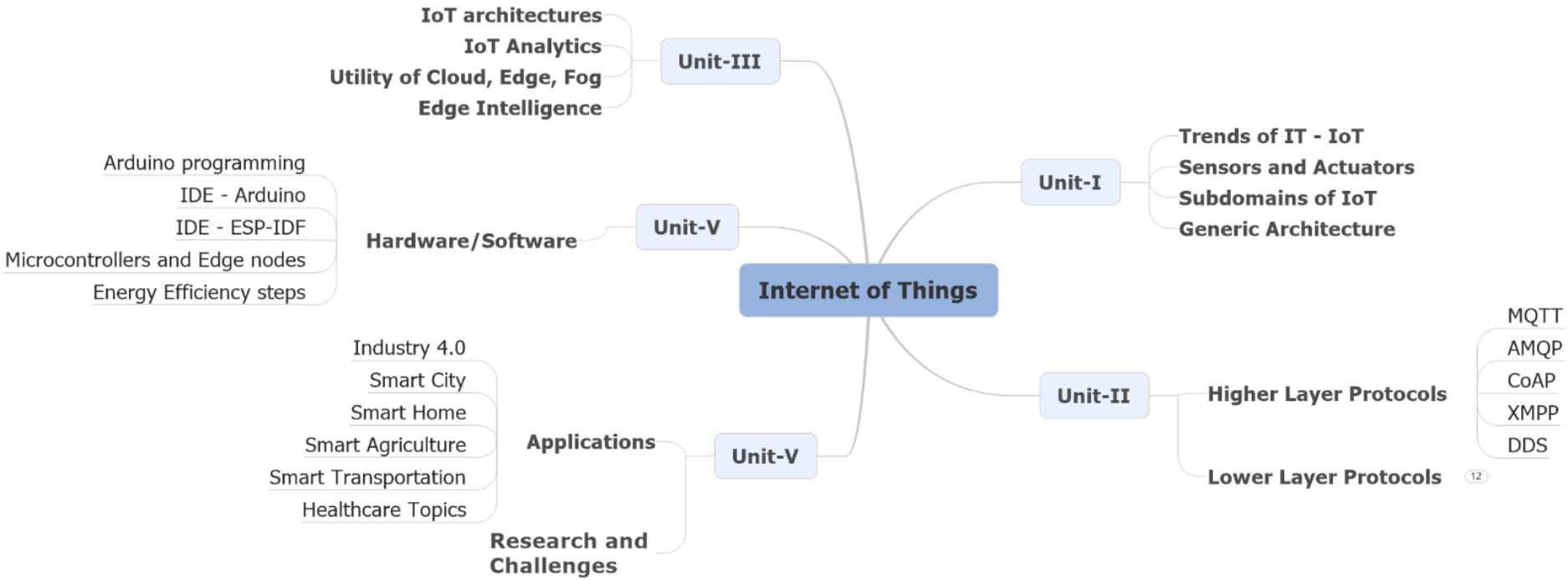
Selected Topics in Computer Architecture, Computer Networks, and Distributed Systems
(Internet of Things)
(IN3450)

–

Dr. Shajulin Benedict
shajulin@iiitkottayam.ac.in
shajulinbenedict@mytum.de

Prof. Dr. Michael Gerndt
gerndt@in.tum.de

Syllabus


Internet of Things
Unit-I
Trends of IT - IoT
Sensors and Actuators
Subdomains of IoT
Generic Architecture
Unit-II
Higher Layer Protocols
MQTT
AMQP
CoAP
XMPP
DDS
Lower Layer Protocols
12
Unit-III
IoT architectures
IoT Analytics
Utility of Cloud, Edge, Fog
Edge Intelligence
Unit-V
Hardware/Software
Arduino programming
IDE - Arduino
IDE - ESP-IDF
Microcontrollers and Edge nodes
Energy Efficiency steps
Unit-V
Applications
Industry 4.0
Smart City
Smart Home
Smart Agriculture
Smart Transportation
Healthcare Topics
Research and Challenges

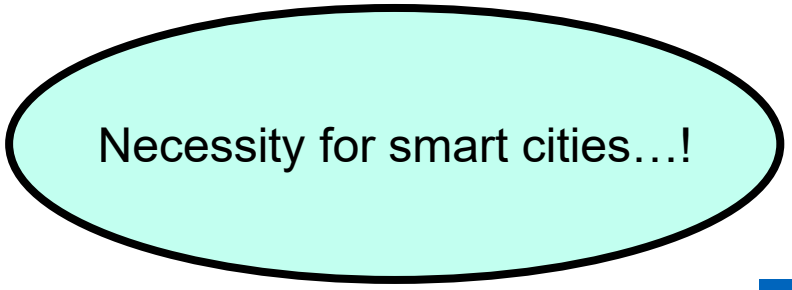
Announcements – Revised – 21.7.2022

- Exam Venue - specified in TUM website.
- Exam points – 50 marks/points
  - (converted to 100 marks)
  - Graded
- Exam Mode: OFFLINE
  - i.e., answer sheets will be printed and given to you in the hall.
- Exam Date: 28.7.2022
  - (Thursday at 4 PM – Duration: 1 hour)
- Any modifications will be communicated via. emails.

- IoT Applications

Smart cities

- UN Report: Two-thirds of world population choose cities to live by 2030.
- UN Report: By 2050, around 2.5 billion more people will be living in cities.
- In India…
  - Cities accommodate nearly 31% of India's current population and contribute 63% of GDP (Census 2011).
  - Urban areas are expected to house 40% of India's population and contribute 75% of India's GDP by 2030.
- Comprehensive development of
  - Physical
  - Institutional
  - Social
  - Economic infrastructure



What is smart city?

- According to Wikipedia…
  - A **smart city** is an urban area that uses different types of electronic data collection sensors to supply information which is used to manage assets and resources efficiently.
  - Data are collected from citizens, devices, and assets.
  - Data are processed and analyzed.
  - The inference enables monitoring and managing
    - traffic and transportation systems,
    - power plants,
    - water supply networks,
    - waste management,
    - law enforcement,
    - information systems,
    - schools, libraries, hospitals, and other community services

Smart Cities – Comparison to Normal Cities

- In addition to regular infrastructures, we need some platform using ICT technologies to keep the cities in a smart manner.
- Regular infrastructures of cities:
  - Hospitals and Schools
  - Traffic control and Policing
  - Waste management
  - Water / Electricity supply
  - Transport
- How to keep these components smart?
  - Applying sensors, actuators, communication technologies and so forth in an intelligent manner would be a solution.
  - Ie. The application of the smart city concept.

Objectives of Smart Cities

- To provide opportunities to improve lives.
- To promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions.
- (Ref: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1814400)

Smart cities in India

- Ministry of Urban Development (MoUD) implements the smart city MISSION.
- The total number of 100 Smart Cities have been distributed among the States and Union Territories.
- The mission supports Rs.48000 crores over five years (since FY2015-16).

- Often, India organizes the

Smart India Challenge …

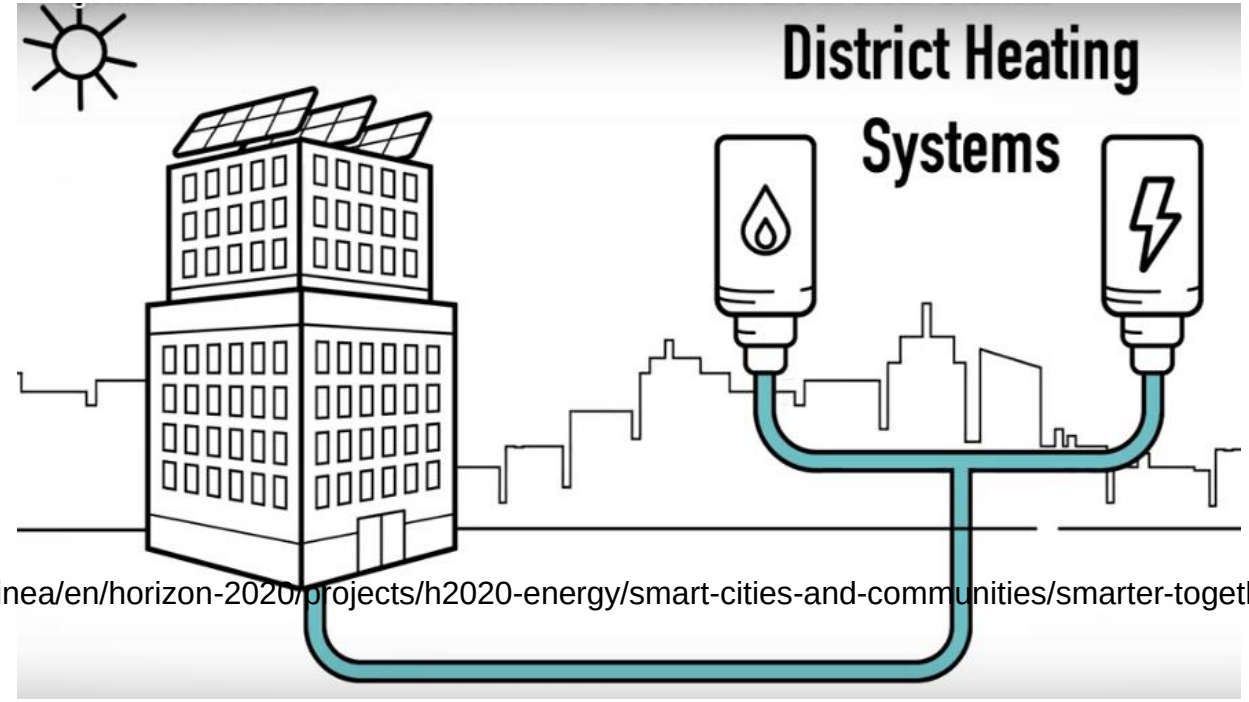
Smart City in Europe

- Smarter Together project of Europe implements SmartCities in Europe.
- Understanding that by 2050 around 70% of population would live in urban cities, Europe has taken measures to implement several smart cities (and, allied solutions).
- Several funding sources have been started via. the funding initiative namely Horizon2020.
- They have targeted a few cities namely
  - Vienna - Austria,
  - Lyon - France
  - Munich – Germany
  - **Zurich, Switzerland**

  ….

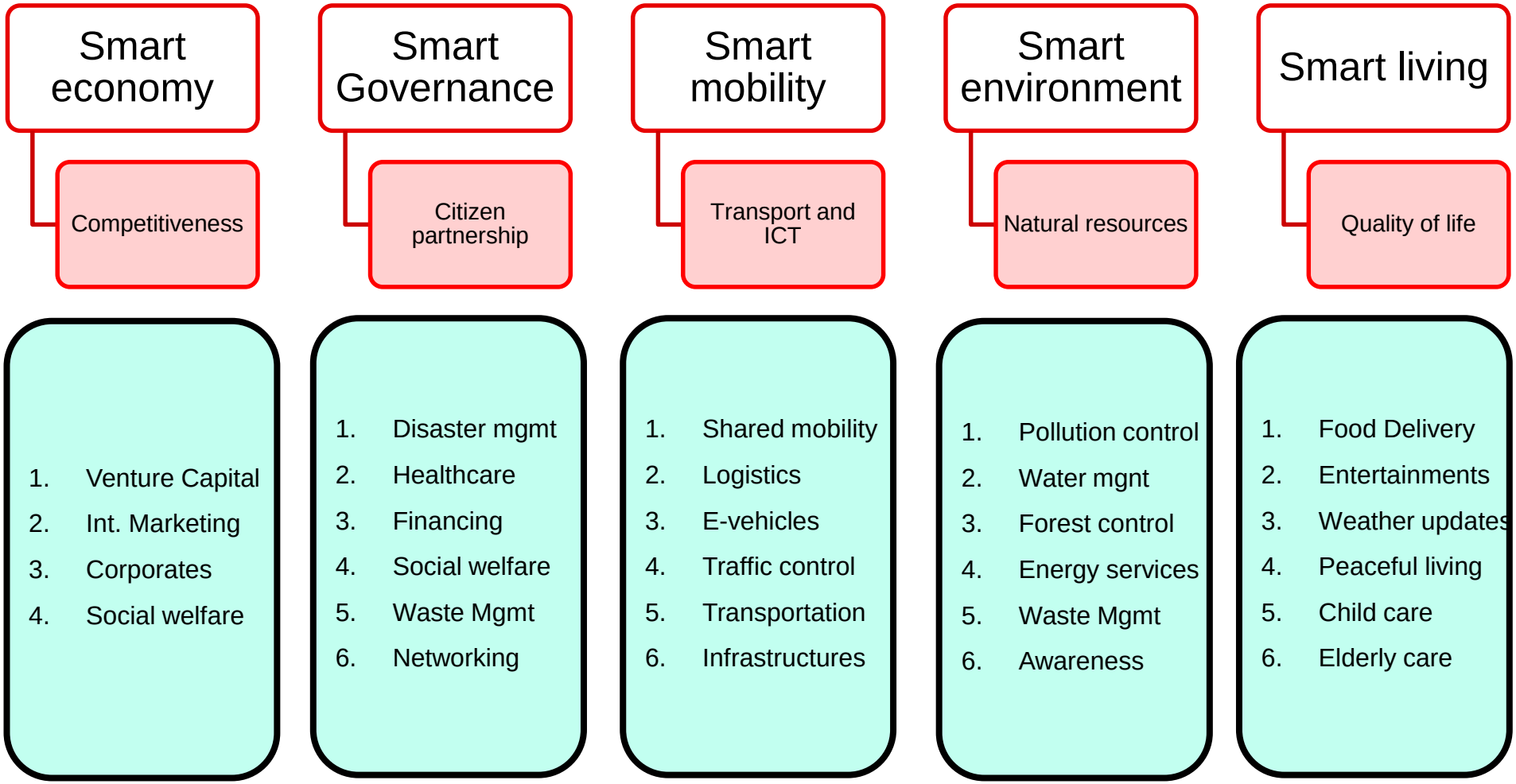
Focus Areas of SmarterTogether

- Citizen engagement – Personal connections
- District heating and renewables (to avoid CO2 emissions)
- Data protection and privacy
- E-mobility

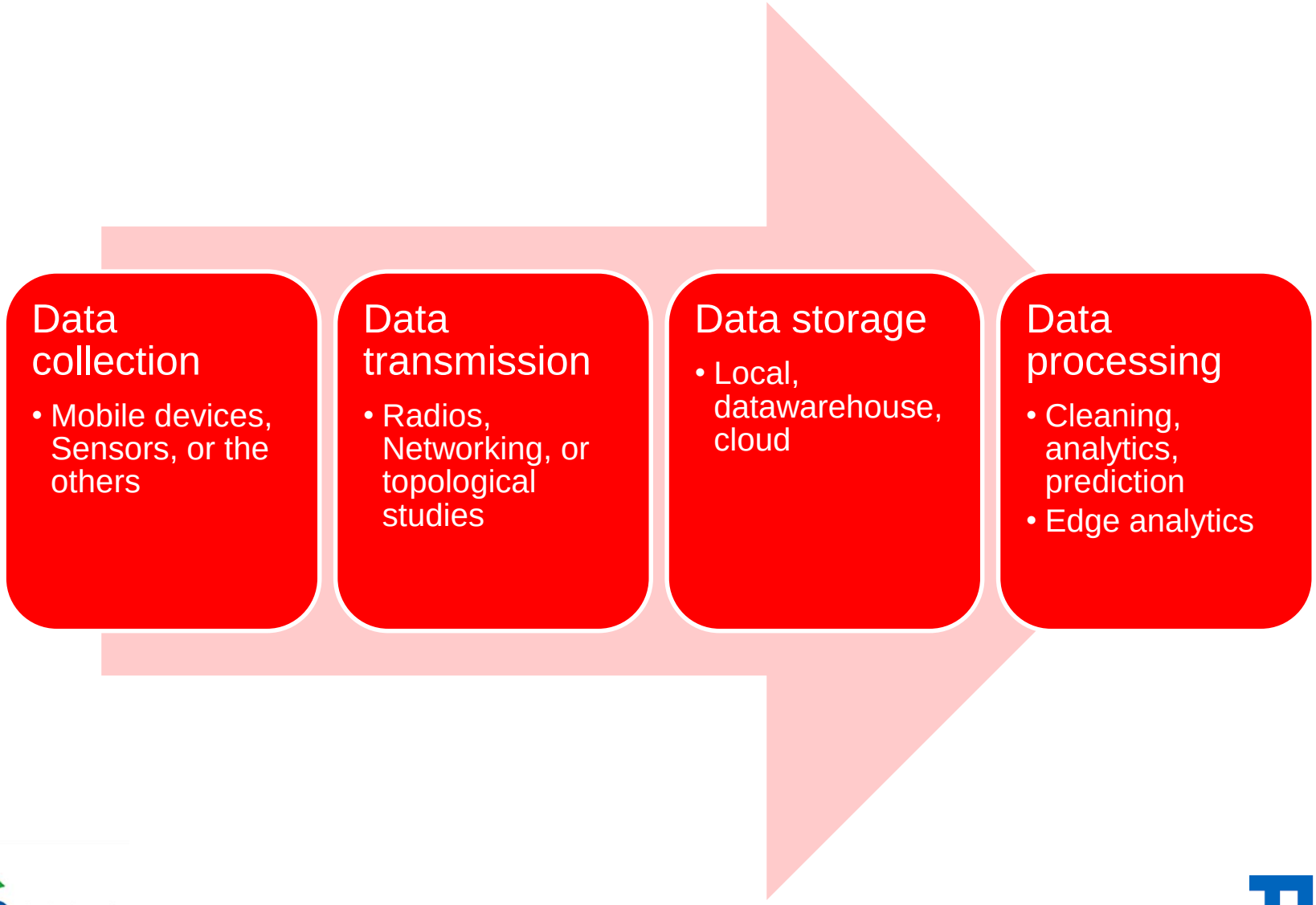


https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/smart-cities-and-communities/smarter-together

Smart City Applications -- Domains



Technological focus areas



Intelligent Transportation System

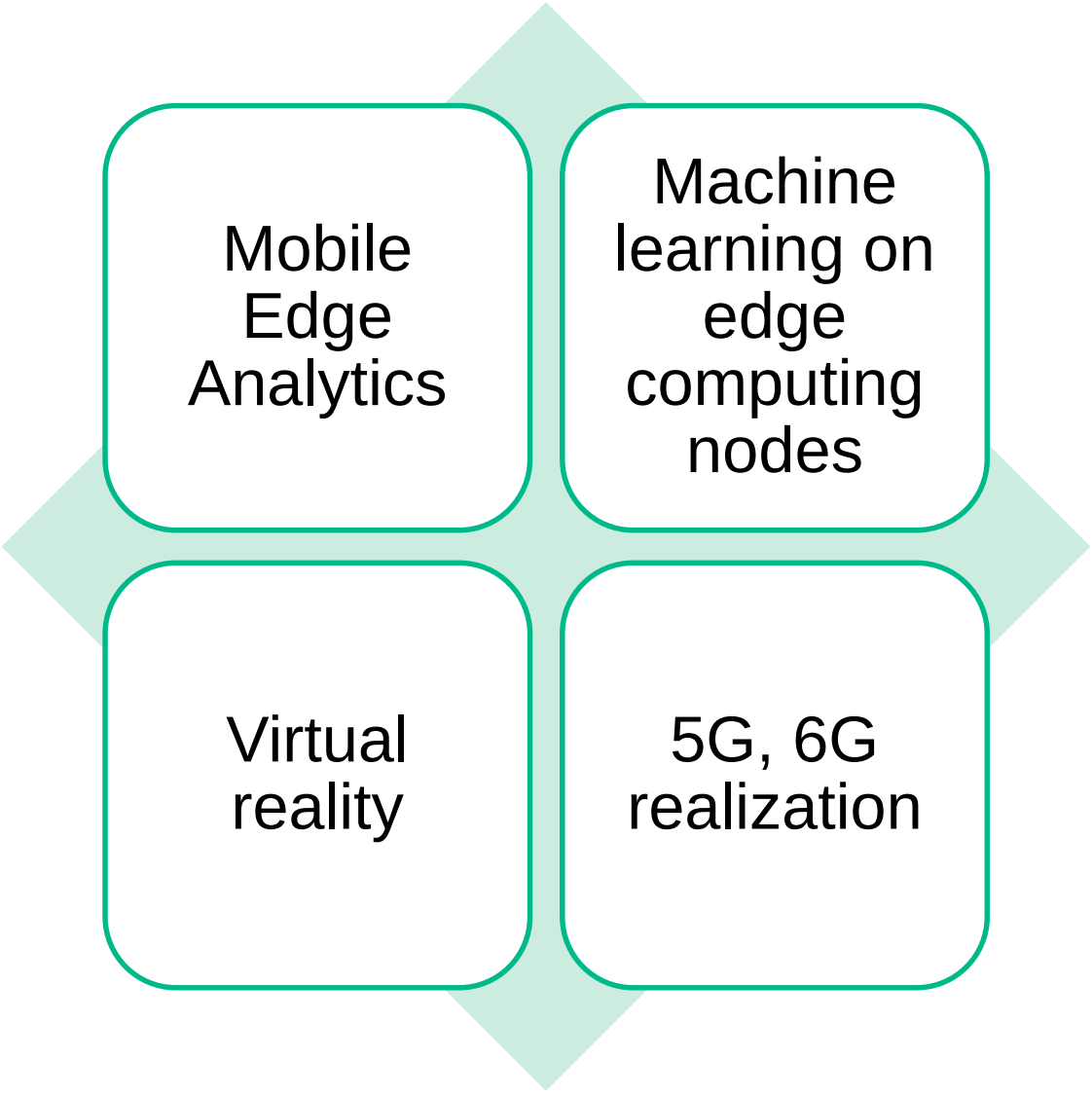
- Intelligent transportation system deals with providing smart transportation…
  - in cities or rural areas.
  - ITS is also applicable in tourism sector.
  - In connected cars.
- In cities
  - Identifying the parking lots
  - Mobilizing ventilators through COVID-19 affected sites.
- ITS in tourism sector
  - To predict the tourism status and availability of hotels
  - To understand the tourism based on a given budget.

ITS -contd

- ITS in connected cars
  - Connected cars and edge assisted mobile applications are getting popular in ITS domain.
  - Quickly identifying the pedestrian passage.
  - Quickly applying brakes and enabling protection systems.
- ITS is utilized for
  - location-based services,
  - destination management systems,
  - carbon calculators,
  - virtual reality

- Zi Yang, Lilian S.C. Pun-Cheng, Vehicle detection in intelligent transportation systems and its applications under varying environments: A review, Image and Vision Computing 69 (2018) 143–154.

ITS key technologies



Remote Healthcare Monitoring…

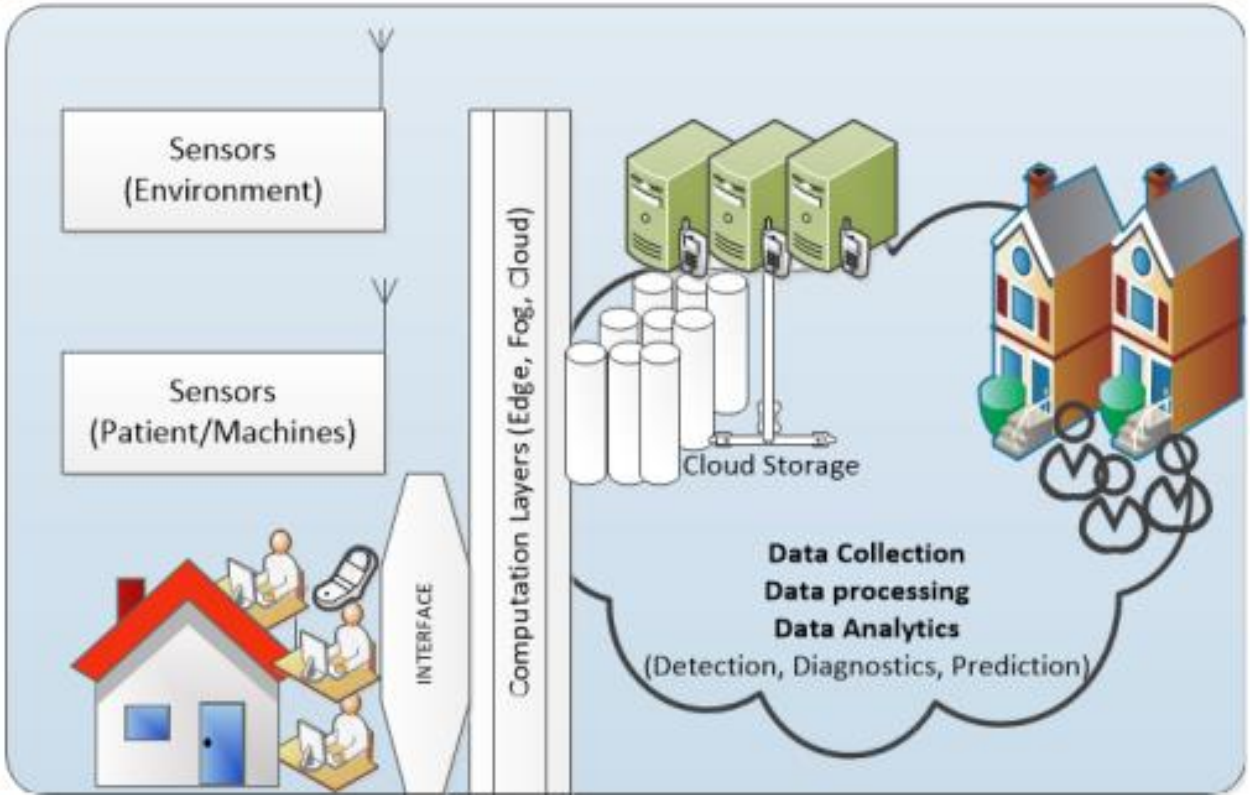
Why Remote health monitoring?

- As the COVID-19 pandemic goes ahead offering a limited accessibility to hospitals, there is a near certainty among patients that they would be proactively prevented from diseases.
- The pandemic created direct and indirect impacts to chronic patients who visit hospitals.
- It leads to several innovations in the recent past…

Shajulin Benedict, IoT-Enabled Remote Monitoring Techniques for Healthcare Applications -- An Overview, in Informatica Journal, Vol. 46, pp. 131--149, DOI: https://doi.org/10.31449/inf.v46i2.3912, 2022.

Healthcare Monitoring Architecture

- User Interface
  - Responsive designs, Interactive bots,
  - Support for multi-factor authentication
- Sensors/Actu..
  - Authenticated
  - Accurate data



Sensors/Actuators

- In-body devices
  - Implantable devices – sensors or actuators
  - E.g, Neurostimulators, cardiac defibrillators, Insulin pumps
  - E.g., cochlear stimulators,
- On-body devices
  - These devices are often attached to bodies.
  - E.g., wrist watches, dresses, rings, adorable devices, or
  - E.g., devices that follow IEEE802.15.4 standards.
  - E.g., accelerometers, gyroscopes (for measuring angular rate).
  - E.g., pedometers, and so forth.
- Portable devices
  - Medical things that are mobile in nature.
  - These devices are often directly connected to the cloud services.
  - E.g., to monitor the heartrate of patients.

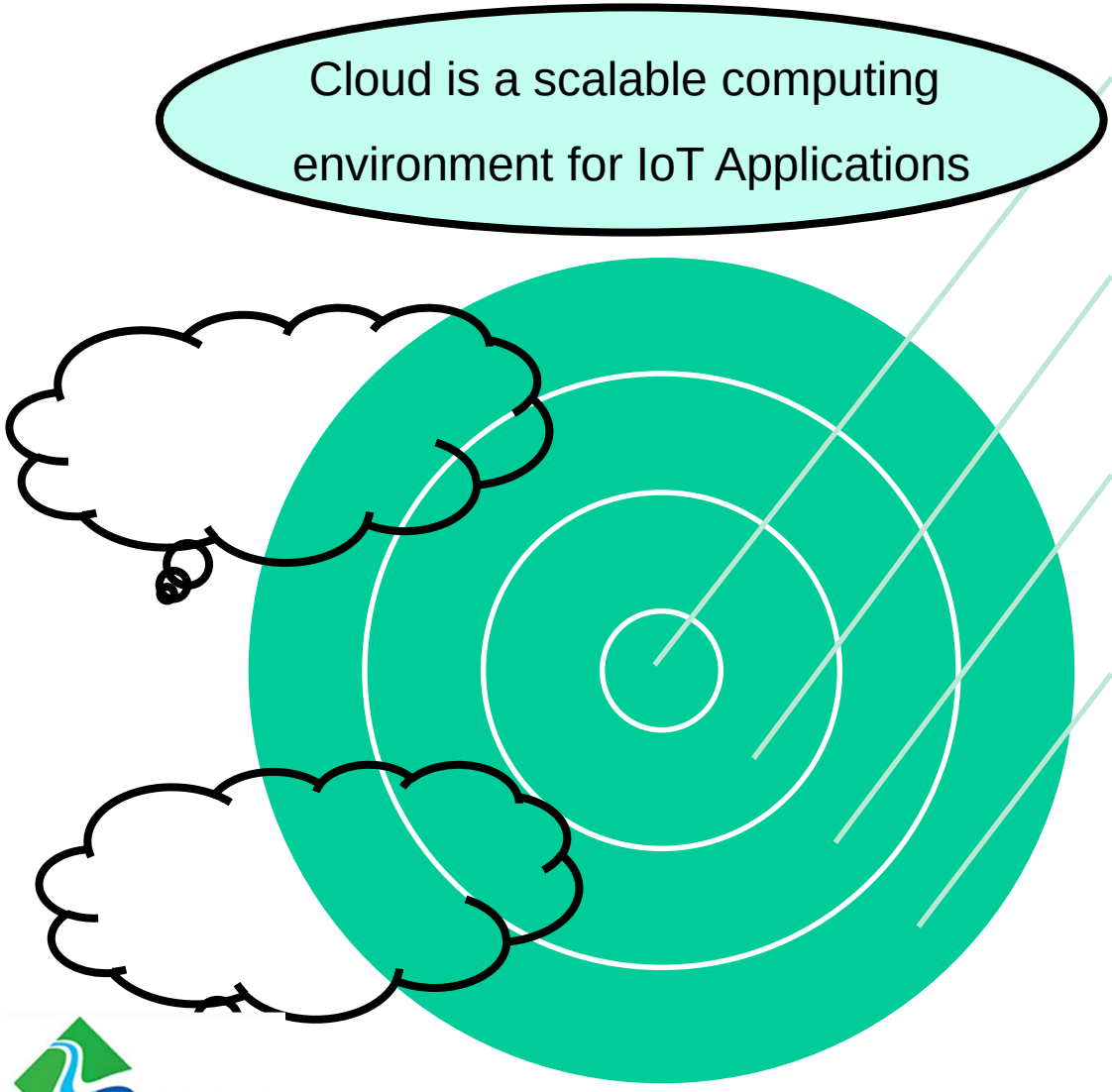
Sensors/Actuators

- Static devices
  - Devices such as temperature sensor or air pollution sensor nodes that are attached to environments such as smart home are denoted as static nodes.
  - E.g., sending alarms or short messages to doctors.
- Ambulatory devices
  - Devices fitted to mobile vehicles such as ambulance.
  - These devices have to consider the real-time delivery of information to hospitals.
  - It has to be error-prone too.
- Hospital devices
  - Sensors that locate medical equipments in hospitals.
  - Sensors attached to hospitals.
  - E.g., patients wanting for medical equipments such as defibrillators, nebulizers, oxygen pumps, and so forth, have to be guided to the nearest available wards in the hospital.

Some Health monitoring sensors

- i) glucose monitors,
- ii) temperature sensors,
- iii) heart-rate monitors,
- iv) Oxygen pulse monitors,
- v) Electromyography sensors (ECG) for heart-care checks,
- vi) wheeze anomaly detection sensors,
- vii) movement disorder checks,
- viii) stress indicator,
- ix) posture indicator,
- x) lung status indicator

Cloud in Practice…(Traditional – A RECAP…)



Performing DL or ML intelligence.

Scalable computing infrastructure

Data mobility – i.e., data could be accessed from any locations.

Cost effectiveness (when compared to owning a machine).

Includes storage costs and computation costs.

Importance of Edge (A RECAP…)

- Edge is a distributed computing technology in which information processing is located close to the things/objects – Gartner.

- To reduce network bandwidth or requirements
- To improve the response time.
- To process local data without transferring them to cloud infrastructures (e.g., video files or face images)
- To improve security and privacy.
- To improve collaborative learning processes.

Remote Health Monitoring Techniques

based on the utilization of different computing systems
(cloud, fog, edge)

based on importance to serve tasks
(critical, periodic, preventive, educational),

based on communications involved
(WIFI, LoRA, 5G)

based on accessibility features
(local vs. global connectivity)

based on the level of intelligence
(descriptive, diagnostic, discovery, predictive, prescriptive)

based on specified focused delivery
(Elderly, Disability, Mentalcare)

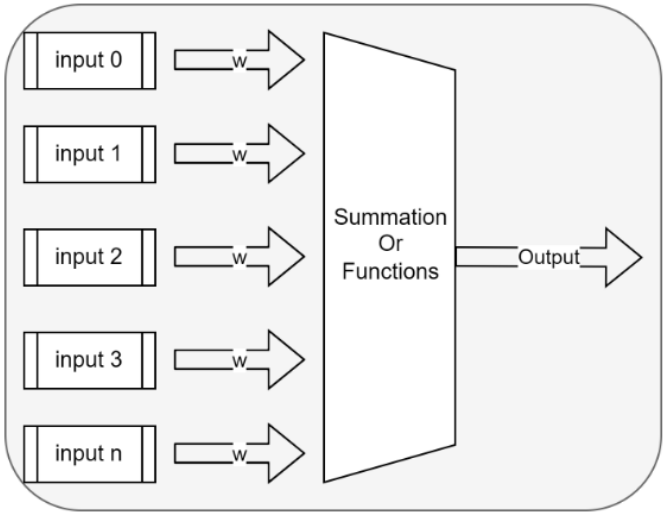
Intelligence for IoT Applications

- Many IoT-enabled remote health monitoring applications utilize computer vision problems or learning inferences. – DL is applied…
- What is deep learning?
  - It is an ML technique that learns features from images, audio, or texts.
  - It is a subset of ML domain.
  - It has more hidden layers to learn the features of data.
- Why DL models?
  - They are more accurate.
  - Specialized hardware or GPU-enabled executions are available – it takes less time.
  - Apt datasets are now available.
  - Many popular models such as CNNs.

Deep Learning Techniques

- CNN – Convolutional Neural Networks
  - A subclass of neural networks.
  - It is applied in computer vision problems.
  - YOLO – You Only Look Once

Shajulin Benedict, Deep Learning Techniques for Social Impact, BOOK, in IOPPublishers, UK (London) , pp. 1 - 264, July 2022.



Single Perceptron

Deep Learning Techniques

- Sentiment analysis problems
  - Document level
  - Sentence level
  - Aspect Level
- Recommendation systems
  - Housing recommendation
  - Hotel recommendation
  - Tourism recommendation
  - Movie recommendation
  - Course recommendation
  - Product recommendation
- LSTM models – Long short term memory models (for sequence prediction problems).

Shajulin Benedict, Deep Learning Techniques for Social Impact, BOOK, in IOPPublishers, UK (London) , pp. 1 - 264, July 2022.

M.G.Christopher, Jiby Maria Jose, Muhammed Nihal K.V., Tijo Thomas, Rumaise, and Shajulin Benedict, CatBoost and Genetic Algorithm Implementations for University Recommendation Systems, in 5th Int. Conf. on Inventive Computation Technologies (IEEE-ICICT2022), India.

Deep Learning Techniques

- Autoencoders
  - Autoencoder is a deep learning technique that applies data encoding methods to convert the higher dimensional data/image to a lower-dimensional data/image in a compressed form.
  - Applications
    - Image reconstruction
    - Image colorization
    - High resolution image generation

Shajulin Benedict, Deep Learning Techniques for Social Impact, BOOK, in IOPPublishers, UK (London) , pp. 1 - 264, July 2022.

- GANs – Generative Adversarial Networks
  - Generative Adversarial Networks (GAN) are unsupervised learning methods of machine learning domains.
  - Here, generative and descriptive models are utilized to train by the networks (on its own). E.g., styleGANs.

Deep Learning Techniques

- Deep reinforcement learning
  - Agents and reward approach.
  - Applications
    - Autonomous driving
    - Robotics
    - Gaming sector

Shajulin Benedict, Deep Learning Techniques for Social Impact, BOOK, in IOPPublishers, UK (London) , pp. 1 - 264, July 2022.

DL USES – Tensorflow or PyTorch frameworks

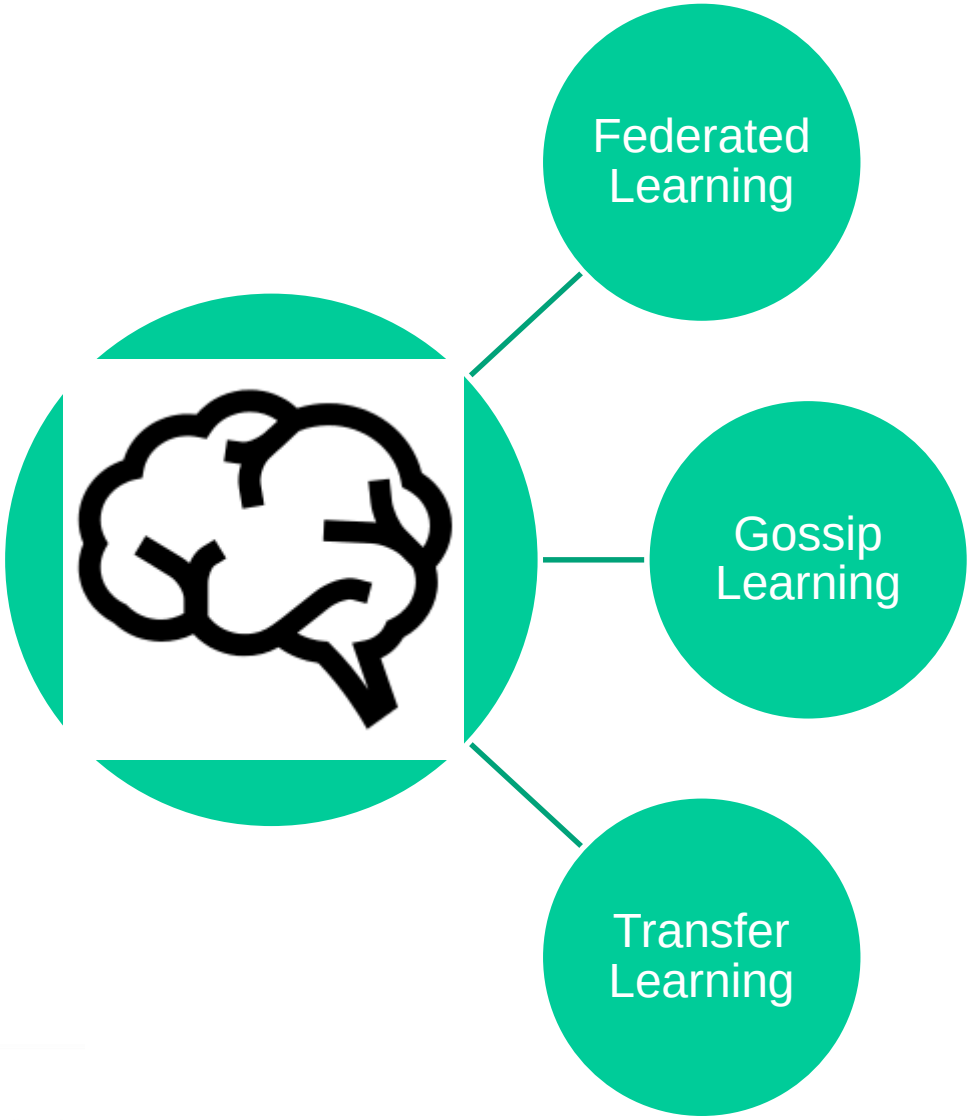
The birth to TinyML

- TinyML is a subfield of ML.
- It aims at performing the learning or intelligence in edge nodes.
- It tries to reduce the DL networks so that the layers fit with tiny devices.

- Hardware:
  - Many microcontrollers or embedded devices.
- Software:
  - Tensorflowlite
  - Python/C++

TinyML Book by Pete Warden Oreilly Publishers

Edge – Learning Techniques



Edge Learning

Techniques

Using

Edge nodes

(Jetson Nano)

(RasperryPI)

(ESP)

(CorelDev)

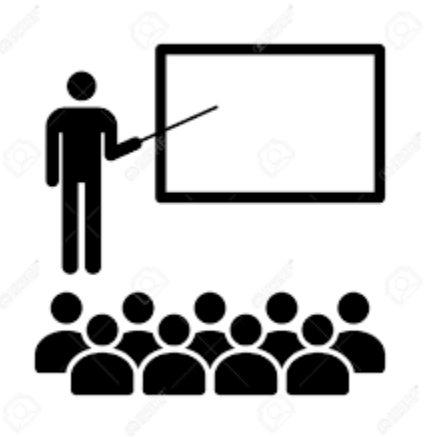
Edge Intelligence – Learning Techniques

- Federated Learning
  - Collaborative learning approach (master – worker approach)
  - An algorithm is trained on decentralized edge devices using local datasets.
  - (Note: Master aggregates model without knowing the local data).

- Gossip Learning
  - It applies decentralized approach of using threads to create models in parallel.
  - It aims at reducing the modeling time.
  - (for e.g., applying gradient decent search in parallel while creating the model).
  - Usually, it uses MPI or similar programming models to create the model.

Edge Intelligence – Learning Techniques

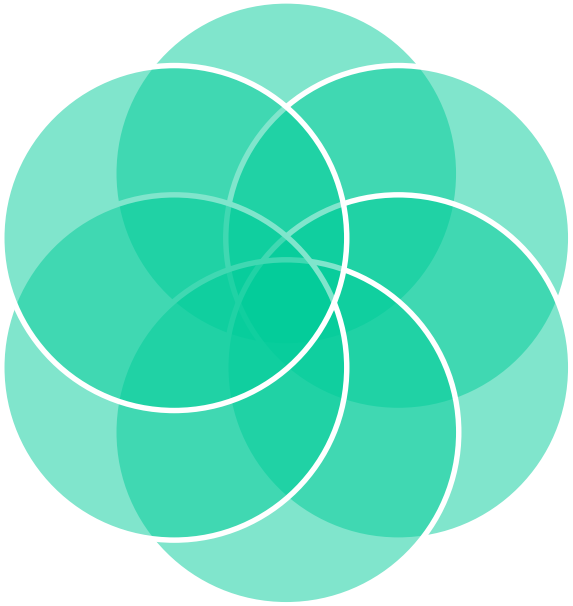
- Transfer Learning
  - Type-I: It uses the knowledge gained from one model based on specific dataset to another learning task (for another data).
    - Typically, it is applied when edge nodes are not willing to learn certain things from scratch.
    - E.g., learn apples from the learned models of fruits.
  - Type-II: It transfers models to mobile nodes for quick learning with local datasets.



Edge Intelligence – Improvement Techniques

Performance Improvement Methods in Edge Intelligence

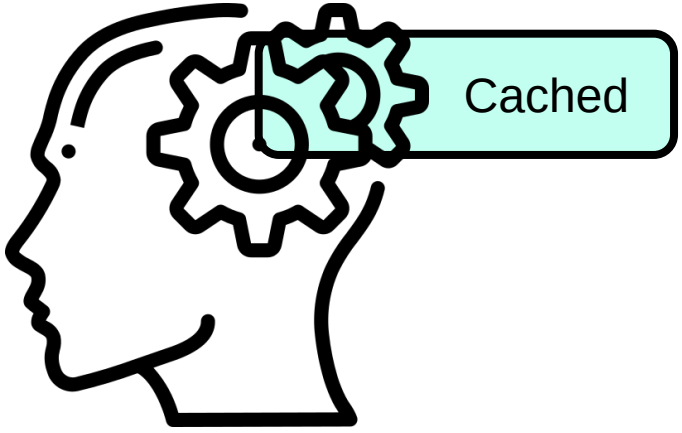
- Edge caching
- DNN splitting
- Model compression
- Service placements
- Edge offloading
- Training/Inference acceleration



Indian Institute of Information Technology Kottayam

Edge Intelligence – Improvement methods

- Edge Caching
  - Providing data proximity to end users or training models.
  - It attempts to keep track of the frequent requests for computations or frequent data uploaded to IoT-enabled applications.
  - For e.g., travelers want to learn about the tourism spot by capturing images (most of the time, the data remains the same).
  - Research Problem: Where do you want to cache?



Edge Intelligence – Improvement methods

- Model compression
  - Models considerably increase memory size and computing power. (including energy consumption).
  - To implement models on battery-constrained edge nodes, model compressions are performed.
  - *Constraint:* Not to reduce the accuracy.
  - *Some techniques*
    - Low rank approximation or Matrix factorization
    - Knowledge distillation (based on transfer learning)
      - i.e., distills some knowledge from bigger model and apply them to local learning network.
      - Teacher-student model
    - Layer Reduction
      - E.g., DNN pruning (less weighted neurons are removed)
    - Parameter quantization (not all parameters are required).

Tensorflow Lite

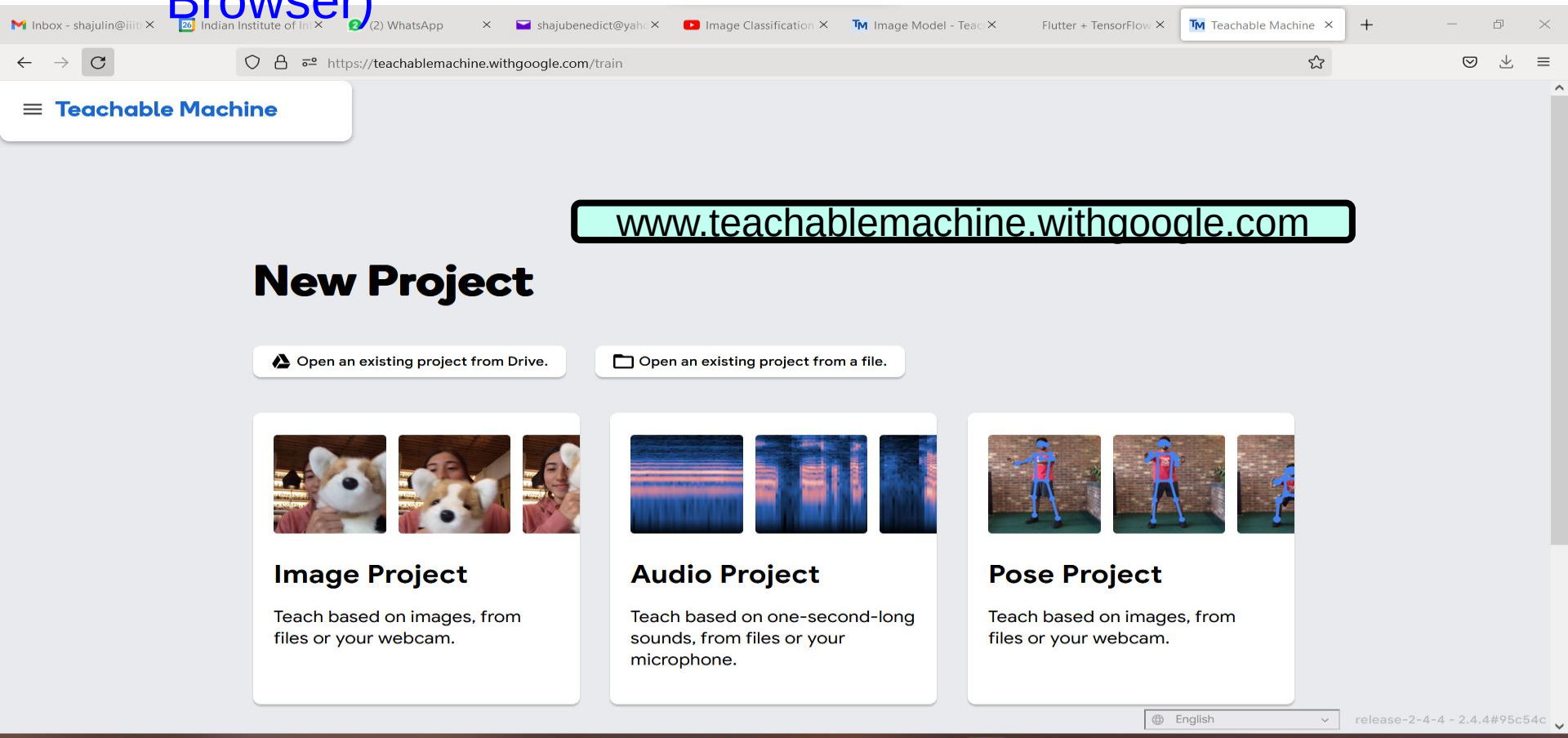
- Learning models can be very large and time-consuming.
- Tensorflowlite allows the learning process (or, creating models) in small computers/devices.
  - E.g., mobile phones, (Tensorflow Mobile exists now!)
  - Arduino boards
  - Sparkfun boards
  - ESP32,
  - CorelAI,
  - Jetson Nano,
  - and so forth.
- It enables offline inferences.
- It is an opensource DL framework for small devices.

Tensorflow Lite -- Steps

- Develop a model
  - Train using data.
- Convert the model to compressed *.tflite* files.
  - It consists of information about model with checkpoints.
- Deploy the model to embedded devices.
- Optimize and Run.
  - On android, ios, or embedded devices or microcontrollers.

Developing Models – Teachable ML

- Google offers teachable ML platform to train images or sound using their services.
- It is a web-based tool for creating models (ML via. Browser)

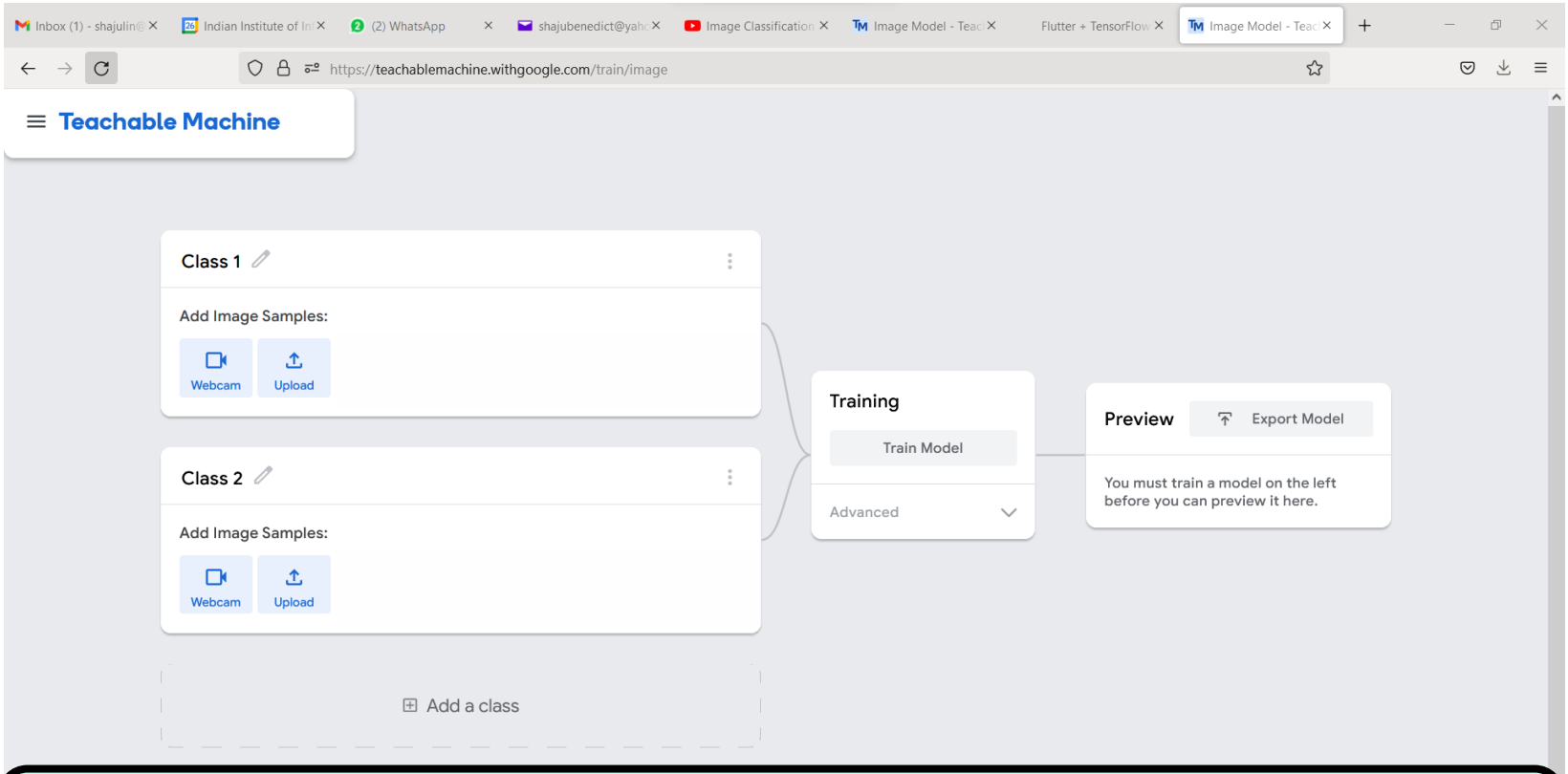


Developing Models – Teachable ML

Develop models such that …

- You can **classify audio samples** based on user specifications of classes.
- You can **classify images** (or webcam streams) based on user-specified classes.
- You can **classify human poses** based on user-specified classes.

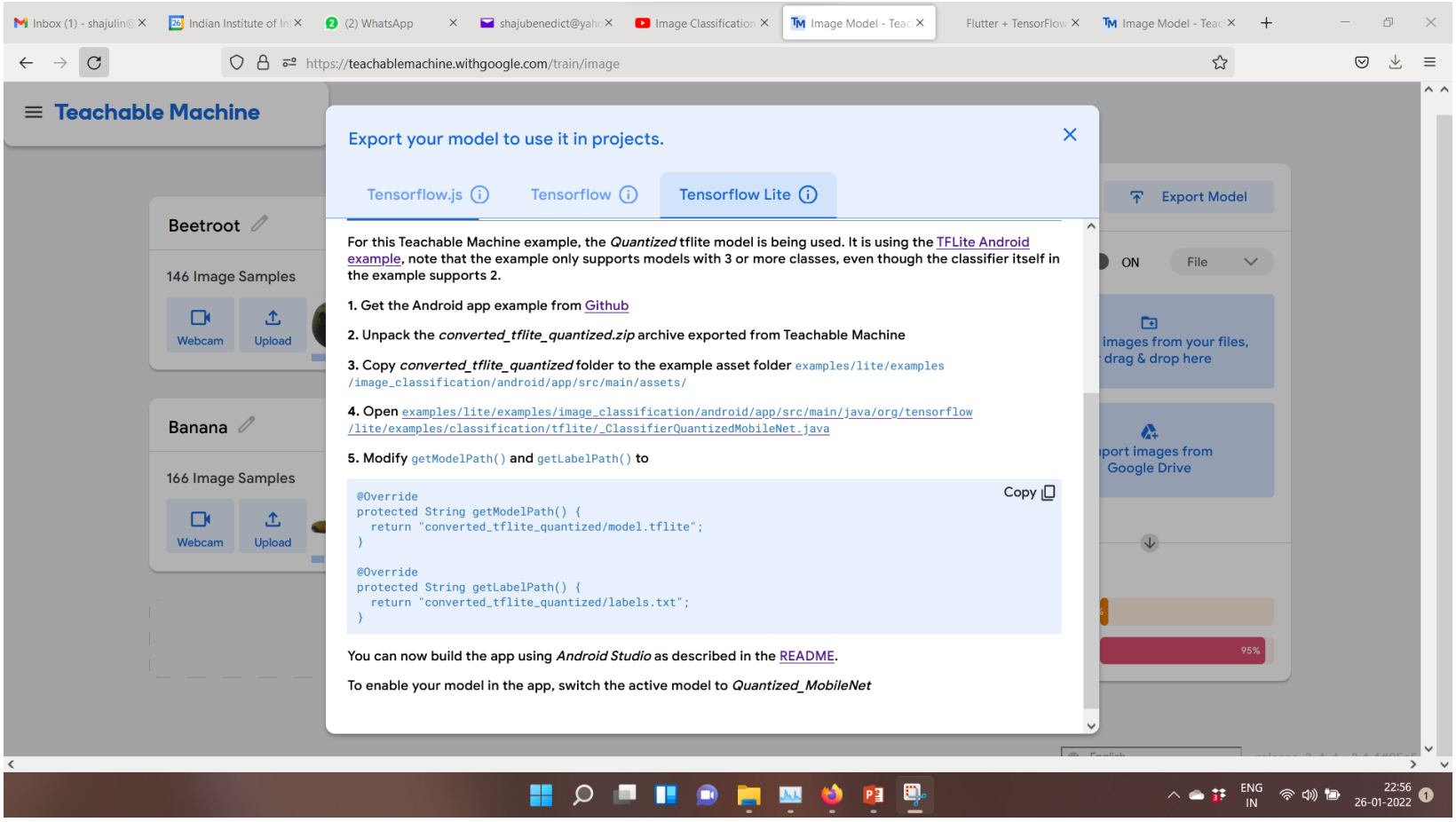
Developing Models



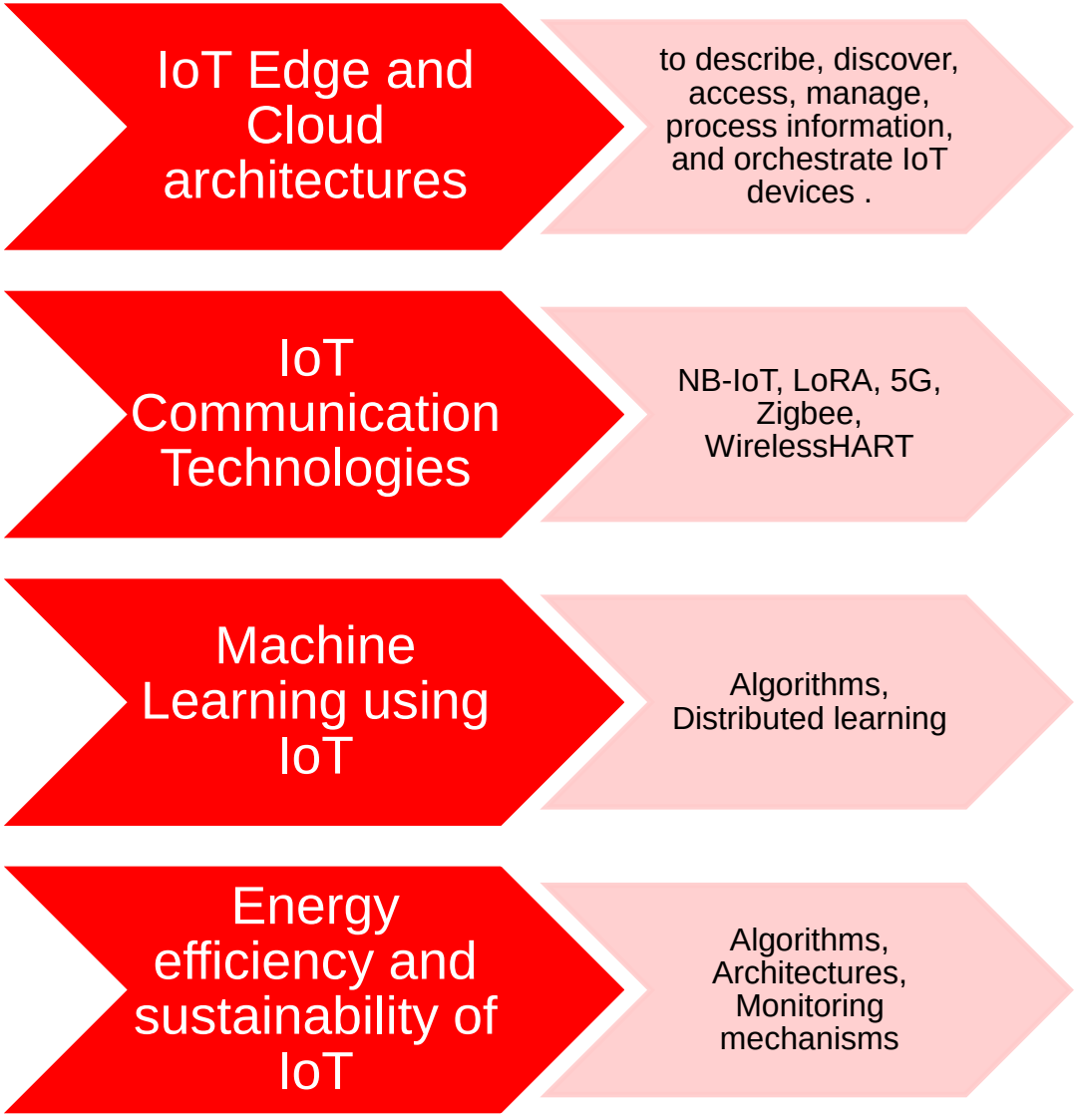
Train and Preview

Webcam may be utilized for uploading images.

Download the Model for Edge nodes



Research Directions



Research Directions

Applications

- Societal,
- Industrial
- City
- Agricultural
- Healthcare,
- Logistics/Supply Chain Management

Data visualization

- Robust information sharing
- Visualization effects

Security, Privacy, Trust

- Insecure ?
- Privacy and policies?
- Trust mechanisms

Our Incubation Centres -- Possible Funding

- MSME-BI-IIITKottayam
  - Eligible business ideas could attract Rs. 15 lakhs per idea.
  - An approved MSME incubation centre could support 10 business ideas per year.

- AIC-IIITKottayam
  - Nodal centres
  - Focusses on startups
  - Supported startups (if successful) will be promoted to attr Rs. 1 crore through our network of investors.

IoT-CSP

MSME-BI
IIIT Kottayam
Innovations Booster

Indian Institute of Information Technology Kottayam

Possible Collaborations

- Joint product development (IoT cloud)
- Joint events (hackathon or product expo)
- Joint marketing / sales
- Consultancy for startups
- MoU between startups/corporates.
- Joint editorial
- Joint publications in leading journals

www.sbenedictglobal.com

IoT-CSP
MSME-BI
IIIT Kottayam
Innovations Booster
Indian Institute of Information Technology Kottayam

Further contacts…

- For Startup or Innovation programs, contact us…
- Contacts:
  - shajulin@iiitkottayam.ac.in
  - www.sbenedictglobal.com
- Starting or scaling up a business on IoT Cloud?
  - Visit us @ http://icentre.iiitkottayam.ac.in or http://msme.iiitkottayam.ac.in
- Invitation:::
  - We invite institutes to join incubation centres of IIITKOTTAYAM as NODAL centre…
  - Joint events
  - Joint entrepreneurial developments
  - Write to us at incubate@iiitkottayam.ac.in or shajulin@iiitkottayam.ac.in