**PAAVAI ENGINEERING COLLEGE**

**(Autonomous)**

**Department of Computer Science & Engineering**

**Lecture Notes**

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UNIT –III

Domain specific IoT

 Outline IoT Applications for :

* Home Automation
* Cities
* Environment
* Energy Systems
* Retail
* Logistics
* Industry
* Agriculture
* Health & Lifestyle

1. Home Automation IoT applications for smart homes:

* Smart Lighting
* Smart Appliances
* Intrusion Detection
* Smoke / Gas Detectors

Presented controllable LED lighting system that is embedded with ambient intelligence gathered from a distributed smart WSN to optimize and control the lighting system to be more efficient and user-oriented.

Energy-aware wireless sensor network with ambient intelligence for smart LED lighting system control [IECON, 2011]  Wireless-enabled and Internet connected lights can be controlled remotely from IoT applications such as a mobile or web application.

Key enabling technologies for smart lighting include: - Solid state lighting (such as LED lights) - IP-enabled lights

Smart lighting achieves energy savings by sensing the human movements and their environments and controlling the lights accordingly.

**Home Automation Smart Lighting**

5. implemented an IoT based appliance control system for smart homes that uses a smart-central controller to set up a wireless sensor and actuator network and control modules for appliances. allows to interact with devices and control them. • Paper: - An IoT-based Appliance Control System for Smart Home [ICICIP, 2013] allows creating both configurations for the controller and user interface designs.

**Control Panel** manages scheduling and runtime integration between devices.

**a Designer** Home Automation Smart Appliances

• Smart appliances make the management easier and provide status information of appliances to the users remotely.

E.g: smart washer/dryer that can be controlled remotely and notify when the washing/drying cycle is complete.

• Open Remote is an open source automation platform for smart home and building that can control various appliances using mobile and web applications.

• It comprises of three components: - a Controller

• implement an intrusion detection system that uses image processing to recognize the intrusion and extract the intrusion subject and generate Universal-Plug-and-Play (UPnP-based) instant messaging for alerts.

• present a controlled intrusion detection system that uses location-aware services, where the geo-location of each node of a home automation system is independently detected and stored in the cloud.

- An Intelligent Intrusion Detection System Based on UPnP Technology for Smart Living [ISDA, 2008] Home Automation Intrusion Detection

• Home intrusion detection systems use security cameras and sensors to detect intrusions and raise alerts.

• The form of the alerts can be in form: - SMS - Email - Image grab or a short video clip as an email attachment

• Papers : - Could controlled intrusion detection and burglary prevention stratagems in home automation systems [BCFIC, 2012]

• designed a system that can detects gas leakage and smoke and gives visual level indication.

**Home Automation Smoke / Gas Detectors**

• Smoke detectors are installed in homes and buildings to detect smoke that is typically an early sign of fire.

• It uses optical detection, ionization or air sampling techniques to detect smoke

• The form of the alert can be in form :

• Signals that send to a fire alarm system

• Gas detector can detect the presence of harmful gases such as carbon monoxide (CO), liquid petroleum gas (LPG), etc.

• Paper : - Development of Multipurpose Gas Leakage and Fire Detector with Alarm System [TIIEC, 2013]

**Cities IoT applications for smart cities:**

1. Smart Parking

2. Smart Lighting for Road

3. Smart Road

4. Structural Health Monitoring

5. Surveillance

6. Emergency Response

1. Smart Parking

• designed and implemented a prototype smart parking system based on wireless sensor network technology with features like remote parking monitoring, automate guidance, and parking reservation mechanism

• Finding the parking space in the crowded city can be time consuming and frustrating

• Smart parking makes the search for parking space easier and convenient for driver.

• It can detect the number of empty parking slots and send the information over the Internet to the smart parking applications which can be accessed by the drivers using their smart phones, tablets, and in car navigation systems.

• Sensors are used for each parking slot to detect whether the slot is empty or not, and this information is aggregated by local controller and then sent over the Internet to database.

• Design and implementation of a prototype Smart Parking (SPARK) system using WSN [International Conference on Advanced Information Networking and Applications Workshop, 2009]

 described the need for smart lighting system in smart cities, smart lighting features and how to develop interoperable smart lighting solutions.

Cities Smart Lighting for Roads

• It can help in saving energy

• Smart lighting for roads allows lighting to be dynamically controlled and also adaptive to ambient conditions.

• Smart light connected to the Internet can be controlled remotely to configure lighting schedules and lighting intensity.

• Custom lighting configurations can be set for different situations such as a foggy day, a festival, etc.

• Paper : • Smart Lighting solutions for Smart Cities [International Conference on Advance Information Networking and Applications Workshop, 2013]

 proposed a distributed and autonomous system of sensor network nodes for improving driving safety on public roads, the system can provide the driver and passengers with a consistent view of the road situation a few hundred meters ahead of them or a few dozen miles away, so that they can react to potential dangers early enough.

Cities Smart Roads

• Smart Roads provides information on driving conditions, travel time estimates and alerts in case of poor driving conditions, traffic congestions and accidents.

• Such information can help in making the roads safer and help in reducing traffic jams

• Information sensed from the roads can be communicated via internet to cloud-based applications and social media and disseminated to the drivers who subscribe to such applications.

• Paper: • Sensor networks for smart roads [PerCom Workshop, 2006]

Explored energy harvesting technologies of harvesting ambient energy, such as mechanical vibrations, sunlight, and wind.

 proposed an environmental effect removal based structural health monitoring scheme in an IoT environment.

- Energy harvesting technologies for structural health monitoring applications [IEEE Conference on Technologies for Sustainability, 2013]

Cities Structural Health Monitoring

• It uses a network of sensors to monitor the vibration levels in the structures such as bridges and buildings.

• The data collected from these sensors is analyzed to assess the health of the structures.

• By analyzing the data it is possible to detect cracks and mechanical breakdowns, locate the damages to a structure and also calculate the remaining life of the structure.

• Using such systems, advance warnings can be given in the case of imminent failure of the structure.

• Paper: - Environmental Effect Removal Based Structural Health Monitoring in the Internet of Things [International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2013]

Cities Surveillance

• Surveillance of infrastructure, public transport and events in cities is required to ensure safety and security.

• City wide surveillance infrastructure comprising of large number of distributed and Internet connected video surveillance cameras can be created.

• The video feeds from surveillance cameras can be aggregated in cloud-based scalable storage solutions.

• Cloud-based video analytics applications can be developed to search for patterns of specific events from the video feeds.

Cities Emergency Response

• IoT systems can be used for monitoring the critical infrastructure cities such as buildings, gas, and water pipelines, public transport and power substations.

• IoT systems for critical infrastructure monitoring enable aggregation and sharing of information collected from lager number of sensors.

• Using cloud-based architectures, multi-modal information such as sensor data, audio, video feeds can be analyzed I near real-time to detect adverse events.

• The alert can be in the form :

* Alerts sent to the public
* Re-rerouting of traffic
* Evacuations of the affected areas

 Environment IoT applications for smart environments:

1. Weather Monitoring

2. Air Pollution Monitoring

3. Noise Pollution Monitoring

4. Forest Fire Detection

5. River Flood Detection

 Presented a pervasive weather monitoring system that is integrated with buses to measure weather variables like humidity, temperature, and air quality during the bus path

Environment Weather Monitoring

• It collects data from a number of sensor attached such as temperature, humidity, pressure, etc and send the data to cloud-based applications and store back-ends.

• The data collected in the cloud can then be analyzed and visualized by cloud-based applications.

• Weather alert can be sent to the subscribed users from such applications.

• AirPi is a weather and air quality monitoring kit capable of recording and uploading information about temperature, humidity, air pressure, light levels, UV levels, carbon monoxide, nitrogen dioxide and smoke level to the Internet.

• Paper: - PeWeMoS – Pervasive Weather Monitoring System [ICPCA, 2008]

 Presented a real time air quality monitoring system that comprises of several distributed monitoring stations that communicate via wireless with a back- end server using machine-to machine communication.

Environment Air Pollution Monitoring

• IoT based air pollution monitoring system can monitor emission of harmful gases by factories and automobiles using gaseous and meteorological sensors.

• The collected data can be analyzed to make informed decisions on pollutions control approaches.

• Paper: - Wireless sensor network for real-time air pollution monitorings [ICCSPA, 2013]

 Designed a Smartphone application that allows the users to continuously measure noise levels and send to a central server here all generated information is aggregated and mapped to a meaningful noise visualization map.

Environment Noise Pollution Monitoring

• Noise pollution monitoring can help in generating noise maps for cities.

• It can help the policy maker in making policies to control noise levels near residential areas, school and parks.

• It uses a number of noise monitoring stations that are deployed at different places in a city.

• The data on noise levels from the stations is collected on servers or in the cloud and then the collected data is aggregate to generate noise maps.

• Papers : - Noise mapping in urban environments : Applications at Suez city center [ICCIE, 2009]Presented a noise mapping study for a city which revealed that the city suffered from serious noise pollution. - SoundOfCity – Continuous noise monitoring for a health city [PerComW,2013]

 Presented a forest fire detection system based on wireless sensor network. The system uses multi-criteria detection which is implemented by the artificial neural network.

The ANN fuses sensing data corresponding to ,multiple attributes of a forest fire such as temperature, humidity, infrared and visible light to detect forest fires.

**Environment Forest Fire Detection**

• IoT based forest fire detection system use a number of monitoring nodes deployed at different location in a forest.

• Each monitoring node collects measurements on ambient condition including temperature, humidity, light levels, etc.

• Early detection of forest fires can help in minimizing the damage.

• Papers: • A novel accurate forest fire detection system using wireless sensor networks [International Conference on Mobile Ad- hoc and Sensor Networks, 2011]

 Described a motes-based sensor network for **river flood monitoring** that includes a water level monitoring module, network video recorder module, and data processing module that provides floods information n the form of raw data, predict data, and video feed.

 Described a river flood monitoring system that measures river and weather conditions through wireless sensor nodes equipped with different sensors

• Urban Flash Flood Monitoring, Mapping and Forecasting via a Tailored Sensor Network System [ICNSC, 2006]

Environment River Flood Detection

• IoT based river flood monitoring system uses a number of sensor nodes that monitor the water level using ultrasonic sensors and flow rate using velocity sensors.

• Data from these sensors is aggregated in a server or in the cloud, monitoring applications raise alerts when rapid increase in water level and flow rate is detected.

• Papers: • RFMS : Real time flood monitoring system with wireless sensor networks [MASS, 2008]

 Energy IoT applications for smart energy systems:

1. Smart Grid

2. Renewable Energy Systems

3. Prognostics

 Condition monitoring data collected from power generation and transmission systems can help in detecting faults and predicting outages.

 Cloud-based monitoring of smart grids data can improve energy usage usage levels via energy feedback to users coupled with real-time pricing information.

 Storage collection and analysis of smarts grids data in the cloud can help in dynamic optimization of system operations, maintenance, and planning.

 By analyzing the data on power generation, transmission and consumption of smart grids can improve efficiency throughout the electric system.

 Smart grid collect the data regarding :

- Electricity generation

- Electricity consumption

- Storage

- Distribution and equipment health data

 Smart grid technology provides predictive information and recommendation s to utilize, their suppliers, and their customers on how best to manage power.

**Energy Smart Grids**

 Provided the closed-loop controls for wind energy system that can be used to regulate the voltage at point of interconnection which coordinate wind turbine outputs and provides reactive power support.

 Paper: - Communication systems for grid integration of renewable energy resources [IEEE Network, 2011]

 To ensure the grid stability, one solution is to simply cut off the overproductions.

 IoT based systems integrated with the transformer at the point of interconnection measure the electrical variables and how much power is fed into the grid.

 Due to the variability in the output from renewable energy sources (such as solar and wind), integrating them into the grid can cause grid stability and reliability problems.

Energy Renewable Energy System

**Open PDC** is a set of applications for processing of streaming time-series data collected from **Phasor Measurements Units (PMUs)** in real-time.

 Analyzing massive amounts of maintenance data collected from sensors in energy systems and equipment can provide predictions for impending failures.

 In the system such as power grids, real time information is collected using specialized electrical sensors called Phasor Measurement Units (PMU)

 IoT based prognostic real-time health management systems can predict performance of machines of energy systems by analyzing the extent of deviation of a system from its normal operating profiles.

**Energy Prognostics**

 Retail IoT applications in smart retail systems:

1. Inventory Management

2. Smart Payments

3. Smart Vending Machines

described an RFID data-based inventory management system for time-sensitive materials

**1.Retail Inventory Management**

• IoT system using Radio Frequency Identification (RFID) tags can help inventory management and maintaining the right inventory levels.

• RFID tags attached to the products allow them to be tracked in the real-time so that the inventory levels can be determined accurately and products which are low on stock can be replenished.

• Tracking can be done using RFID readers attached to the retail store shelves or in the warehouse.

• Paper: - RFID data-based inventory management of time-sensitive materials [IECON, 2005]

 NFC maybe used in combination with Bluetooth, where NFC initiates initial pairing of devices to establish a Bluetooth connection while the actual data transfer takes place over Bluetooth.

 Customer can store the credit card information in their NFC-enabled smart-phones and make payments by bringing the smart-phone near the point of sale terminals.

 NFC is a set of standards for smart-phones and other devices to communicate with each other by bringing them into proximity or by touching them

 Smart payments solutions such as contact-less payments powered technologies such as Near field communication (NFC) and Bluetooth.

**2.Retail Smart Payments**

** Retail Smart Vending Machines**

- Smart vending machines connected to the Internet allow remote monitoring of inventory levels, elastic pricing of products, promotions, and contact-less payments using NFC.

- Smart-phone applications that communicate with smart vending machines allow user preferences to be remembered and learned with time. E.g: when a user moves from one vending machine to the other and pair the smart-phone, the user preference and favorite product will be saved and then that data is used for predictive maintenance.

- Smart vending machines can communicated each others, so if a product out of stock in a machine, the user can be routed to nearest machine

- For perishable items, the smart vending machines can reduce the price as the expiry date nears.

**Logistic IoT applications for smart logistic systems:**

1. Fleet Tracking

2. Shipment Monitoring

3. Remote Vehicle Diagnostics

 provided a system that can analyze messages sent from the vehicles to identify unexpected incidents and discrepancies between actual and planned data, so that remedial actions can be taken.

1.**Logistics Fleet Tracking**

- Vehicle fleet tracking systems use GPS technology to track the locations of the vehicles in the real- time.

- Cloud-based fleet tracking systems can be scaled up on demand to handle large number of vehicles.

- The vehicle locations and routers data can be aggregated and analyzed for detecting bottlenecks I the supply chain such as traffic congestions on routes, assignments and generation of alternative routes, and supply chain optimization .

Paper: - A Fleet Monitoring System for Advanced Tracking of commercial Vehicles [IEEE International Conference in Systems, Man and Cybernetics, 2006]

**2. Logistics Shipment Monitoring**

- Shipment monitoring solutions for transportation systems allow monitoring the conditi Proposed a system that can monitor the vibrations patterns of a container and its contents to reveal information related to its operating environment and integrity during transport, handling, and storage.

 proposed a cloud based framework for real time fresh food supply tracking and monitoring

- Container Integrity and Condition Monitoring using RF Vibration Sensor Tags [IEEE International Conference on Automation Science and Engineering, 2007]

ons inside containers. - E.g : Containers carrying fresh food produce can be monitored to prevent spoilage of food.

IoT based shipment monitoring systems use sensors such as temperature, pressure, humidity, for instance, to monitor the conditions inside the containers and send the data to the cloud, where it can be analyzed to detect food spoilage.

- Paper: - On a Cloud-Based Information Technology Framework for Data Driven Intelligent Transportation System [Journal of Transportation Technologies, 2013]

**3. Logistics Remote Vehicle Diagnostics**

- It can detect faults in the vehicles or warn of impending faults.

- These diagnostic systems use on-board IoT devices for collecting data on vehicle operation such as speed, engine RPM, coolent temperature, fault code number and status of various vehicle sub- system.

- Modern commercial vehicles support on-board diagnostic (OBD) standard such as OBD-II - OBD systems provide real-time data on the status of vehicle sub-systems and diagnostic trouble codes which allow rapidly identifying the faults in the vehicle.

- IoT based vehicle diagnostic systems can send the vehicle data to centralized servers or the cloud where it can be analyzed to generate alerts and suggest remedial actions.

** Agriculture IoT applications for smart agriculture:**

1. Smart Irrigation

2. Green House Control

**1.Agriculture Smart Irrigation**

- Smart irrigation system can improve crop yields while saving water.

- Smart irrigation systems use IoT devices with soil moisture sensors to determine the amount of moisture on the soil and release the flow of the water through the irrigation pipes only when the moisture levels go below a predefined threshold.

- It also collects moisture level measurements on the server on in the cloud where the collected data can be analyzed to plan watering schedules.

- Cultivar’s Rain Could is a device for smart irrigation that uses water valves, soil sensors, and a Wi-Fi enabled programmable computer. [http://ecultivar.com/rain-cloud-product-project/]

Provided a system that uses wireless sensor network to monitor and control the agricultural parameters like temperature and humidity in the real time for better management and maintenance of agricultural production.

**Agriculture Green House Control**

- It controls temperature, humidity, soil, moisture, light, and carbon dioxide level that are monitored by sensors and climatologically conditions that are controlled automatically using actuation devices.

- IoT systems play an importance role in green house control and help in improving productivity.

- The data collected from various sensors is stored on centralized servers or in the cloud where analysis is performed to optimize the control strategies and also correlate the productivity with different control strategies.

- Paper: - Wireless sensing and control for precision Green house management [ICST, 2012]

** Industry IoT applications in smart industry:**

1. Machine Diagnosis & Prognosis

2. Indoor Air Quality Monitoring

**1. Industry Machine Diagnosis & Prognosis**

- Machine prognosis refers to predicting the performance of machine by analyzing the data on the current operating conditions and how much deviations exist from the normal operating condition.

- Machine diagnosis refers to determining the cause of a machine fault.

- Sensors in machine can monitor the operating conditions such as temperature and vibration levels, sensor data measurements are done on timescales of few milliseconds to few seconds which leads to generation of massive amount of data.

- Case-based reasoning (CBR) is a commonly used method that finds solutions to new problems based on past experience.

- CBR is an effective technique for problem solving in the fields in which it is hard to establish a quantitative mathematical model, such as machine diagnosis and prognosis.

 provided a wireless solution for

 presented a hybrid sensor system for indoor air quality monitoring which contains both stationary sensor and mobile sensors.

- Indoor air quality monitoring using wireless sensor network [International Conference on Sensing Technology, 2012]

**2.Industry Indoor Air Quality Monitoring**

- Harmful and toxic gases such as carbon monoxide (CO), nitrogen monoxide (NO), Nitrogen Dioxide, etc can cause serious health problem of the workers.

- IoT based gas monitoring systems can help in monitoring the indoor air quality using various gas sensors.

- The indoor air quality can be placed for different locations

- Wireless sensor networks based IoT devices can identify the hazardous zones, so that corrective measures can be taken to ensure proper ventilation.

- Papers: - A hybrid sensor system for indoor air quality monitoring [IEEE International Conference on Distributed Computing in Sensor System, 2013] indoor air quality monitoring that measures the environmental parameters like temperature, humidity, gaseous pollutants , aerosol and particulate matter to determine the indoor air quality.

**Health & Lifestyle IoT applications in smart health & lifestyle:**

1. Health & Fitness Monitoring

2. Wearable Electronics

 Health & Lifestyle Health & Designed a wearable ubiquitous health-care monitoring system that uses integrated electrocardiogram (ECG), accelerometer and oxygen saturation (SpO2) sensors.

 Proposed an ubiquitous mobility approach for body sensor network in health-care.

- A wireless sensor network compatible wearable u-healthcare monitoring system using integrated ECG, accelerometer and SpO2 [International Conference of the IEEE Engineering in Medicine and Biology Society, 2008]

**1.Fitness Monitoring**

• Wearable IoT devices allow to continuous monitoring of physiological parameters such as blood pressure, heart rate, body temperature, etc than can help in continuous health and fitness monitoring.

• It can analyze the collected health-care data to determine any health conditions or anomalies.

• The wearable devices may can be in various form such as:

• Belts

• Wrist-bands

• Papers: - Toward ubiquitous mobility solutions for body sensor network health care [IEEE Communications Magazine, 2012]

**2. Health & Lifestyle Wearable Electronics**

• Wearable electronics such as wearable gadgets (smart watch, smart glasses, wristbands, etc) provide various functions and features to assist us in our daily activities and making us lead healthy lifestyles.

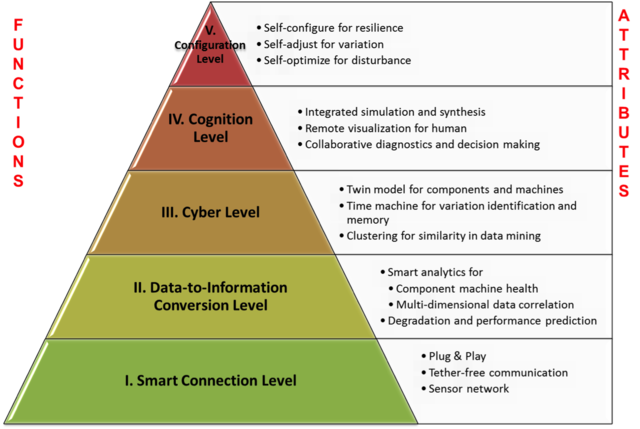
• Using the smart watch, the users can search the internet, play audio/video files, make calls, play games, etc.

• Smart glasses allows users to take photos and record videos, get map directions, check flight status or search internet using voice commands

• Smart shoes can monitor the walking or running speeds and jumps with the help of embedded sensors and be paired with smart-phone to visualize the data.

• Smart wristbands can tract the daily exercise and calories burnt.

<https://www.slideshare.net/khusuma/domain-specific-iot?from_action=save>



### ****Data Protocols****

[MQTT](https://mqtt.org/) (Message Queuing Telemetry Transport)  
"The MQTT protocol enables a publish/subscribe messaging model in an extremely lightweight way. It is useful for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium."  
[*-Additional resources*](http://postscapes2.webhook.org/cms#mqtt)

[MQTT-SN](https://mqtt.org/2013/12/mqtt-for-sensor-networks-mqtt-sn) (MQTT For Sensor Networks) - An open and lightweight publish/subscribe protocol designed specifically for machine-to-machine and mobile applications

-[Mosquitto](http://mosquitto.org/): An Open Source MQTT v3.1 Broker  
- [IBM MessageSight](https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?subtype=ca&infotype=an&appname=iSource&supplier=877&letternum=ENUSZP13-0146#h2-abstrx)

[CoAP](https://datatracker.ietf.org/doc/draft-ietf-core-coap/) (Constrained Application Protocol)  
"CoAP is an application layer protocol that is intended for use in resource-constrained internet devices, such as WSN nodes. CoAP is designed to easily translate to HTTP for simplified integration with the web, while also meeting specialized requirements such as multicast support, very low overhead, and simplicity. The CoRE group has proposed the following features for CoAP: RESTful protocol design minimizing the complexity of mapping with HTTP, Low header overhead and parsing complexity, URI and content-type support, Support for the discovery of resources provided by known CoAP services. Simple subscription for a resource, and resulting push notifications, Simple caching based on max-age."  
[*-Additional resources*](http://postscapes2.webhook.org/cms#coap)

- [SMCP](https://github.com/darconeous/smcp/tree/smcp-0.6)— A C-based CoAP stack which is suitable for embedded environments. Features include: Support draft-ietf-core-coap-13, Fully asynchronous I/O, Supports both BSD sockets and UIP.

[STOMP](https://stomp.github.io/implementations.html) - The Simple Text Oriented Messaging Protocol

[XMPP](https://xmpp.org/) (Extensible Messaging and Presence Protocol)  
"An open technology for real-time communication, which powers a wide range of applications including instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalized routing of XML data."  
[*-Additional resources*](http://postscapes2.webhook.org/cms#xmpp)

- [XMPP-IoT](https://github.com/joachimlindborg/XMPP-IoT)  
"In the same manor as XMPP silently has created people to people communication interoperable. We are aiming to make communication machine to people and machine to machine interoperable."

[Mihini/M3DA](https://wiki.eclipse.org/Mihini/M3DA_Specification)  
"The Mihini agent is a software component that acts as a mediator between an M2M server and the applications running on an embedded gateway. M3DA is a protocol optimized for the transport of binary M2M data. It is made available in the Mihini project both for means of Device Management, by easing the manipulation and synchronization of a device's data model, and for means of Asset Management, by allowing user applications to exchange typed data/commands back and forth with an M2M server, in a way that optimizes the use of bandwidth"

[AMQP](http://www.amqp.org/) (Advanced Message Queuing Protocol)  
"An open standard application layer protocol for message-oriented middleware. The defining features of AMQP are message orientation, queuing, routing (including point-to-point and publish-and-subscribe), reliability and security."  
- [Additional Resources](http://postscapes2.webhook.org/cms#amqp)

[DDS](http://portals.omg.org/dds/)(Data-Distribution Service for Real-Time Systems)  
"The first open international middleware standard directly addressing publish-subscribe communications for real-time and embedded systems."

JMS (Java Message Service) - A Java Message Oriented Middleware (MOM) API for sending messages between two or more clients.

[LLAP](http://openkontrol.org/llap/index.php/openkontrol/69-LLAP%20-%20Lightweight%20Local%20Automation%20Protocol)(lightweight local automation protocol)  
"LLAP is a simple short message that is sent between inteligent objects using normal text, it's not like TCP/IP, bluetooth, zigbee, 6lowpan, WiFi etc which achieve at a low level "how" to move data around. This means LLAP can run over any communication medium. The three strengths of LLAP are, it'll run on anything now, anything in the future and it's easily understandable by humans."

[LWM2M](http://yucianga.info/?p=786) (Lightweight M2M)  
"Lightweight M2M (LWM2M) is a system standard in the Open Mobile Alliance. It includes DTLS, CoAP, Block, Observe, SenML and Resource Directory and weaves them into a device-server interface along with an Object structure."

[SSI](https://en.wikipedia.org/wiki/Simple_Sensor_Interface_protocol) (Simple Sensor Interface)  
"a simple communications protocol designed for data transfer between computers or user terminals and smart sensors"

[Reactive Streams](http://www.reactive-streams.org/)  
"A standard for asynchronous stream processing with non-blocking back pressure on the JVM."

[ONS 2.0](http://www.gs1.org/gsmp/kc/epcglobal/ons)

[REST](https://en.wikipedia.org/wiki/Representational_state_transfer) (Representational state transfer) - RESTful HTTP  
-[*Additional Resources in context of IoT*](http://postscapes2.webhook.org/cms#http)

[*HTTP/2*](http://httpwg.org/specs/rfc7540.html) - Enables a more efficient use of network resources and a reduced perception of latency by introducing header field compression and allowing multiple concurrent exchanges on the same connection.  
[SOAP](https://en.wikipedia.org/wiki/SOAP) (Simple Object Access Protocol), JSON/XML, [WebHooks](http://wiki.webhooks.org/w/page/13385124/FrontPage), [Jelastic](http://jelastic.com/), [MongoDB](https://en.wikipedia.org/wiki/MongoDB)

[Websocket](https://websocket.org/)  
The WebSocket specification—developed as part of the HTML5 initiative—introduced the WebSocket JavaScript interface, which defines a full-duplex single socket connection over which messages can be sent between client and server. The WebSocket standard simplifies much of the complexity around bi-directional web communication and connection management.

[JavaScript / Node.js IoT projects](http://postscapes2.webhook.org/javascript-and-the-internet-of-things)

A list of IoT software projects like Contiki, Riot OS, etc can be found [here](http://postscapes2.webhook.org/internet-of-things-software-guide).

# software-defined networking (SDN)

Software-defined networking (SDN) is an architecture that aims to make networks agile and flexible. The goal of SDN is to improve network control by enabling enterprises and service providers to respond quickly to changing business requirements.

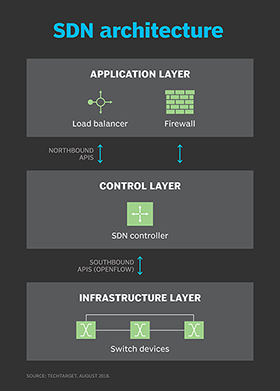
In a software-defined network, a network engineer or administrator can shape traffic from a centralized control console without having to touch individual switches in the network. The centralized [SDN controller](https://searchsdn.techtarget.com/definition/SDN-controller-software-defined-networking-controller) directs the switches to deliver network services wherever they're needed, regardless of the specific connections between a server and devices.

This process is a move away from traditional network architecture, in which individual network devices make traffic decisions based on their configured routing tables.

### SDN architecture

A typical representation of SDN architecture comprises three layers: the application layer, the control layer and the infrastructure layer.

The application layer, not surprisingly, contains the typical network applications or functions organizations use, which can include intrusion detection systems, load balancing or firewalls. Where a traditional network would use a specialized appliance, such as a firewall or load balancer, a software-defined network replaces the appliance with an application that uses the controller to manage [data plane](https://searchsdn.techtarget.com/definition/data-plane-DP) behavior.

SDN architecture separates the network into three distinguishable layers, connected through northbound and southbound APIs.

The control layer represents the centralized SDN controller software that acts as the brain of the software-defined network. This controller resides on a server and manages policies and the flow of traffic throughout the network.

The infrastructure layer is made up of the physical switches in the network.

These three layers communicate using respective [northbound and southbound](https://whatis.techtarget.com/definition/northbound-interface-southbound-interface) application programming interfaces ([APIs](https://searchmicroservices.techtarget.com/definition/application-program-interface-API)). For example, applications talk to the controller through its northbound interface, while the controller and switches communicate using southbound interfaces, such as [OpenFlow](https://whatis.techtarget.com/definition/OpenFlow) -- although other protocols exist.

There is currently no formal standard for the controller's northbound API to match OpenFlow as a general southbound interface. It is likely the OpenDaylight controller's northbound API may emerge as a de facto standard over time, given its broad vendor support.

### How SDN works

SDN encompasses several types of technologies, including functional separation, network virtualization and [automation](https://searchnetworking.techtarget.com/definition/network-automation) through programmability.

Originally, SDN technology focused solely on separation of the network [control plane](https://searchsdn.techtarget.com/definition/control-plane-CP) from the data plane. While the control plane makes decisions about how packets should flow through the network, the data plane actually moves packets from place to place.

In a classic SDN scenario, a packet arrives at a network switch, and rules built into the switch's proprietary firmware tell the switch where to forward the packet. These packet-handling rules are sent to the switch from the centralized controller.

The switch -- also known as a data plane device -- queries the controller for guidance as needed, and it provides the controller with information about traffic it handles. The switch sends every packet going to the same destination along the same path and treats all the packets the exact same way.

Software-defined networking uses an operation mode that is sometimes called adaptive or dynamic, in which a switch issues a route request to a controller for a packet that does not have a specific route. This process is separate from [adaptive routing](https://searchnetworking.techtarget.com/definition/adaptive-routing), which issues route requests through routers and algorithms based on the network topology, not through a controller.

The virtualization aspect of SDN comes into play through a virtual overlay, which is a logically separate network on top of the physical network. Users can implement end-to-end overlays to abstract the underlying network and segment network traffic. This microsegmentation is especially useful for service providers and operators with [multi-tenant](https://whatis.techtarget.com/definition/multi-tenancy) cloud environments and cloud services, as they can provision a separate virtual network with specific policies for each tenant.

### Benefits of SDN

With SDN, an administrator can change any network switch's rules when necessary -- prioritizing, deprioritizing or even blocking specific types of packets with a granular level of control and security. This is especially helpful in a [cloud computing](https://searchcloudcomputing.techtarget.com/definition/cloud-computing) multi-tenant architecture, because it enables the administrator to manage traffic loads in a flexible and more efficient manner. Essentially, this enables the administrator to use less expensive commodity switches and have more control over network traffic flow than ever before.

Other benefits of SDN are network management and end-to-end visibility. A network administrator need only deal with one centralized controller to distribute policies to the connected switches, instead of configuring multiple individual devices. This capability is also a security advantage because the controller can monitor traffic and deploy security policies. If the controller deems traffic suspicious, for example, it can reroute or drop the packets.

SDN also virtualizes hardware and services that were previously carried out by dedicated hardware, resulting in the touted benefits of a reduced hardware footprint and lower operational costs.

Additionally, software-defined networking contributed to the emergence of software-defined wide area network ([SD-WAN](https://searchsdn.techtarget.com/definition/SD-WAN-software-defined-WAN)) technology. SD-WAN employs the virtual overlay aspect of SDN technology, abstracting an organization's connectivity links throughout its WAN and creating a virtual network that can use whichever connection the controller deems fit to send traffic.

### Challenges with SDN

Security is both a benefit and a concern with SDN technology. The centralized SDN controller presents a single point of failure and, if targeted by an attacker, can prove detrimental to the network

Ironically, another challenge with SDN is there's really no established definition of software-defined networking in the networking industry. Different vendors offer various approaches to SDN, ranging from hardware-centric models and virtualization platforms to hyper-converged networking designs and controllerless methods.

Some networking initiatives are often mistaken for SDN, including white box networking, network disaggregation, network automation and programmable networking. While SDN can benefit and work with these technologies and processes, it remains a separate technology.

SDN technology emerged with a lot of hype around 2011, when it was introduced alongside the OpenFlow protocol. Since then, adoption has been relatively slow, especially among enterprises that have smaller networks and fewer resources. Also, many enterprises cite the cost of SDN deployment to be a deterring factor.

Main adopters of SDN include service providers, network operators, telecoms and carriers, along with large companies, like Facebook and Google, all of which have the resources to tackle and contribute to an emerging technology.

# Python Program to Merge Two Lists and Sort it

This is a Python Program to merge two lists and sort it.

Problem Description

The program takes two lists, merges them and sorts the merged list.

Problem Solution

1. Take in the number of elements for the first list and store it in a variable.  
2. Take in the elements of the list one by one.  
3. Similarly, take in the elements for the second list also.  
4. Merge both the lists using the ‘+’ operator and then sort the list.  
5. Display the elements in the sorted list.  
6. Exit.

Program/Source Code

Here is source code of the Python Program to merge two lists and sort it. The program output is also shown below.

PROGRAM

a=[]

c=[]

n1=int(input("Enter number of elements:"))

for i in range(1,n1+1):

b=int(input("Enter element:"))

a.append(b)

n2=int(input("Enter number of elements:"))

for i in range(1,n2+1):

d=int(input("Enter element:"))

c.append(d)

new=a+c

new.sort()

print("Sorted list is:",new)

Program Explanation

1. User must enter the number of elements for the first list and store it in a variable.  
2. User must then enter the elements of the list one by one using a for loop and store it in a list.  
3. User must similarly enter the elements of the second list one by one.  
4. The ‘+’ operator is then used to merge both the lists.  
5. The sort function then sorts the list in ascending order.  
6. The sorted list is then printed.

Runtime Test Cases

Case 1:

Enter number of elements:5

Enter element:10

Enter element:20

Enter element:35

Enter element:55

Enter element:71

Enter number of elements:2

Enter element:5

Enter element:37

Sorted list is: [5, 10, 20, 35, 37, 55, 71]

Case 2:

Enter number of elements:3

Enter element:2

Enter element:4

Enter element:8

Enter number of elements:3

Enter element:2

Enter element:4

Enter element:0

Sorted list is: [0, 2, 2, 4, 4, 8]