NPTEL ONLINE CERTIFICATION COURSES

Cloud Computing

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Module 12: Cloud Computing Paradigms
Lecture 56: Cloud Computing in 5G Era

CONCEPTS COVERED

- 5G Network
- Cloud Computing in 5G

KEYWORDS

- Spatial Data
- Spatial Cloud Computing

Cloud Computing in 5G

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5G Network

- 5G is the 5th generation mobile network. It is a new global wireless standard after 1G, 2G, 3G, and 4G networks. 5G enables a new kind of network that is designed to connect virtually everyone and everything together including machines, objects, and devices.
- 5G wireless technology is meant to deliver higher multi-Gbps peak data speeds, ultra low latency, more reliability, massive network capacity, increased availability, and a more uniform user experience to more users. Higher performance and improved efficiency empower new user experiences and connects new industries.

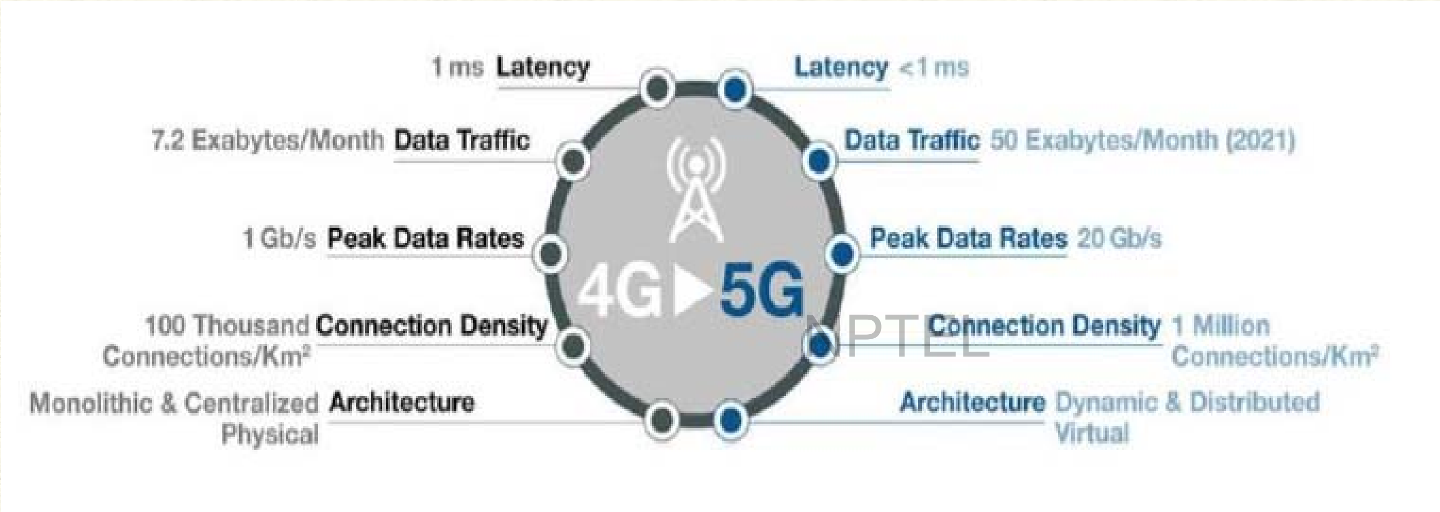
Different Generations

- **First generation - 1G -** 1980s: 1G delivered analog voice.
- **Second generation - 2G -** Early 1990s: 2G introduced digital voice (e.g. CDMA- Code Division Multiple Access).
- **Third generation - 3G -** Early 2000s: 3G brought mobile data (e.g. CDMA2000).
- **Fourth generation - 4G LTE -** 2010s: 4G LTE ushered in the era of mobile broadband.
- 1G, 2G, 3G, and 4G all led to **5G**, which is designed to provide more connectivity than was ever available before.
- **5G** is a unified, more capable air interface. It has been designed with an extended capacity to enable next-generation user experiences, empower new deployment models and deliver new services.
- With high speeds, superior reliability and negligible latency, 5G is all set to expand the mobile ecosystem into new realms.
- 5G will impact Cloud Computing paradigm in a big way.

Evolution of Mobile Networks

	1G	2G	3G	4G	5G
Approximate deployment date	1980s	1990s	2000s	2010s	2020s
Theoretical download speed	2kbit/s	384kbit/s	56Mbit/s	1Gbit/s	10Gbit/s
Latency	N/A	629 ms	212 ms	60-98 ms	< 1 ms

4G vs 5G Features



Use of 5G

- 5G is that it is designed for forward compatibility—the ability to flexibly support future services.
- 5G is used across three main types of connected services.
- **Enhanced mobile broadband**
  In addition to making our smartphones better, 5G mobile technology can usher in new immersive experiences such as VR and AR with faster, more uniform data rates, lower latency, and lower cost-per-bit.
- **Mission-critical communications**
  5G can enable new services that can transform industries with ultra-reliable, available, low-latency links like remote control of critical infrastructure, vehicles, and medical procedures.
- **Massive IoT**
  5G is meant to seamlessly connect a massive number of embedded sensors in virtually everything through the ability to scale down in data rates, power, and mobility—providing extremely lean and low-cost connectivity solutions.

5G Network - Features

- **Enhanced mobile broadband (eMBB)** – enhanced indoor and outdoor broadband, enterprise collaboration, augmented and virtual reality.
- **Massive machine-type communications (mMTC)** – IoT, asset tracking, smart agriculture, smart cities, energy monitoring, smart home, remote monitoring.
- **Ultra-reliable and low-latency communications (URLLC)** – autonomous vehicles, smart grids, remote patient monitoring and telehealth, industrial automation.

5G and Cloud Computing

- 5G is the perfect companion to cloud computing both in terms of its distribution and the diversity of compute and storage capabilities.
- On-premises and edge data centers will continue to close the gap between resource-constrained low-latency devices and distant cloud data centers, leading to driving the need for heterogeneous and distributed computing architectures.
- In this evolving computing paradigm, service providers should look to provide full end-to-end orchestration, with defined service layer agreements, in a self-service and automated way.
- *Network as a Platform* for enterprise services
- Service orchestration will play a key role moving forward, enabling industrial applications to interact with the network resources in advanced ways such as selecting location, quality of service, or influencing the traffic routing to deliver on application demands.

5G and Cloud Computing

- Two key aspects in the relationship between 5G technologies and cloud computing.
  - First, further development of cloud computing has to meet the 5G needs. This is reflected by growing roles of edge, mobile edge, and fog computing in the cloud computing realm.
  - Second aspect is that 5G technologies are undergoing "cloudification" through network "softwarization", NFV, SDN, etc.
  - Both technology types influence the developments of each other.
- 5G deployments bring up discussions about the convergence of computing, cloud, and IoT that takes us to the era of hyper-connectivity.

Edge Computing in 5G

- 5G is the next generation cellular network that aspires to achieve substantial improvement on quality of service, such as higher throughput and lower latency.
- Edge computing is an emerging technology that enables the evolution to 5G by bringing cloud capabilities near to the end users (or user equipment, UEs) in order to overcome the intrinsic problems of the traditional cloud, such as high latency etc.
- Edge computing is preferred to cater for the wireless communication requirements of next generation applications, such as augmented reality and virtual reality, which are interactive in nature.
  - These highly interactive applications are computationally-intensive and have high quality of service (QoS) requirements, including low latency and high throughput.
  - Further, these applications are expected to generate a massive amount

Edge Computing in 5G

- 5G is expected to cater following needs of today's network traffic
  - Handle massive amount of data is generated by mobile devices/ IoTs
  - Stringent QoS requirements are imposed to support highly interactive applications, requiring ultra-low latency and high throughput
  - Heterogeneous environment must be supported to allow inter-operability of a diverse range of end-user equipment, QoS requirements, network types etc.

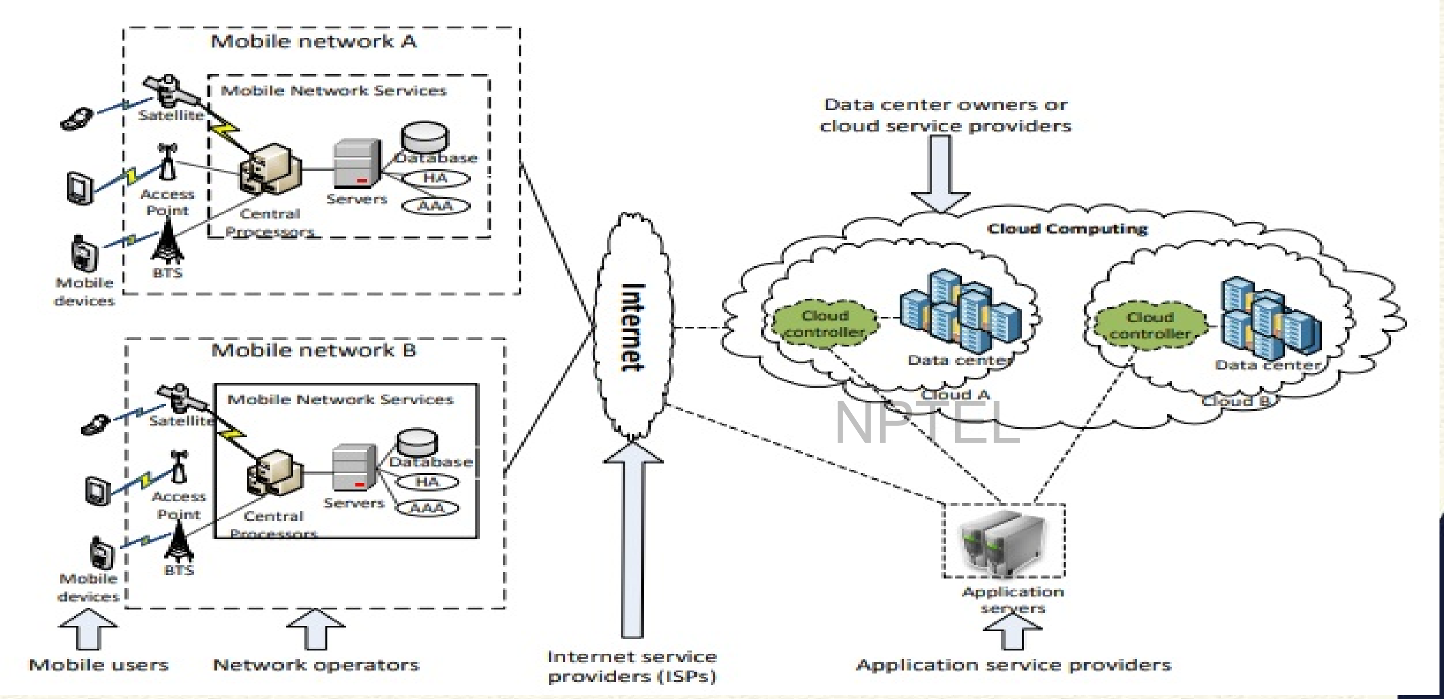
Edge Computing in 5G - Applications

- Healthcare
- Entertainment and multimedia applications
- Virtual reality, augmented reality, and mixed reality
- Tactile internet
- Internet of Things
- Factories of the future
- Emergency response
- Intelligent Transportation System

5G and Mobile Cloud Computing (MCC)

- MCC is a cloud computing system including mobile devices and delivering applications to the mobile devices.
- Key features of MCC for 5G networks include sharing resources for mobile applications and improved reliability as data is backed up and stored in the cloud.
- As data processing is offloaded by MCC from the devices to the cloud, fewer device resources are consumed by applications.
- Compute-intensive processing of mobile users' requests is off-loaded from mobile networks to the cloud. Mobile devices are connected to mobile networks via base stations (e.g., base transceiver station, access point, or satellite).

Mobile Cloud Computing (MCC)



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Thank you

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Cloud Computing

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Module 12: Cloud Computing Paradigms

Lecture 57: CPS and Cloud Computing

CONCEPTS COVERED

- Cyber Physical System (CPS)
- CPS and Cloud Computing

KEYWORDS

- Cyber Physical System (CPS)

CPS and Cloud Computing

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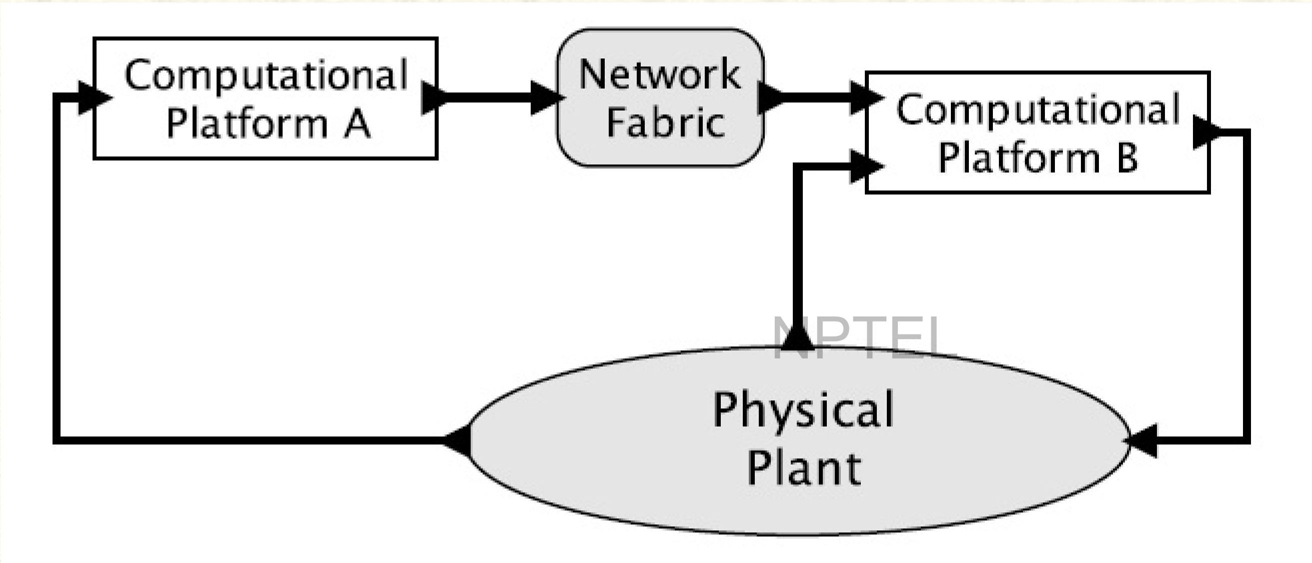
Cyber-Physical System (CPS)

- A cyber-physical system (CPS) is an orchestration of computers and physical systems. Embedded computers monitor and control physical processes, usually with feedback loops, where physical processes affect computations and vice versa.
- The term “cyber-physical systems” emerged around 2006, when it was coined by Helen Gill at the National Science Foundation , USA
- CPS is about the intersection, not the union, of the physical and the cyber. It combines engineering models and methods from mechanical, environmental, civil, electrical, biomedical, chemical, aeronautical and industrial engineering with the models and methods of computer science.
- Applications of CPS include automotive systems, manufacturing, medical devices, military systems, assisted living, traffic control and safety, process control, power generation and distribution, energy conservation etc.

Cyber-Physical System (CPS)



Cyber-Physical System (CPS)

- CPS describes a broad range of complex, multi-disciplinary, physically-aware next generation engineered system that integrates embedded computing technologies (cyber part) into the physical world.
- In cyber-physical systems, physical and software components are deeply intertwined, able to operate on different spatial and temporal scales, exhibit multiple and distinct behavioral modalities, and interact with each other in ways that change with context.
- CPS involves transdisciplinary approaches, merging theory of cybernetics, mechatronics, design and process science.
- Cyber + Physical + Computation + Dynamics + Communication + Security + Safety

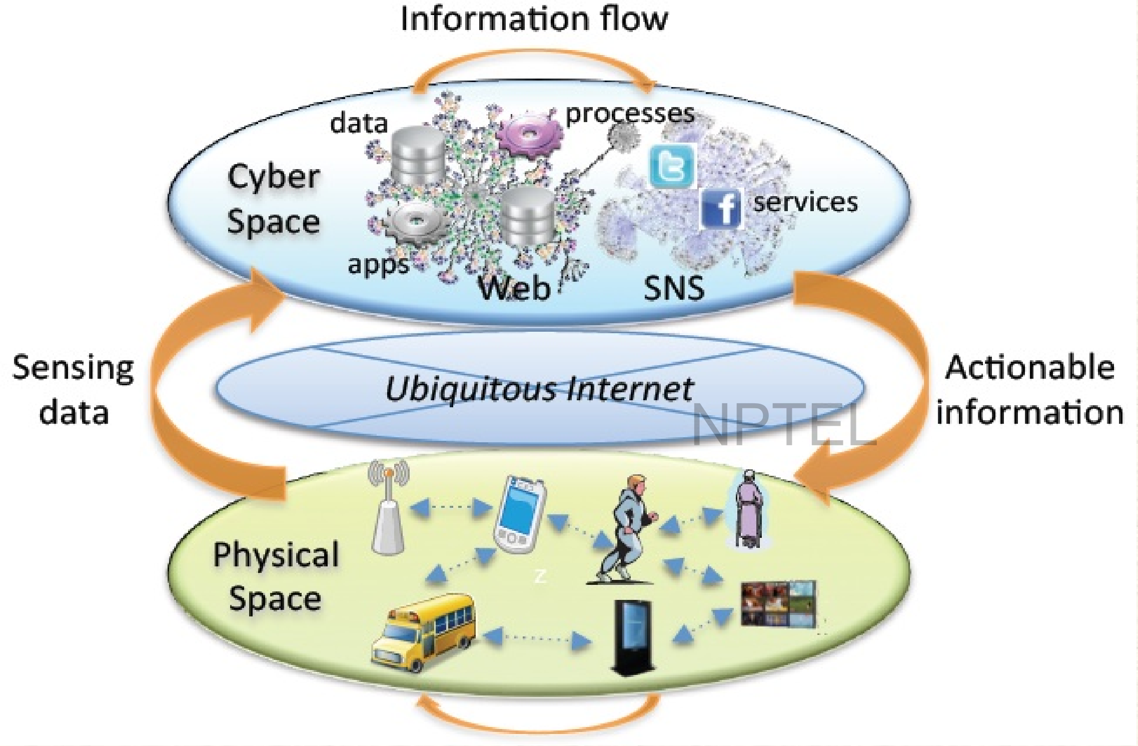
Cyber-Physical System (CPS)

- Cyber physical systems (CPS) are an emerging discipline that involves engineered computing and communicating systems interfacing the physical world.
- Ongoing advances in science and engineering improve the tie between computational and physical elements by means of intelligent mechanisms, increasing the adaptability, autonomy, efficiency, functionality, reliability, safety, and usability of cyber-physical systems.
- Potential applications of cyber-physical systems are in several areas, including: *intervention* (e.g., collision avoidance); *precision* (e.g., robotic surgery and nano-level manufacturing); *operation in dangerous or inaccessible environments* (e.g., search and rescue, firefighting, and deep-sea exploration); *coordination* (e.g., air traffic control, war fighting); *efficiency* (e.g., zero-net energy buildings); and *augmentation of human capabilities* (e.g. in healthcare monitoring and delivery).
- Typical examples of CPS include : smart grid, autonomous automobile systems, medical monitoring, industrial control systems, robotics systems, and automatic pilot avionics.

Cyber-Physical System (CPS)

- The interlinked networks of sensors, actuators and processing devices create a vast network of connected computing resources, things and humans.
- A CPS is the "integration of computation with physical processes" and uses sensors and actuators to link the computational systems to the physical world.
- CPS can be viewed as "computing as a physical act" where the real world is monitored through sensors that transfer sensing data into the cyberspace where cyber applications and services use the data to affect the physical environment
- ***Cloud Computing Services*** provide a flexible platform for realizing the goals of CPS

Cyber-Physical System (CPS)

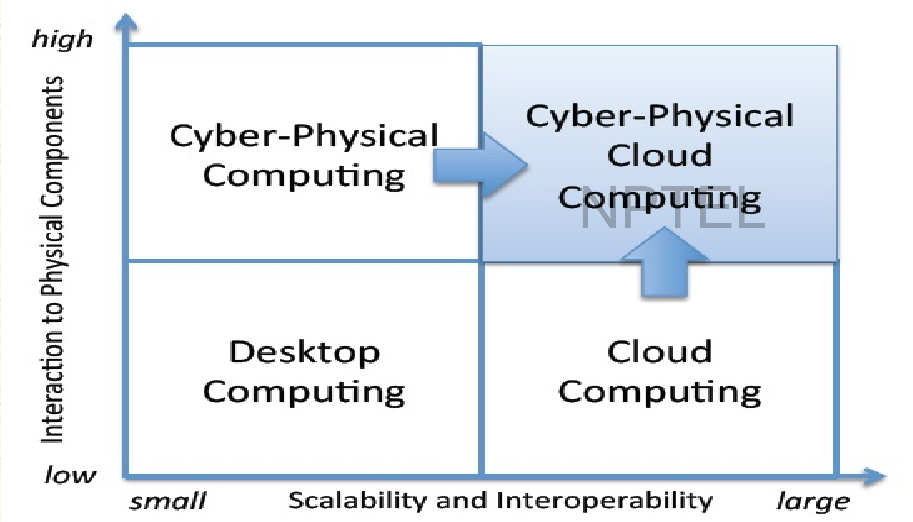


Cyber-Physical System (CPS)

- The interlinked networks of sensors, actuators and processing devices create a vast network of connected computing resources, things and humans that we will refer to as a Smart Networked Systems and Societies (SNSS).
- A CPS is the "integration of computation with physical processes" and uses sensors and actuators to link the computational systems to the physical world.
- CPS can be viewed as "computing as a physical act" where the real world is monitored through sensors that transfer sensing data into the cyberspace where cyber applications and services use the data to affect the physical environment
- ***Cloud Computing Services*** provide a flexible platform for realizing the goals of CPS
- A Cyber-Physical Cloud Computing (CPCC) architectural framework is defined as "a system environment that can rapidly build, modify and provision cyber-physical systems composed of a set of cloud computing based sensor, processing, control, and data services."

CPS and Cloud - Cyber-Physical Cloud Computing (CPCC)

- A Cyber-Physical Cloud Computing (CPCC) architectural framework can be defined as "a system environment that can rapidly build, modify and provision cyber-physical systems composed of a set of cloud computing based sensor, processing, control, and data services."

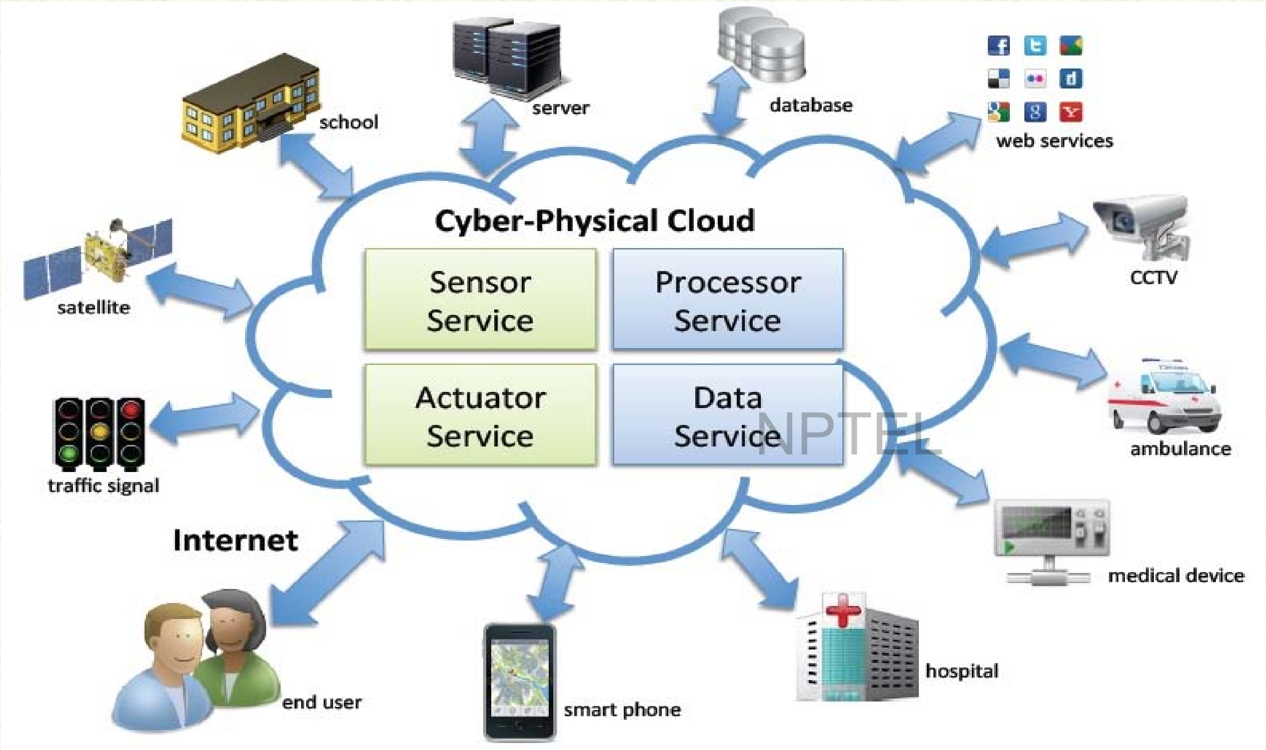


Ref: A Vision of Cyber-Physical Cloud Computing for Smart Networked Systems, NIST Report NIST, USA, August 2013

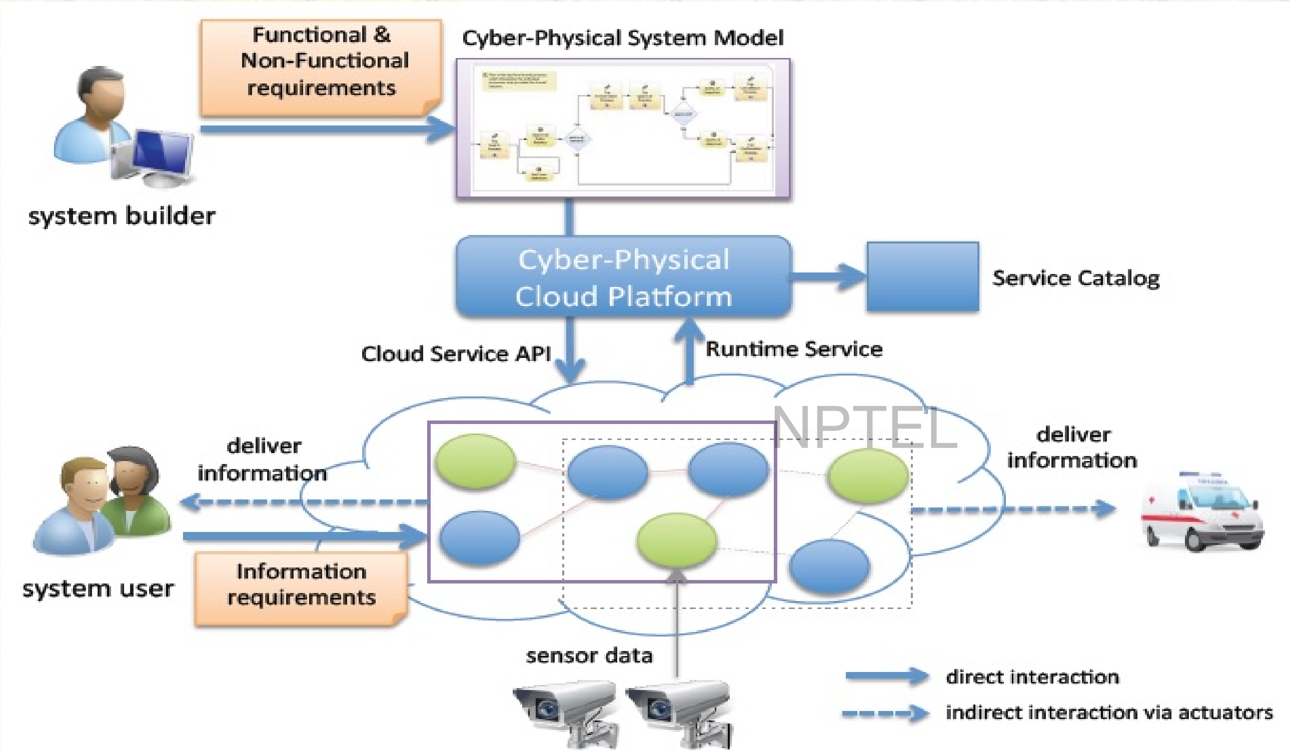
CPCC Benefits

- Efficient use of resources
- Modular composition
- Rapid development and scalability
- Smart adaptation to environment at every scale
- Reliable and resilient architecture

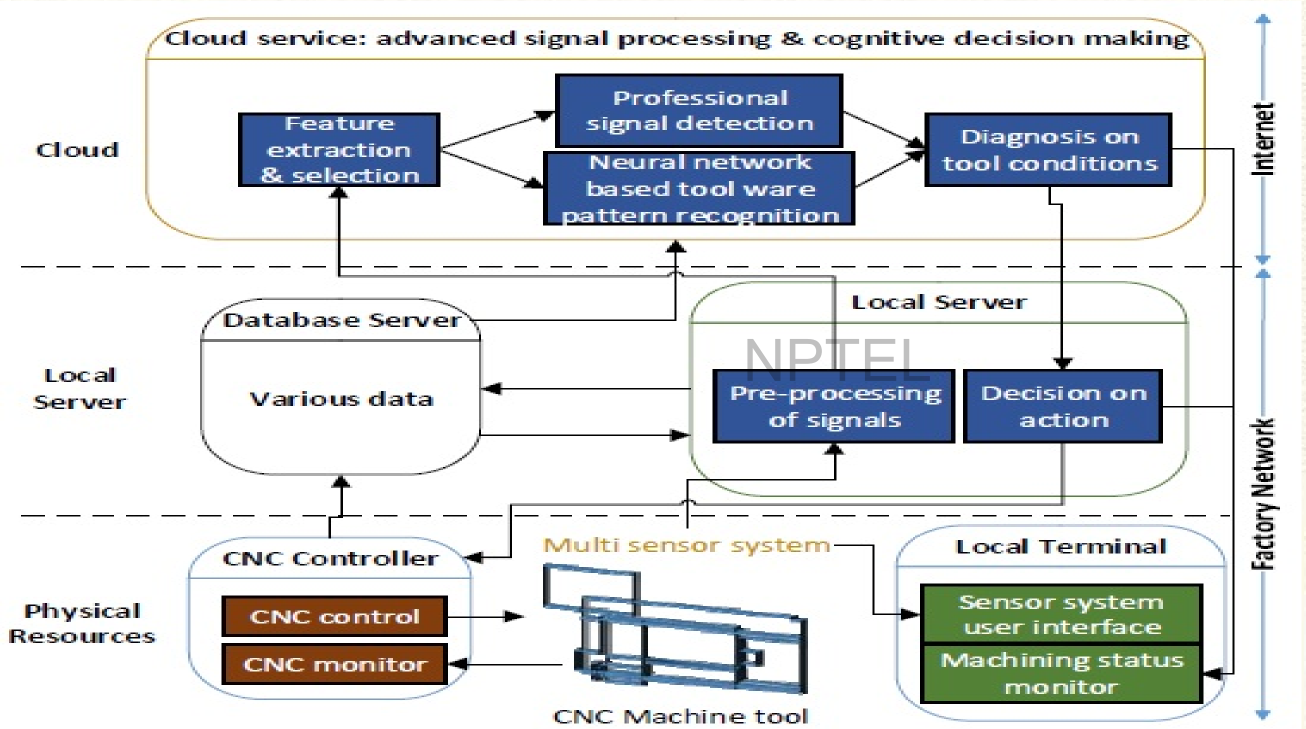
CPS and Cloud



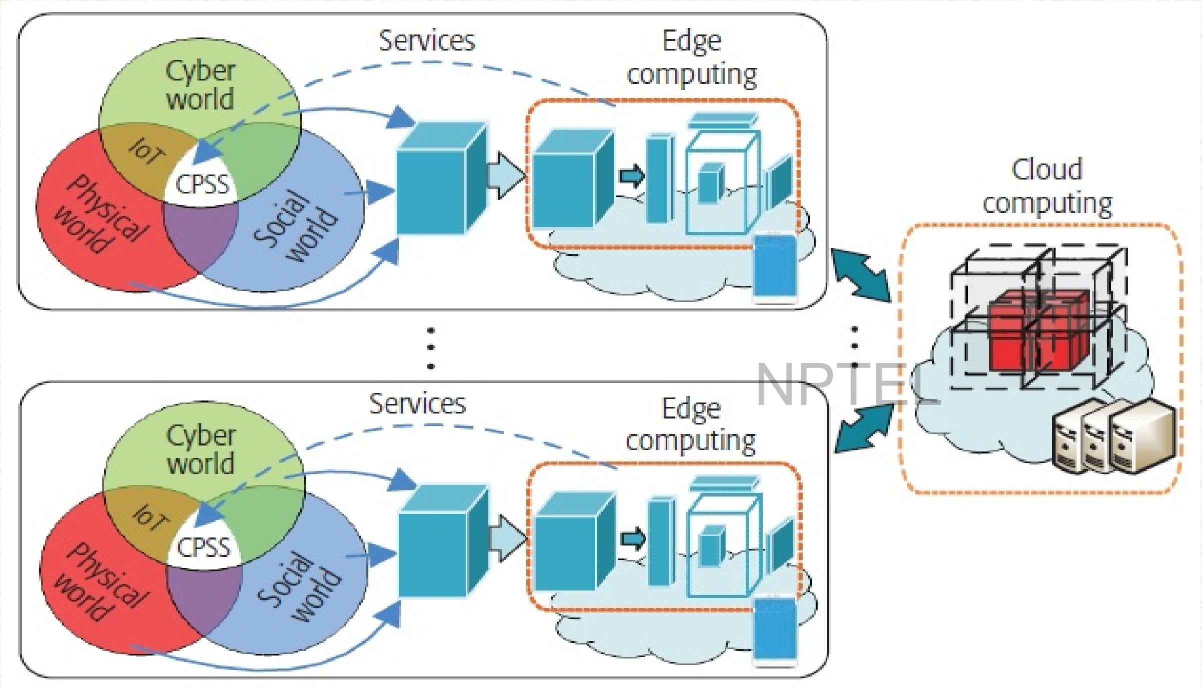
High level CPCC Scenario



A Cloud-based CPS architecture for Intelligent Monitoring of Machining Processes

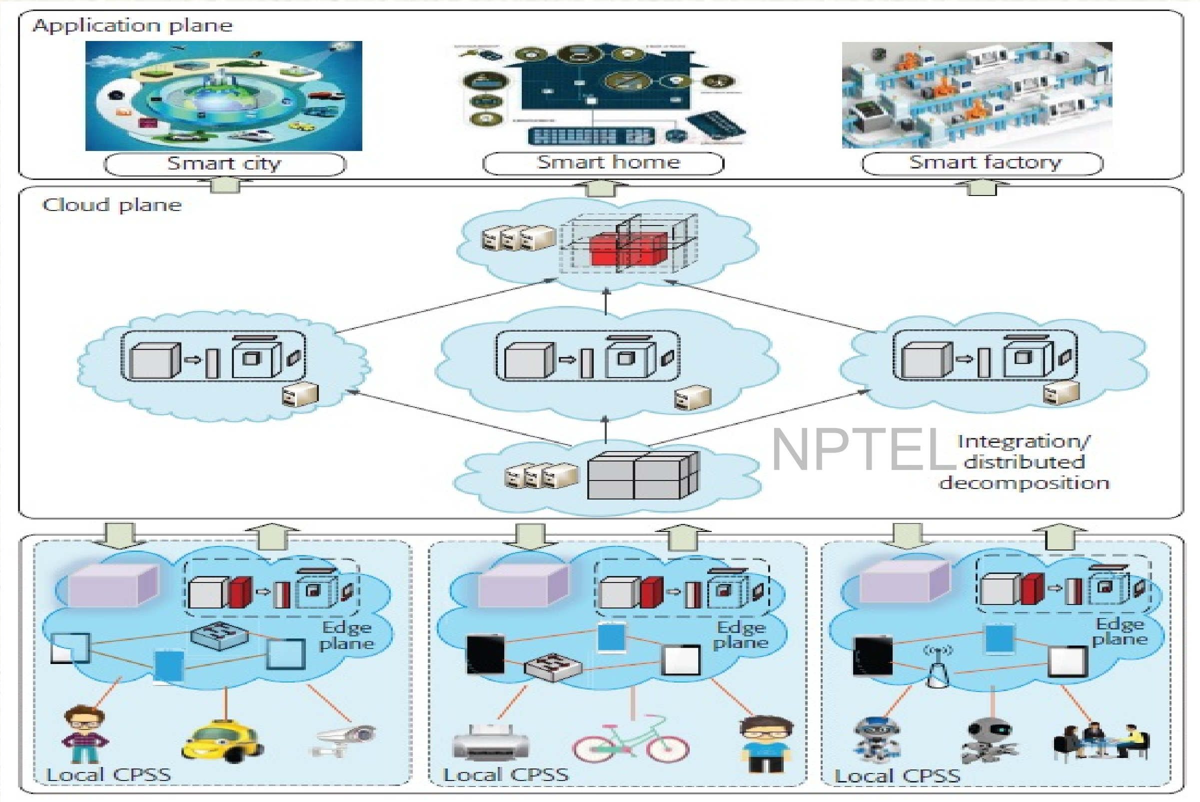


Cloud-Edge Computing Framework for CPS



Ref: X. Wang, L. T. Yang, X. Xie, J. Jin and M. J. Deen, "A Cloud-Edge Computing Framework for Cyber-Physical-Social Services," in IEEE Communications Magazine, vol. 55, no. 11, pp. 80-85, Nov. 2017, doi: 10.1109/MCOM.2017.1700360

Cloud-Edge Computing Framework for CPS



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Module 12: Cloud Computing Paradigms

Lecture 58: Case Study I (Spatial Cloud Computing)

CONCEPTS COVERED

- Spatial Data
- Spatial Cloud
- Spatial Analysis on Cloud

KEYWORDS

- Spatial Data
- Spatial Cloud Computing

Spatial Analysis on Cloud

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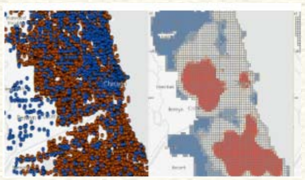
Spatial Data and Analysis

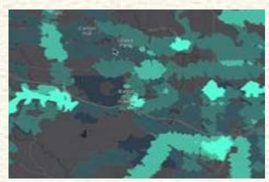
- Spatial (or Geospatial) data is information that describes objects, events or other features with a location on or near the surface of the earth.
- Geospatial data typically combines location information (usually coordinates on the earth) and attribute information (the characteristics of the object, event or phenomena concerned) with temporal information (the time or life span at which the location and attributes exist).

> ***Whenever we look at a map, we inherently start turning that map into information by analyzing its contents—finding patterns, assessing trends, or making decisions.***



Crime Studies

Drought Analysis

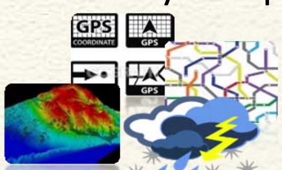


Finding optimal paths

Predictions

Spatial Analysis

- Attempt to solve location-oriented problems and better understanding of where and what is occurring in surrounding world/ region.
  - Beyond mapping - study the characteristics of places/ regions and the relationships between them
- Spatial analysis lends new perspectives to any decision-making
- Spatial analysis lets you pose questions and derive answers on spatial data.
- Help to derive new information and make informed decisions.
- The organizations that use spatial analysis in their work are wide-ranging—local and state governments, national agencies, businesses of all kinds, utility companies, colleges and universities, NGOs…



Identify →

Analyze →

Inference

Spatial Analysis - Challenges

Voluminous Spatio-temporal data instances

Integration of heterogeneous data sources

- Better support discovery, access and utilization of data and data processing so as to relieve scientists and engineers of IT tasks and focus on scientific discoveries
- Provide real-time IT resources to enable real-time applications, such as emergency response
- Deal with access spikes
- Provide more reliable and scalable service for massive numbers of concurrent users to advance public knowledge

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable **computing** resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction

Spatial Analytics + Cloud Computing

Emergence of cloud computing provides a potential solution with an ***elastic, on-demand computing platform to integrate – observation systems, parameter extracting algorithms, phenomena simulations, analytical visualization and decision support***, and to provide social impact and user feedback

- *Search, access and utilize* geospatial data
- *Configure computing infrastructure* to enable the computability of intensive simulation models disseminate and utilize research results for massive numbers of concurrent users
- *Adopt spatiotemporal principles* to support spatiotemporal intensive applications

Spatial cloud computing refers to the cloud computing paradigm that is driven by geospatial sciences, and optimized by spatiotemporal principles for enabling geospatial science discoveries and cloud computing within distributed computing environment

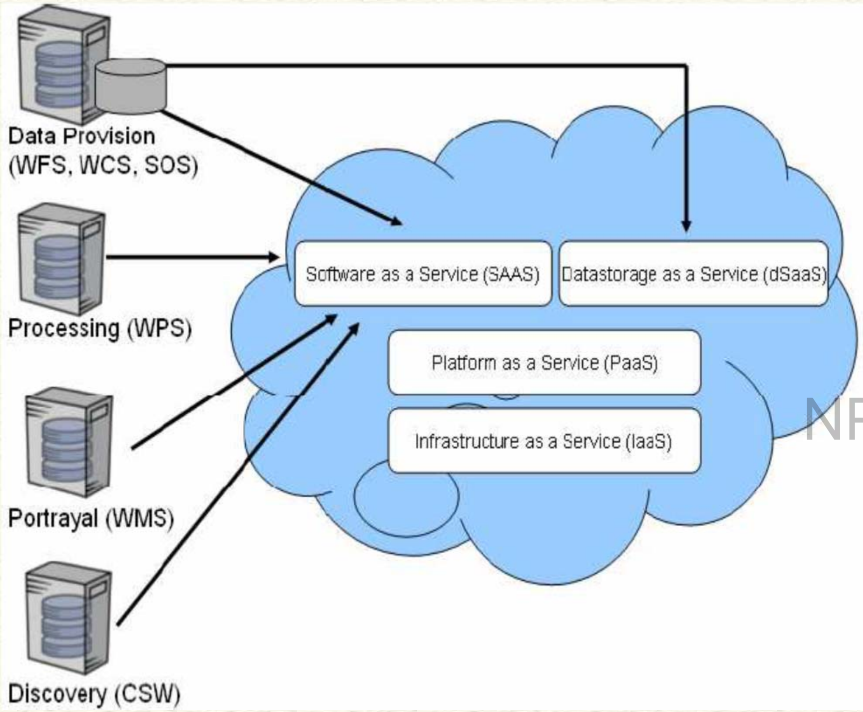
Spatial Cloud

- It supports shared resource pooling which is useful for participating organizations with common or shared goals
  - Network, Servers, Apps, Services, Storages and Databases
- Choice of various deployment, service and business models to best suit organization goals
- Managed services prevent data loss from frequent outages, minimizing financial risks, while increasing efficiency

Spatial Cloud - Advantages

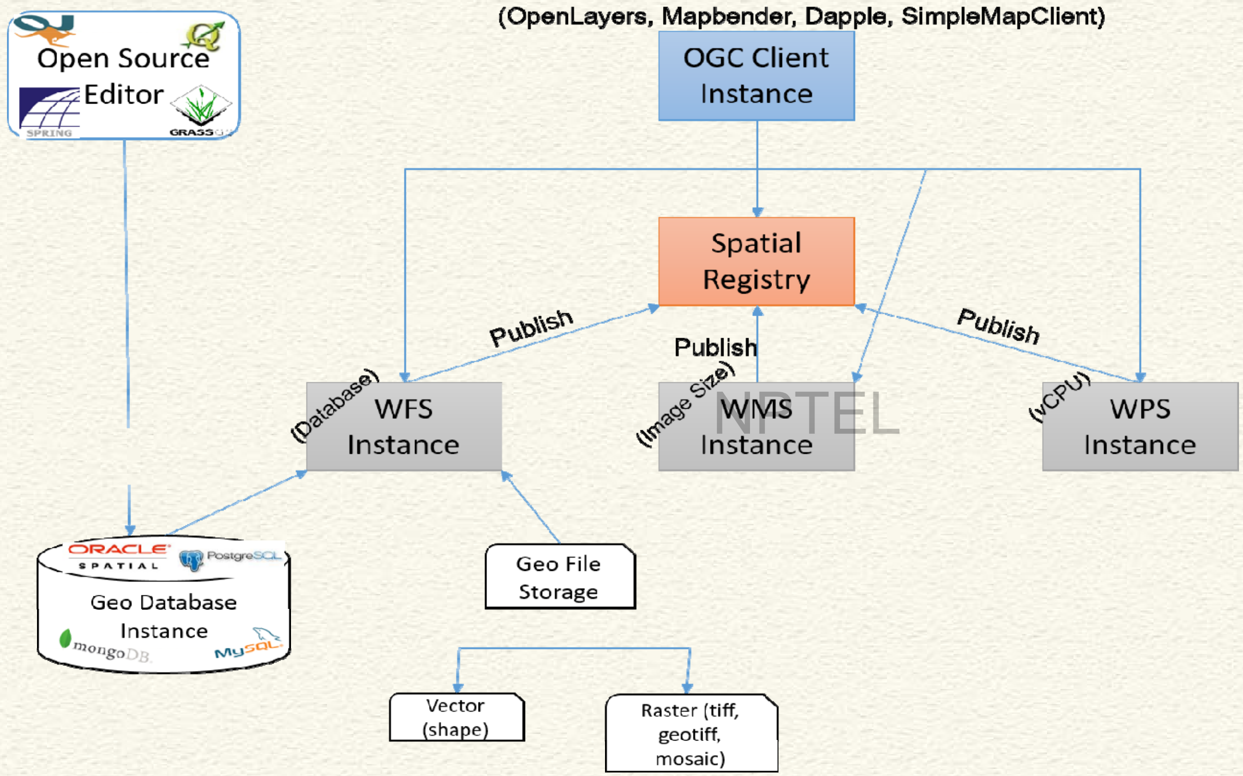
- **Easy to Use**- Infrastructure deployment with click of mouse, API and Network.
- **Scalability**- Infrastructure requirement is based on application, nothing to purchase.
- **Cost**- Optimized as it is resource usage based
- **Reliability**- Based on Enterprise grade Hardware; can subscribe to multiple clouds.
- **Risk**- Change instantly (even OS).

Spatial Cloud – Typical Architecture



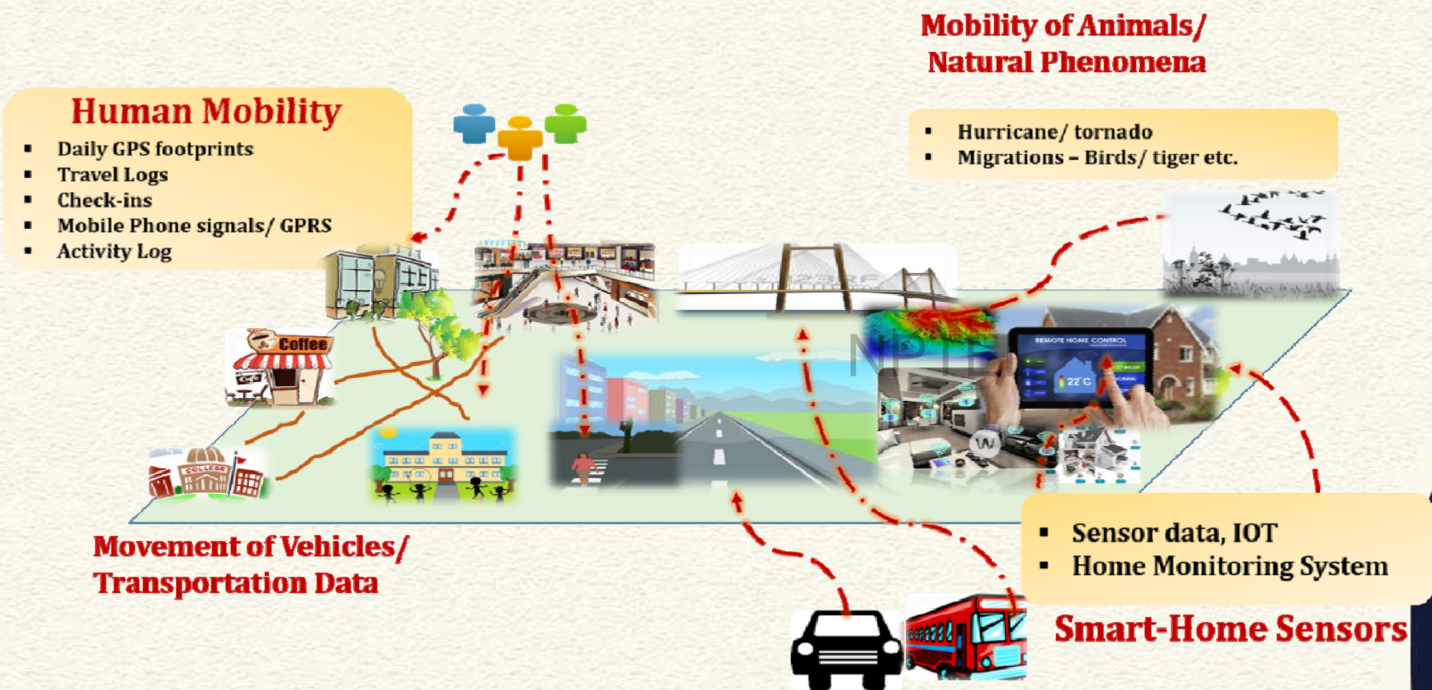
- **Private and public organization wants to share their spatial data**
  - Different requirement of geospatial data space and network bandwidth
- **Easy access of spatial services**
- **GIS decisions are made easier**
  - Integrate latest databases
  - Merge disparate systems
  - Exchange information internally and externally

Spatial Cloud – Typical Architecture

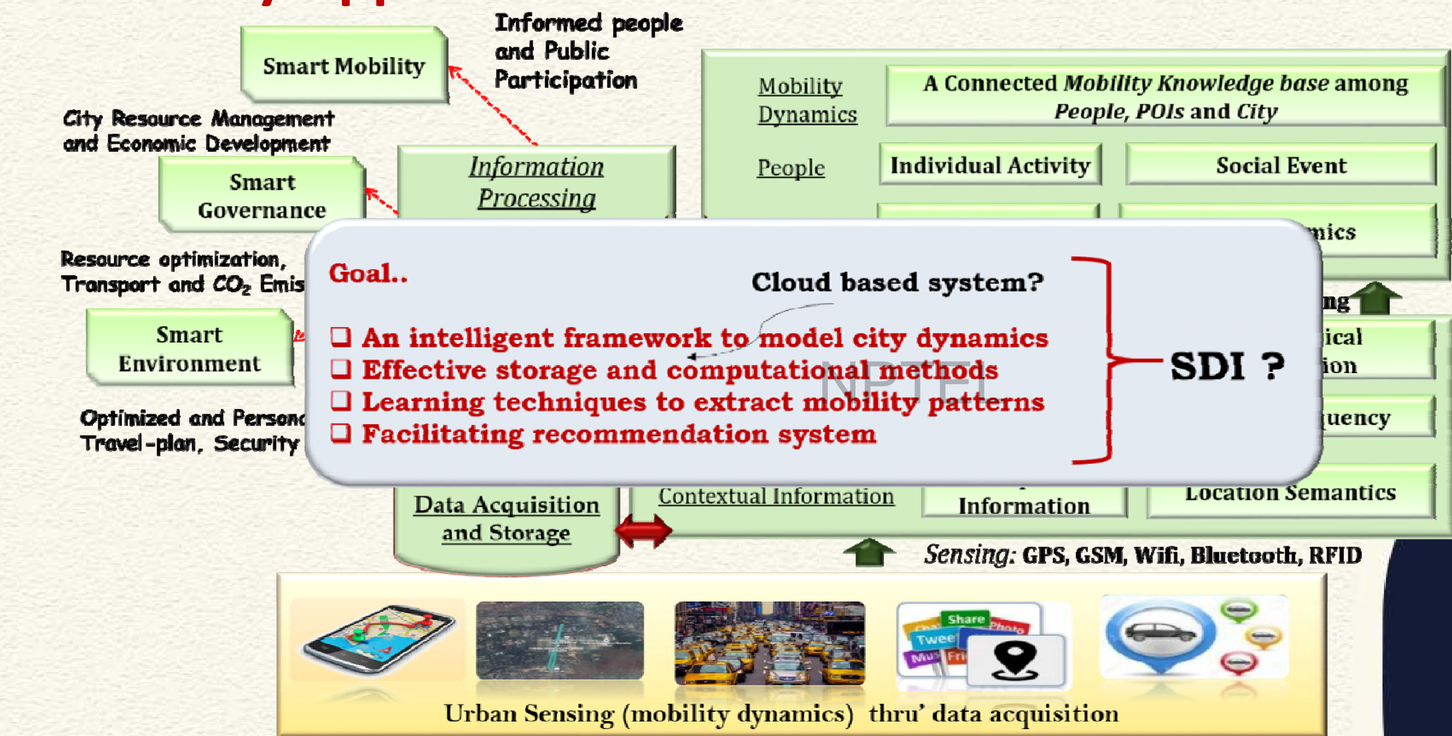


Mobility Analytics

(Utilize Cloud platform for computation and storage)



A general framework of Trajectory Trace Mining for Smart-City Applications

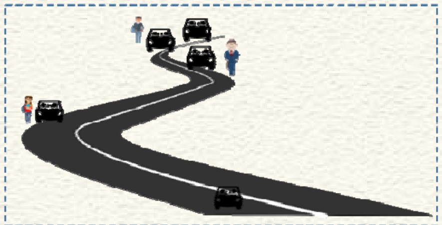


A Trajectory Cloud for enabling Efficient Mobility Services

Trip-Planning Service

Travel Time Prediction

Ride Sharing Service



Spatial Trajectory

- A ***spatial trajectory*** is a trace generated by a moving object in geographical spaces, usually represented by a series of chronologically ordered points
- Sequence of time stamped locations (latitude, longitude):

$$<(lat_1,lon_1),t_1>, <(lat_2,lon_2),t_2>, \ldots <(lat_n,lon_n),t_n>$$

Semantic Trajectory

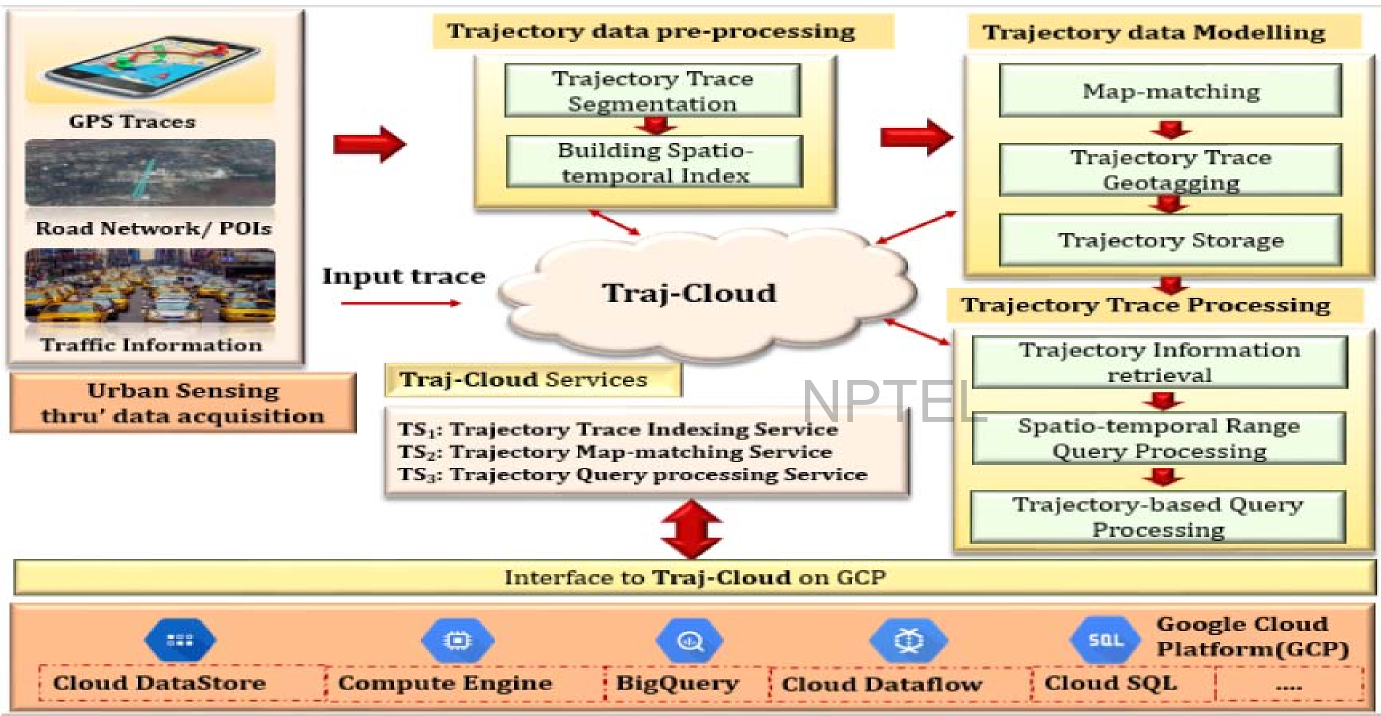
- "***Human movement follows an intent***" – How to capture the implicit knowledge/information?
- For better understanding additional information (stay-point information, activity performed at stay points?) are appended

Traj-Cloud for analyzing Urban Dynamics

- Mobility trace analysis has a significant role in mapping the *urban dynamics*.
  - This analysis helps in location-based service-provisioning and facilitates an effective transportation resource planning.
- Key aspect of the intelligent transportation system (ITS) is efficient mobility analytics to understand the movement behaviours of the people.
- Analysing mobility traces and providing location-aware service is a challenging task.

- ➢ An end-to-end cloud-based framework may facilitate efficient location-based service provisioning.
- ➢ It helps to minimize the service-waiting time and service-provisioning time of location-based services such as food delivery or medical emergency

Traj-Cloud for analyzing Urban Dynamics



Traj-Cloud Services

Trajectory data Indexing Service (TS_1):

- *Input*: GPS trajectory trace (G) and other semantic information, such as, geotagged locations or road network
- *Output*: Spatio-temporal indices of input traces and storage of the information
- *GCP Component*: Google BigQuery and Cloud SQL storage.

Trajectory Map-matching Service (TS_2):

- *Input*: GPS trajectory trace (G) and road network (R)
- *Output*: Projection of G into the corresponding R utilizing the MapReduce based platform to effectively handle huge data load in near real-time.
- *GCP Component*: Google Compute Engine

Trajectory Query Service (TS_3):

- *Input*: GPS trajectory trace (G) log, Trajectory point and range Query Q
- *Output*: Trajectory Trace (Point or Line shape)
- *GCP Component*: Google Compute Engine and Cloud SQL

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Thank you

NPTEL ONLINE CERTIFICATION COURSES

Cloud Computing

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Department of Computer Science and Engineering

Module 12: Cloud Computing Paradigms

Lecture 59: Case Study II (Internet of Health Things) (Part-A)

CONCEPTS COVERED

- Cloud-Fog-Edge-IoT Framework
- Internet of Health Things (IoHT)
- Case Study on Cloud-Fog-Edge-IoHT

KEYWORDS

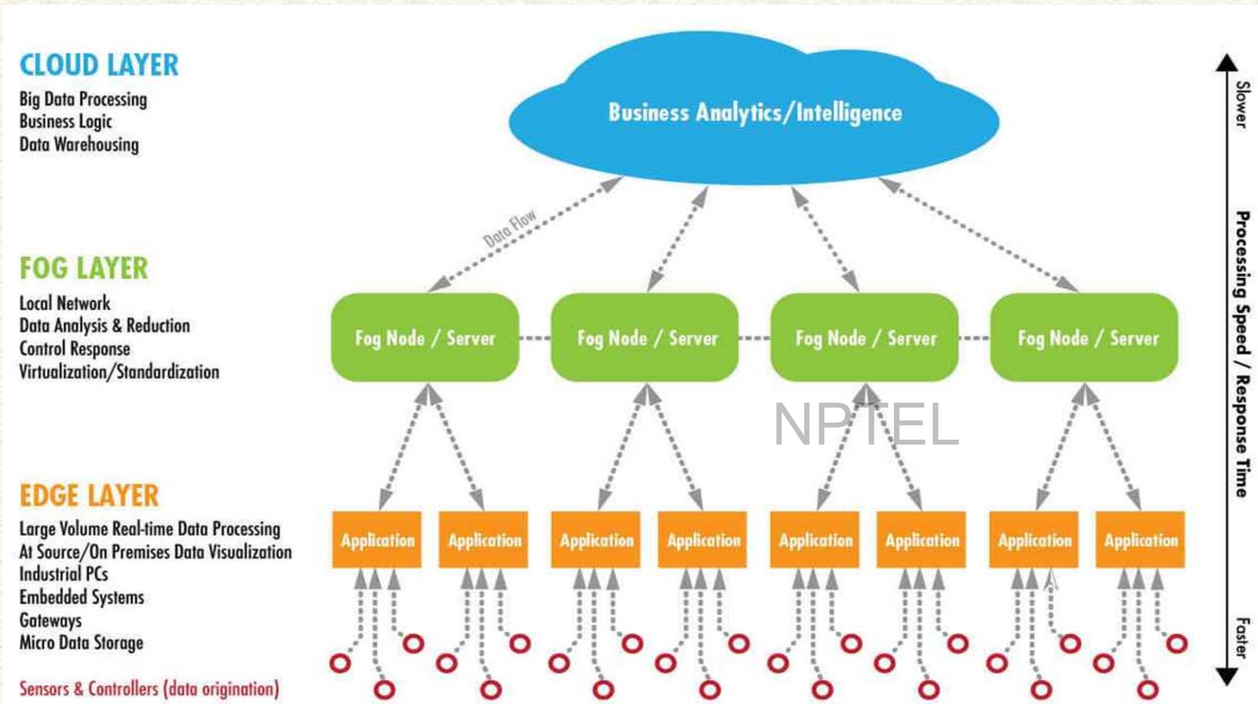
- Internet of Health Things (IoHT)

Cloud-Fog-Edge Computing for **Internet of Health Things (IoHT)**

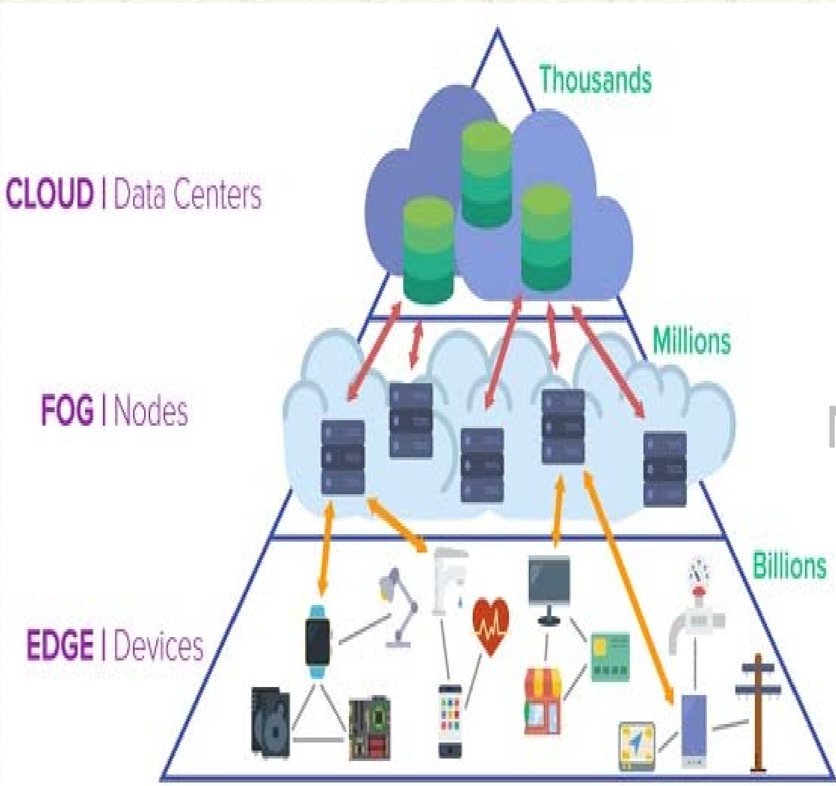
Fog Computing

- Fog Computing takes the cloud closer to the data producing sensor devices. Devices such as routers, servers, switches act as fog nodes if their processing power is employed for data processing and result generation.
- Use of Fog technology for real time applications
- Aim is to develop a Fog Based Healthcare model based on data collected by IoT based health sensor.
- Collected data will be processed at Edge devices to reduce latency, network usage and overall cost incurred at the cloud.
- The performance to be evaluated using simulator tool as well as actual hardware

Cloud-Fog-Edge-IoT



Cloud-Fog-Edge Hierarchy



Cloud Limitations

- Latency
- Large volume of data being generated.
- Bandwidth requirement

IoT Device Limitations

- Processing
- Storage
- Power requirement

Fog-Edge Computing

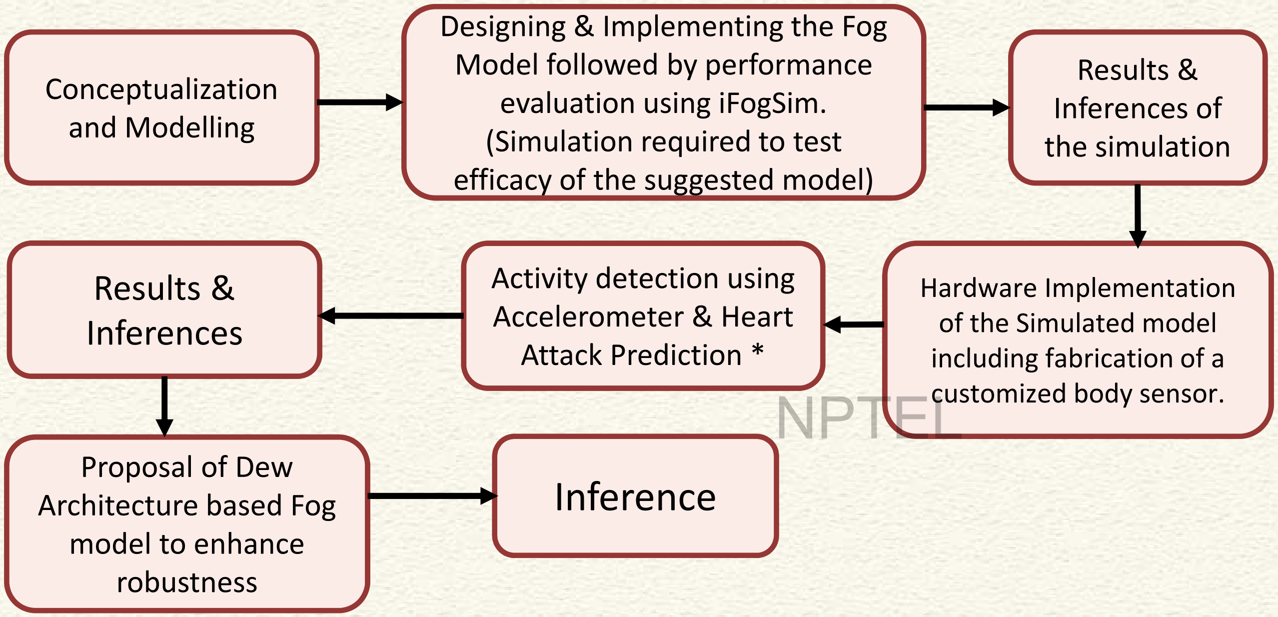
- Reduced **latency** supports Real-time applications
- Less n**etwork congestion**
- Reduced **cost of execution** at cloud
- Better handling of colossal data generated by sensors
- More of data location awareness

Cloud-Fog-Edge-IoHT

Objectives

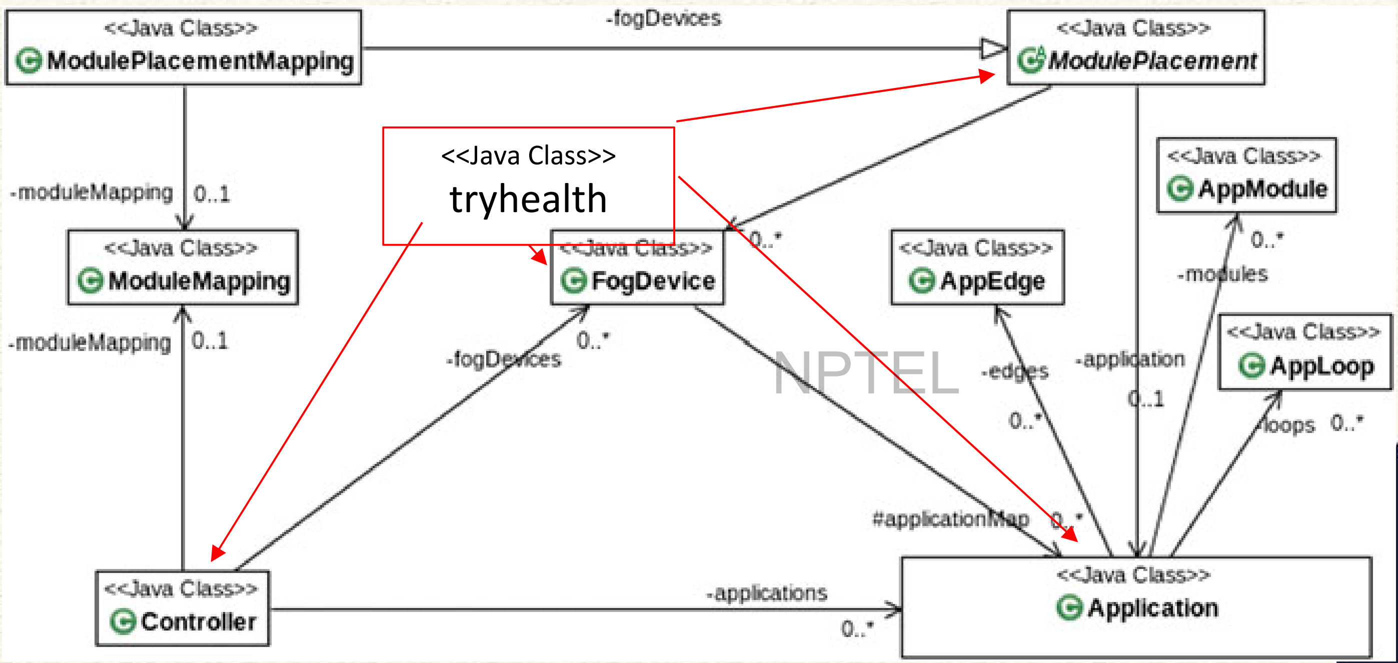
- To design a Fog-Edge Computing based health model to reduce latency, network usage and cost incurred at the cloud.
- To test the designed fog model using iFogSim simulator.
- To develop a customized wearable device for collection of health parameters.
- To implement the proposed model over hardware and test its efficacy.
- To study dew based computing and study its efficacy in the proposed health scenario

Overall Workflow

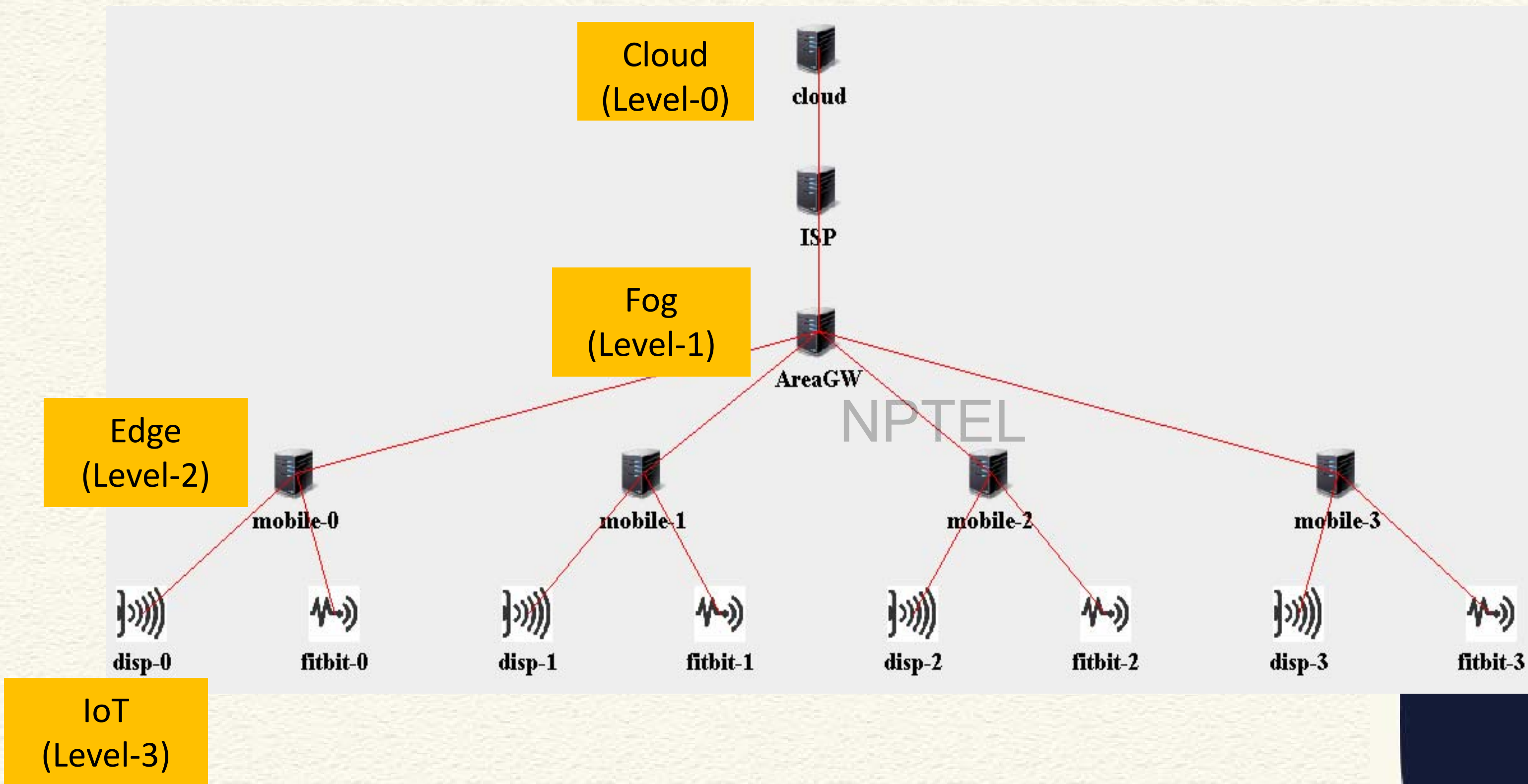


<u>Note</u>:
**Heart Attack Prediction algorithm has no medical/ clinical implication and has been used only for demonstration purposes.*

Simulation using iFogSim



Hierarchical Network Topology Model



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- Anish Poonia, Shreya Ghosh, Akash Ghosh, Shubha Brata Nath, Soumya K. Ghosh, Rajkumar Buyya, CONFRONT: Cloud-fog-dew based monitoring framework for COVID-19 management, Internet of Things, Elsevier, Volume 16, 2021
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Thank you

NPTEL ONLINE CERTIFICATION COURSES

Cloud Computing

Prof. Soumya K Ghosh

Department of Computer Science and Engineering

Module 12: Cloud Computing Paradigms

Lecture 60: Case Study II (Internet of Health Things) (Part-B)

CONCEPTS COVERED

- Cloud-Fog-Edge-IoT Framework
- Internet of Health Things (IoHT)
- Case Study on Cloud-Fog-Edge-IoHT

KEYWORDS

- Internet of Health Things (IoHT)

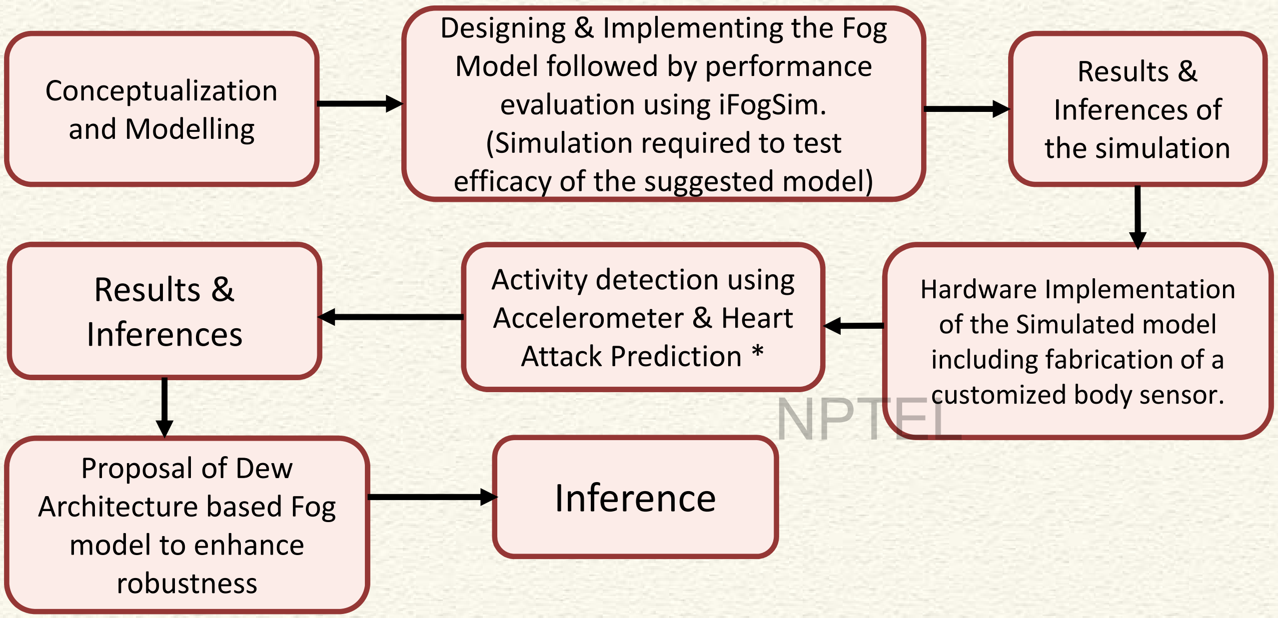
Cloud-Fog-Edge Computing for **Internet of Health Things (IoHT)**

Cloud-Fog-Edge-IoHT

Objectives

- To design a Fog-Edge Computing based health model to reduce latency, network usage and cost incurred at the cloud.
- To test the designed fog model using iFogSim simulator.
- To develop a customized wearable device for collection of health parameters.
- To implement the proposed model over hardware and test its efficacy.
- To study dew based computing and study its efficacy in the proposed health scenario

Overall Workflow



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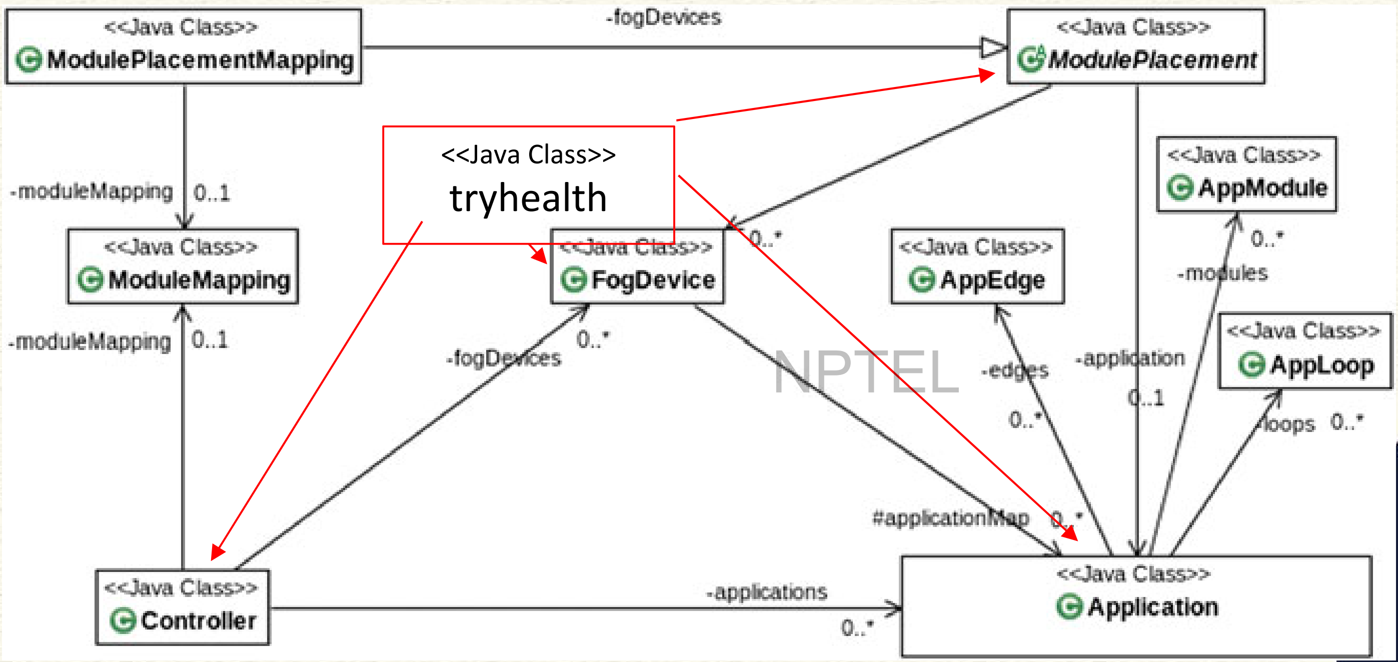
Simulation using iFogSim



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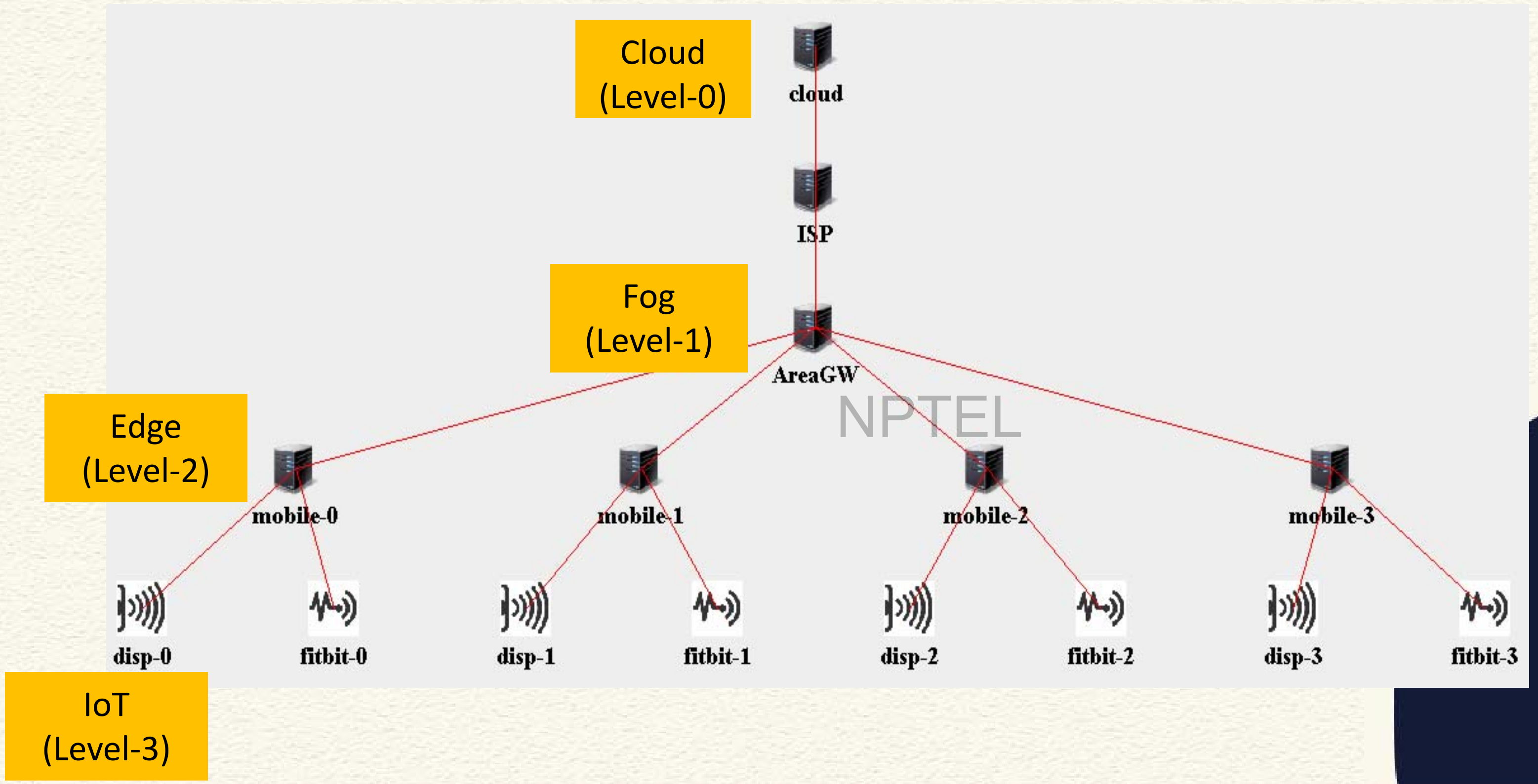


Cloud-Fog-Edge-IoHT – Typical Configuration

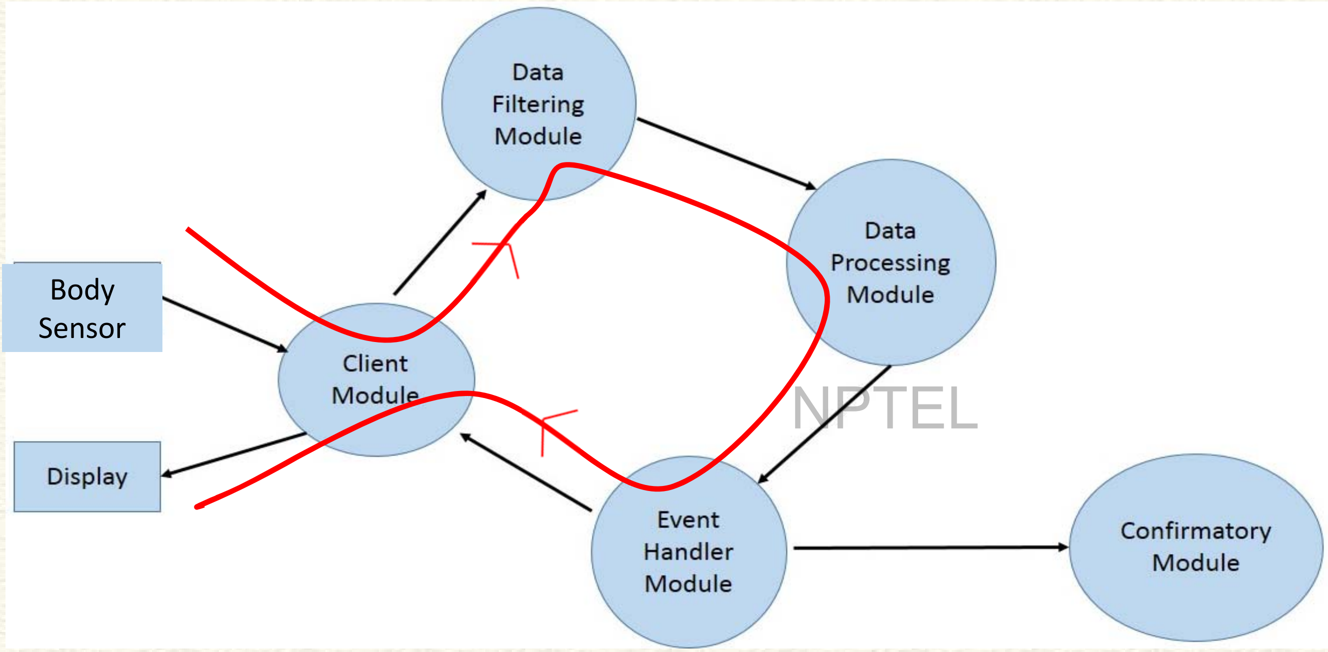
Device Configuration

Device	MIPS	RAM (MB)	Up Bw (Kbps)	Down Bw (Kbps)	Level	Cost/ MIPS	BusyPower (Watts)	Idle Power (Watts)
Cloud	44800	40000	100	10000	0	0.01	16*103	16*83.25
ISP	2800	4000	10000	10000	1	0	107.339	83.4333
AreaGW	2800	4000	10000	10000	2	0	107.339	83.4333
Mobile	350	1000	10000	270	3	0	87.53 mW	82.44 mW

Latency

Source	Destination	Latency
Body sensor	Mobile	1
Mobile	Area GW	2
Area GW	ISP GW	2
ISP GW	Cloud	100
Mobile	Display	1

Cloud-Fog-Edge-IoHT – Process Flow

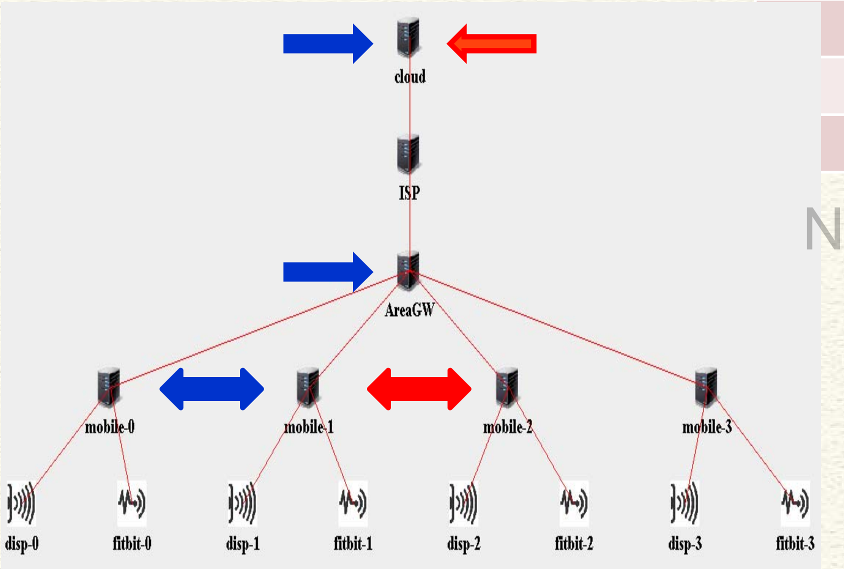


Application Placement

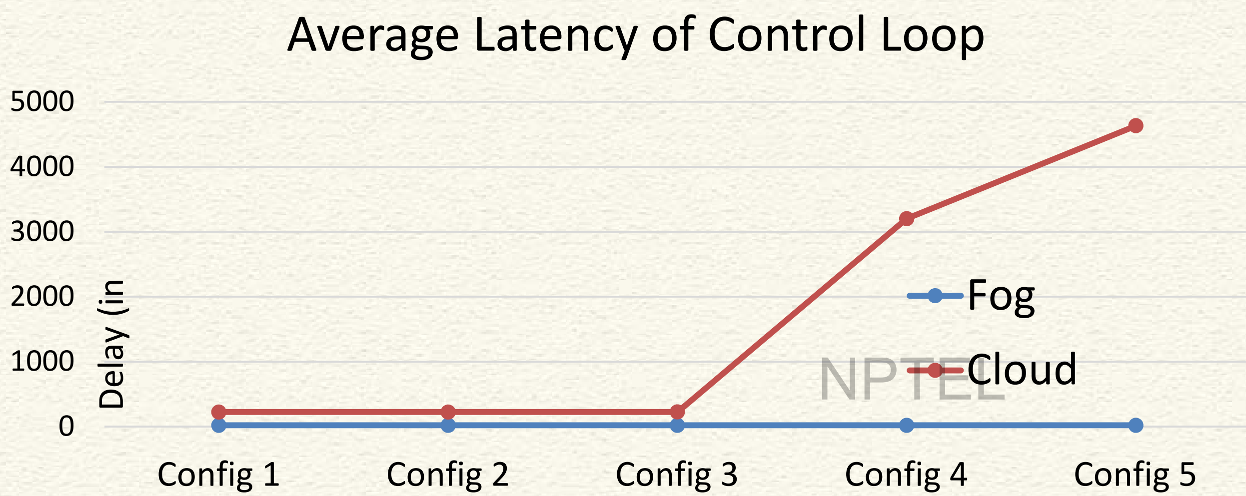
Application Module	Placement in Fog based Model	Placement in Cloudbased Model
Client Module	Mobile (Edge)	Mobile (Edge)
Data Filtering Module	Area Gateway (Fog)	Cloud
Data Processing Module	Area Gateway (Fog)	Cloud
Event Handler Module	Area Gateway (Fog)	Cloud
Confirmatory Module	Cloud	Cloud

Simulation Configuration

Configuration	No. of AreaGW	Total No. of Users
1	1	4
2	2	8
3	4	16
4	8	32
5	16	64

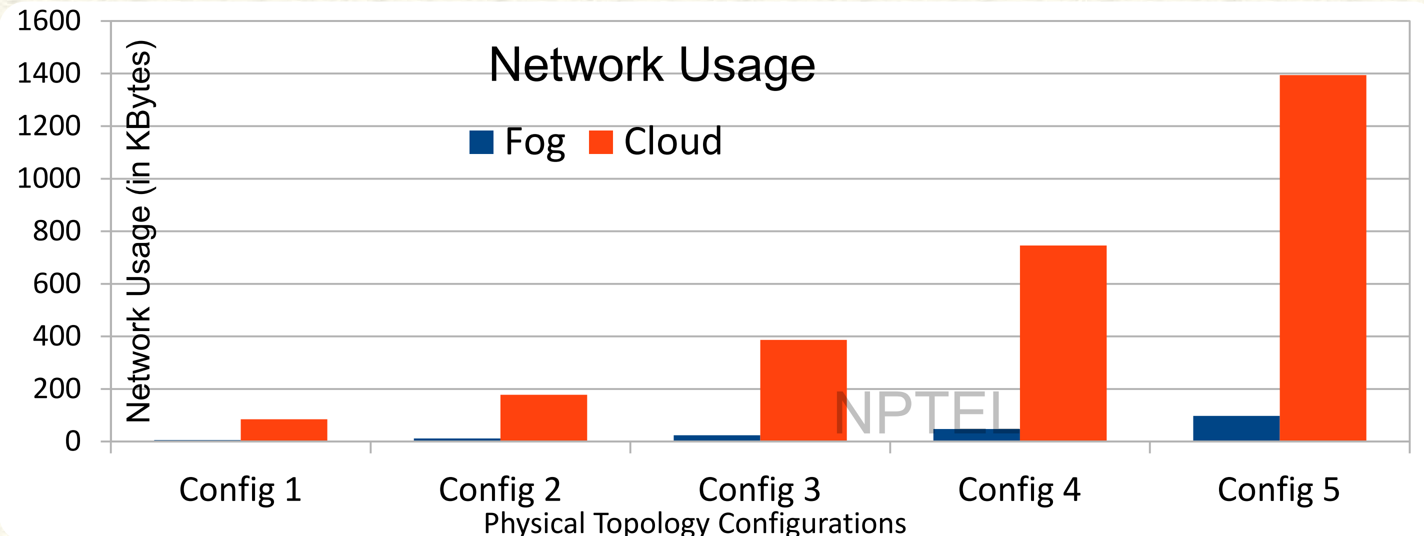


Performance Evaluation - Latency



- Fog: Latency is fixed as the application modules which form part of the control loop are located at Area Gateway itself
- Cloud: Modules are located at the Cloud Datacenter

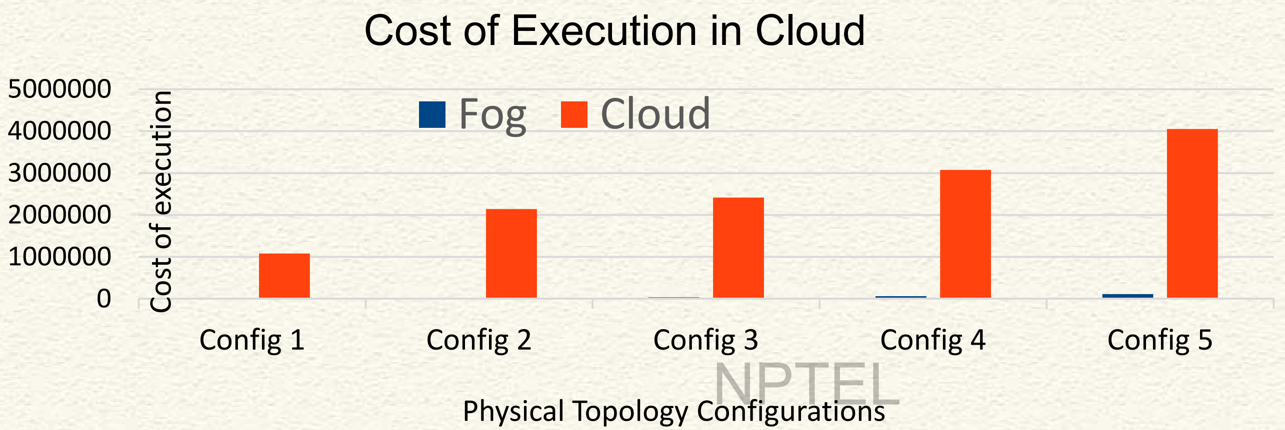
Performance Evaluation – Network Usage



Fog: Network usage is very low as only for few positive cases, the Confirmatory module residing on Cloud is accessed.

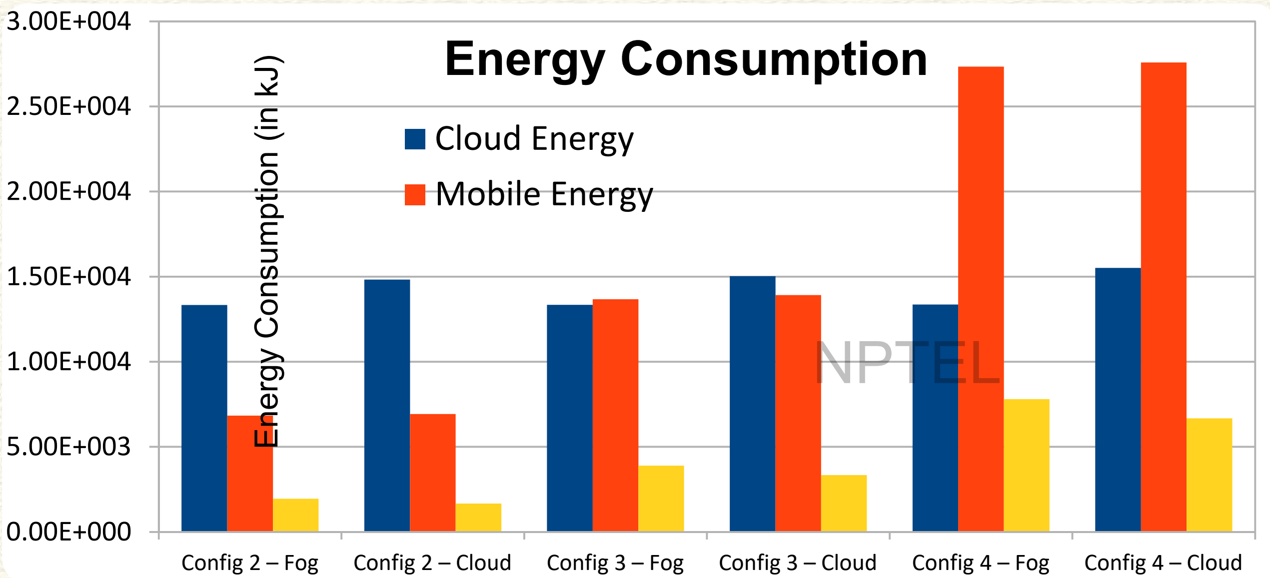
Cloud: Network usage is high as all modules are now on Cloud.

Performance Evaluation – Cost of Execution



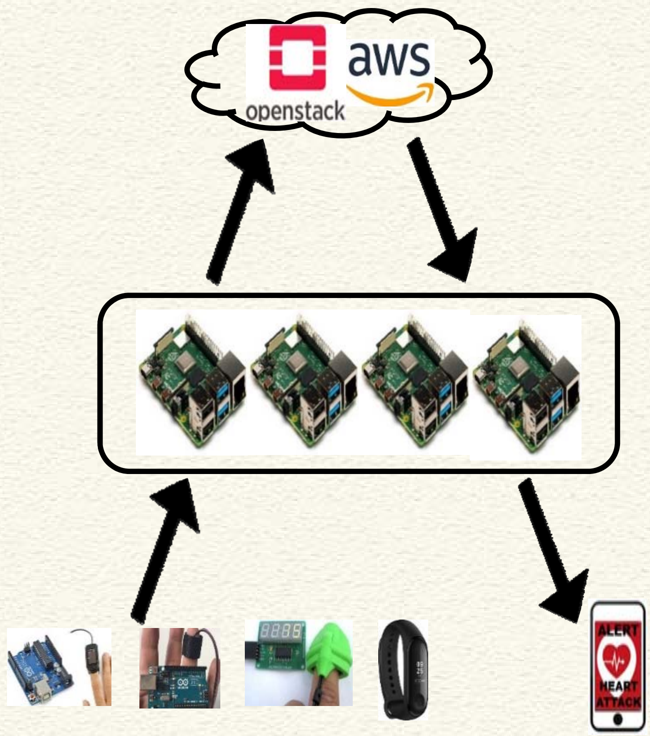
- Fog: Only the resources on Cloud incur cost, other resources are owned by the organization.
- Cloud: More processing at Cloud leads to higher costs in case of Cloud based architecture.

Performance Evaluation – Energy Consumption



- Energy consumption at Mobile devices remains same in Fog as well as Cloud as the load does not change.
- Energy requirement at the fog devices and Datacenter changes as the configuration changes from Fog based to Cloud based architecture owing to shifting of Application modules.

Hardware Implementation



- Simulated model's hardware implementation done using :
  - Customized body sensor
  - Simulated sensor data
  - Raspberry Pi as Fog Devices
  - AWS as Cloud

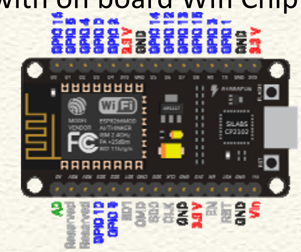
Hardware Implementation

- **Customized BP and Pulsemeter**

  Device has been customized to output serial data at 9600 baud rate in ASCII format.

- **NodeMCU ESP8266 CP2102 Board**

  Arduino like Hardware IO with on board Wifi Chip



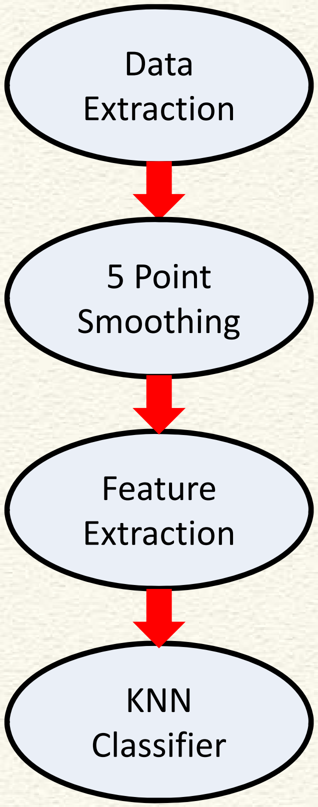
- **Accelerometer (ADXL345)**

  Each value has three components: X-axis, Y-axis and Z-axis

- **Raspberry Pi 3 (Fog Device)**

  64 bit system with 1 GB RAM, wifi and Bluetooth connectivity.

Activity Detection using Accelerometer

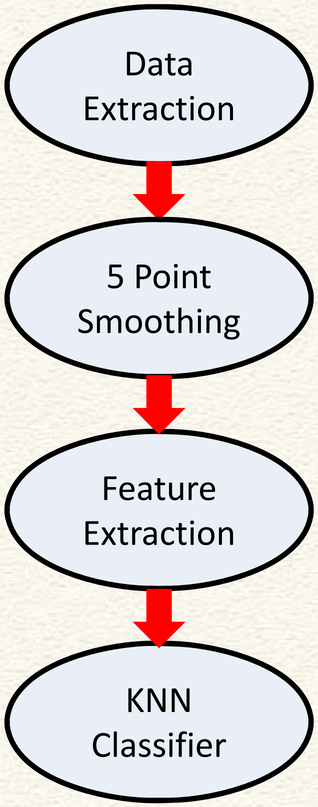


- **Data Extraction** - The collected data has three components: x-axis, y-axis, z-axis.

  A = sqrt(x*x + y*y + z*z)

- **5-Point smoothing** - To reduce any induced noise, each signal is obtained as an average of five signals; two preceding signals, the signal itself and two succeeding signals

Activity Detection using Accelerometer



- Feature Extraction: Following features were extracted from the filtered signal
  Maximum Amplitude
  - Minimum Amplitude
  - Mean Amplitude
  - Standard Deviation in Amplitude
  - Energy in Time Domain
  - Energy in Frequency Domain

- K-Nearest Neighbour Classifier
  Feature values are normalized:
  Y = (x-min)/(max-min)
  K=3 (based on 5-fold cross validation using GridSearchCV lib) is used for classification

Case Study: Cardiac Attack Prediction

Cardiac Attack Prediction Logic

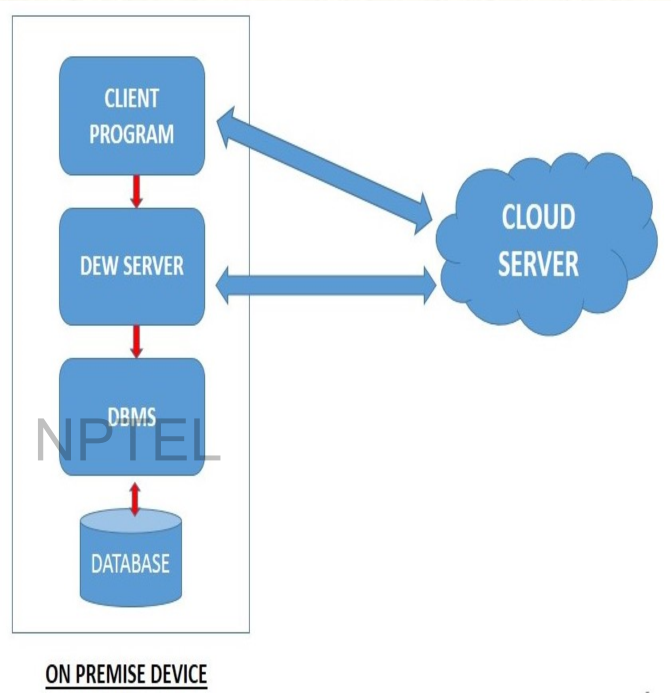
```
HeartAttackAlarm        false
 f            (value returned by KNN) + 1
 p            (BPM/f)
 s            (systolic measurement)/f
 d            (diastolic measurement)/f

if (p>=170) and (s>=180) and (d>=120 )
              then:
                   HeartAttackAlarm = true
              else
                   Heart AttackAlarm = false
 end if
 return HeartAttackAlarm
```

Health Parameter	Alarm Value
BPM	>=170
Diastolic	>=120
Systolic	>=180

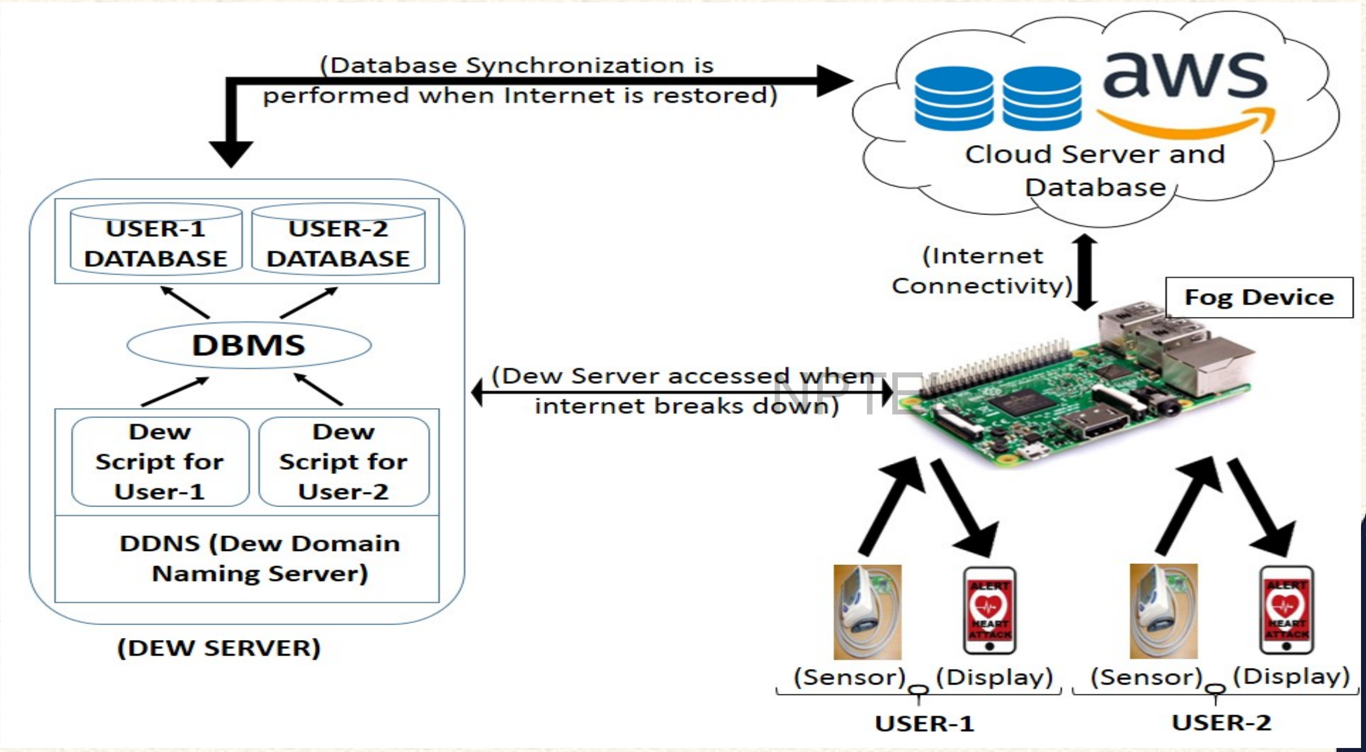
Note:
The proposed approachhas no medical or clinical significance / implication and has been proposed strictly for demonstration purpose.

Dew Computing

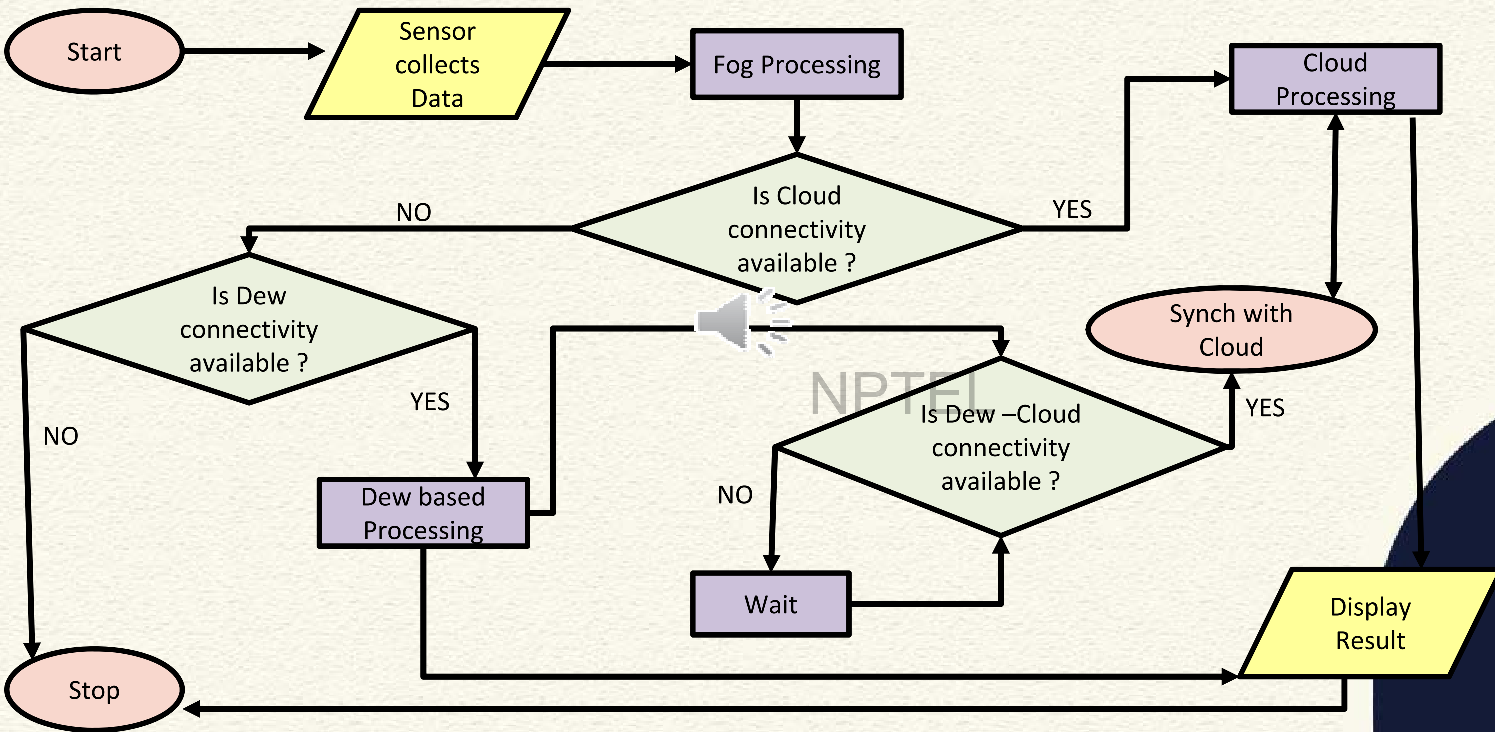
"Dew computing is an *on-premises* computer software-hardware organization paradigm in the cloud computing environment where the on-premises computer provides functionality that is **independent** of cloud services and is also **collaborative** with cloud services. The goal of dew computing is to fully realize the potentials of on-premises computers and cloud services".



Dew based Cloud-Fog-Edge-IoHT Framwork



Dew based Cloud-Fog-Edge-IoHT - Workflow



Comparative Study

FEATURE (from health service provider perspective)	CLOUD	Cloud-FOG-Edge	With DEW
On-premise resource utilization	Low	Sub-optimal	Optimal
Connectivity required	Internet	Local	Local
Uptime	Low	High	High
Bandwidth required	High	Low	Low
Latency	High	Low	Low
Infrastructure requirement	Low	Moderate	Moderate
Processing power	High	Limited	Limited
Data Storage	High	Low	Moderate

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