THE NEW COLLEGE

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INCREASE MY KNOWLEDGE

DEPARTMENT OF COMPUTER APPLICATIONS

(B.C.A)

E-Content

Subject	**: INTERNET OF THINGS**
Class	**: III B.C.A.,**
Unit	**: II**

UNIT-2: Home Automation, Cities, Environment, Energy, Retail, Logistics, Agriculture, Industry, Health and Lifestyle, M2M, Difference between IoT and M2M , SDN and NFV for IoT, Need for IoT Systems Management with NETCONF- YANG.

2.1 Introduction:

Internet of things applications span wide range of Dubai including homes, cities environment, energy systems, retail, logistics, industry, agriculture and health.

2.2 Home Automation

2.2.1 Smart lighting

Smart lighting for homes helps in saving energy by adapting the lighting to the ambient condition and switching on/off or dimming the lights when needed. Key enabling technologies for smart lighting include solid-state lighting such as LED light and IP enabled the lights.

For solid state lighting solution both spectral and temporal characteristics can be configured to adapt illumination to various needs. Smart lighting solutions for Home achieve energy saving by sensing the human movements and their environments and controlling the lights accordingly.

Wireless enabled and internet connected lights can be controlled remotely from IoT applications such as a mobile or web application. Smart lights with sensor for occupancy, Temperature Lux level etc can be configured to adapt the lighting based on the ambient conditions sensed, in order to provide a good ambience. In controllable LED lighting system is presented that is embedded with ambient intelligence gathered from a distributed smart wireless sensor network to optimize and control the lighting system to be more efficient and user oriented, A solid state lighting model is implemented on your wireless sensor network that provide services for sensing illumination changes and dynamically adjusting luminary brightness according to user preferences.

2.2.2 Smart Appliances

Modern homes have a number of appliances such as TVs, refrigerator, music system, washer / dryer etc. Managing and controlling these appliances can be cumbersome with the each appliance having its own controls or remote controls. Smart appliance makes the management easier and also provides status information to the user remotely.

Examples smart watches /dryers that can be controlled remotely and notify when the washing / driving cycle is complete smart thermostat Allow controlling the temperature remotely and can learn the user preferences smart refrigerator can keep track of the item stored and send update to the user when an item is low on stock.

Smart TV Allows user to search and stream videos and movies from the internet on a local storage drive, search TV channel schedule and fetch news weather updates and other content from the internet.

Open remote is an open source automation platform for homes buildings. Open remote is platform agnostic and works with standard hardware. With OpenRemote, user can control various appliances using mobile or web publications.

OpenRemote comprises of three components - a controller that manages scheduling and runtime integrations between device, a designer that allows you to create both configuration for the controller and create user interface design and control panel that allow you to interact with the devices and control them.

2.2.3 Intrusion Detection

Home Intrusion detection system used security cameras and sensor such as PIR sensors and door sensor to detect intrusion and raise alert. Alerts can be in the form of an SMS and an email sent to the user.

Advanced systems can even send detailed alert such as an image grab or a short video clip send to email attachment. cloud controlled intrusion detections system is described in that uses location aware services, where the geo location of each node of your home automation system used independently detected and the stored in the cloud in the event of Institutions the cloud services alert the accurate neighbors who are using the home automation system is independently detected and stored in the cloud.

Event of intrusion, the cloud services after the accurate neighbors or local police. In intrusion detection system based on UPnP technology is described. The system uses image processing to recognize the Institutions and extract institution subject and to generate Universal plug and play instant messaging for alert .

2.2.4 Smoke / Gas Detector

Smoke detectors are installed in home and buildings to detect smoke that is typically and early sign of Fire. Smoke detectors use optical detection class ionization for sampling techniques to detect smoke.

Alerts raised by smoke detectors can be in the form of signals to fire alarm system. Gas detectors can detect the presence of harmful gases such as carbon monoxide liquid Petroleum gas (LPG).

A Smoke / gas detector raise alerts in human was this describing where the problem is send or an SMS or email to the user or the local fire safety department and provide visual feedback on its status the design of the system that detects gas leakage on smoke and it gives visual level indication.

2.3 Cities

2.3.1 Smart Parking

Finding a parking space during rush hours in crowded cities can be time consuming and frustrating. Further for the more drivers blindly searching for parking spaces create additional traffic conditions for Star smart parking make the search for parking space easier and convenient for drivers.

Smart parking for powered by IoT system that detect the number of empty parking slots and send the information over the internet to smart parking application back ends.These applications can be accessed by the drivers from smartphones, tablets and in car navigation system .

In smart parking sensors are used for each parking slot, to detect whether the slot is empty or occupied. This information is aggregated by your local controller and then send over the internet to the database.

Design and implementation of a prototype smart parking system based on wireless sensor Network Technology with just like a remote parking monitoring ,automated guidance , and departing reservations mechanism .

2.3.2 Smart Lighting

Smart lighting system for road parks and building can help in saving energy. According to a IEA report, lightening is responsible for 19 % of global electricity use and around 6% of global Greenhouse gas emission.

Smart lighting allows lighting to be dynamically controlled and also adapted to the ambient conditions. Smart lights connected to the internet can be controlled remotely to configure lighting schedules and lighting intensity.

Lighting configuration can be set for different situations such as a foggy day, a festival etc. Smart. Lights equipped with the sensors and can communicate with other lights and exchange information on the sensed ambient conditions to adapt lightening.

2.3.3 Smart Road

Smart roads equipped with sensors can provide 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 safe and help in reducing traffic jams .

Information sense to from the roads can be communicated via internet to cloud based applications and social media and disseminated to the drivers who subscribed to such applications.

Distributed and autonomous systems of sensor networks notes for improving driving safety proposed system can provide the drivers and passengers with a consistent view of the road situations of a few hundred meters ahead of them or a few dozen miles away, so that they can react to potential dangers early enough.

2.3.4 Structural Health Monitoring

Structural health monitoring system uses a network of sensors to monitor the vibrations levels in the structures such as bridges and buildings. The data collected from the sensors is analyzed to assess the health of the structures.

By analyzing the data it is possible to detect cracks and mechanical breakdown, locate the damage to a structure and also calculate the remaining life of the structure. Using such systems advance warning can be given in the case of imminent failure of the structure.

An environmental effect removal based structural health monitoring schemes is an IoT environment is proposed. Since structural health monitoring schemes use large number of wireless sensor nodes which are powered by traditional batteries researchers are exploring energy harvesting Technologies to harvesting ambient energy, such as mechanical vibrations, sunlight and wind.

2.3.5 Surveillance

Surveillance of infrastructure, public transport and even 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 storage solutions. Cloud-based video analytics applications can be deployed to search for patterns for specific events from the video feed.

2.3.6 Emergency Response

IoT Systems can be used for monitoring the critical infrastructure in cities such as building, gas and water pipelines, public transport and power substation systems. IoT systems for fire directions, gas and water leakage directions can help in generating alerts and minimizing their effects on the critical infrastructure.

IoT systems for critical infrastructure monitoring enable aggregations and sharing of information is collected from large number of sensors. Cloud based architecture multi model information such as sensor data, audio, video feeds can be analyzed in near real-time to detect adverse event.

Response to alerts generated by such systems can be in the form of alerts sent to the public, re-routing of traffic, evacuation of the affected areas. Traffic management system for emergency services is describe the system adapt by dynamically adjusting traffic lights, changing related driving policies, recommending behavior change to drivers and applying essential security controls

2.4 Environment

2.4.1 Weather Monitoring

IoT- based weather monitoring system can collect data from a number of sensor attached such as temperature, humidity, pressure etc. and send the data to cloud based application and storage back-ends. The data collected in the cloud can then be analyzed and visualized by cloud based application.

Weather alerts can be sent to the subscribed users from such applications AirPi 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 .

2.4.2 Air Pollution Monitoring

IoT based air pollution monitoring system can monitor emission of harmful gases (CO2, CO. NO, NO2) by factories and automobiles using gases and dermatological sensors the collected data can be analyzed to make informed decisions on pollutions control approaches.

In real time air quality monitoring system is presented that comprises of several distributed monitoring stations that communicate via wireless with a backend server using machine to machine communication. In addition sums of GPRS modem and GPS module.

2.4.3 Noise Pollution Monitoring

Due to growing Urban Development, noise levels in cities have increased and even become alarmingly high in some cities. Noise pollution can cause health hazards for humans due to sleep destruction and stress. Noise pollution monitoring can help in generating noise maps for cities.

Urban noise maps can help the policy makers in urban planning and making policies to control noise level near Residency areas, schools and parks. IoT based noise pollution smart metering system use a number of noise monitoring station that are deployed at different places in a city.

The data on noise levels from the stations is collected on server or in the cloud. The data is then aggregated to generate noise map. In noise mapping study for a city is presented which revealed that the cities suffers from serious noise pollution .In the design of smart phone application is described that allows a user to continuously measure noise level and send it to a central server where all generated information is aggregated and mapped to a meaningful noise visualizations map.

2.4.4 Forest Fire Detection

Forest fires can cause damage to natural resources, property and human life. There can be different causes of forest fires including lightening, human negligence, volcanic eruptions and sparks from rock fall. Early deduction of forest fires can help in minimizing the damage.

IoT based forest fire detection systems can use a number of monitoring nodes deployed at a different locations in a forest. Each monitoring node collects measurements on ambient conditions including temperature, humidity, and light levels.

A system for early detection of forest fire is described in that provides early warning of a potential forest fire and estimate the scale and intensity of the fire if it materializes in a forest fire detection system based on wireless sensor networks is presented.

The system uses multi-criteria deduction which is implemented by the artificial neural network. The ANN fuses sensing data corresponding to multiple attributes of your forest fire such as temperature, humidity, infrared and divisible light to detect forest fire.

2.4.5 River Flood Detection

River flood can cause extensive damage to the natural and human resources and human life. River flood occurs due to continuous train for which cause the river level to rise and flow rates to increase rapidly. Early warnings of floods can be given by monitoring the water level and flow rate.

IoT based river flood monitoring system uses a number of sensor nodes that monitor the water level using ultrasonic sensors and flow rate using the flow velocity sensors. Data from a number of such sensor nodes is aggregated in a server or in the cloud.

Monitoring applications raise alert when rapid increase in water level and flow rate is detected in a river flood monitoring system is described that Measures River and weather conditions through wireless sensor nodes equipped with different sensors. The systems include water level monitoring module, and data processing module that provide flood information is in the form of raw data, predicted data, and video feed.

2.5 Energy

2.5.1 Smart grid is a data communication network integrated with electrical grid that collects and analyses data captured in real-time about power transmission, distribution and consumption. Smart grid Technology provides protective information and recommendations to utilities, their suppliers, and their customers on how best to manage power.

Smart Grids collect data regarding electricity generation (centralized or distributed conceptions (instantaneous or predictive) storage (or conversion of the energy into other forms), distributions and equipment health data.

Smart fleet use high speed, fully integrated two way communication real time information and power exchange. Smart meters can capture almost real time consumption, remotely control the conceptions of electricity and remotely switch off supply when required.

Power thefts can be prevented using smart metering by analyzing the data on power generation, transmission and consumption smart grid can improve efficiency throughout the electric system.

Storage collection and analysis of smart grids data in the cloud can help in dynamic smart grids data can improve energy usage levels via energy feedback to user coupled with real-time pricing information.

Real time demand response and management strategies can be used for lowering peak demand and the overall load via appliance control and energy storage mechanism.

Condition monitoring data collected from power generation and transmission system can help in detecting fault and predicting outage.

2.5.2 Renewable Energy System

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. Variable output produces local voltage swing that can impact power quality. Existing grids were designed to handle power flow from centralized to generation source to the loads through Transmission and distribution lines.

When distributed renewable energy sources are integrated into the grid, they create power bidirectional power flow for which the great were not originally designed to handle power flow from temperature generation sources to the loss through transmissions and distribution lines.

When Distributed renewable energy sources are integrated into the grid is a create power bi-directional power flows for which the grid were not originally designed. IoT based system integrated within Transformer at the point of interconnections measures the electrical variables and how much power is fed into the grid.

To ensure the grid stability one solution is to simply cut of the over protections. For wind energy systems, closed-loop controls can be used to regulate the voltage at points of interconnection

2.5.3 Prognostics

Energy systems (Smart grids, power plants, wind turbine forms) have a large number of critical components that must function correctly so that the system can perform their operations correctly.

For example a wind turbine has a number of critical components example bearing, turning gears, for instance that must be monitored carefully as wear and tear in such critical components or sudden change in operating conditions of the missions can result in failures. In system such as Power Grids, real time information using specialist electrical sensor is called phasor measurement unit (PMU) substations.

The information received from PMU must be monitored in real time for estimating the state of a system and for predicting failures. Energy systems have thousands of sensors that gather real time maintenance data continuously for condition monitoring and failure prediction purposes. IoT based prognostic real-time health management systems can predict performance of machine or energy Systems by analyzing the extent of deviations of the system from its normal operating profiles.

Analyzing massive amounts of maintenance data collected from sensors in energy systems and equipment can provide protections for the impending failures (potentially in real time) so that their reliability and availability can be improved. Prognostic health Management systems have been developed for different energy systems open PDC set of applications for processing of streaming time series data collected from phasor measurement units PMU in real time.

2.6 Retail

2.6.1 Inventory Management

Inventory management for retail has become increasingly important in recent years with the growing competition. While over stocking of products can result in additional storage expenses and risk under stocking can lead to loss of revenue. IoT system using radio frequency identification RFID tags can help in inventory management and maintaining the right inventory levels.

RFID tags attached to the products allow them to be tracked in real time so that the inventory levels can 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. An RFID database inventory management system for time sensitive materials is described.

2.6.2 Smart Payments

Smart Payments solutions contact list payments powered by technology such as near field communication and Bluetooth. Near field communication 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.

Customers can store credit card information in the NFC enabled Smart phones and make payment by bringing the smart phones and make payments by bringing the smart phones near the point of sale terminals . NFC may be used in combinations with Bluetooth, where NFC initiates initial pairing of devices to establish their Bluetooth connections while the actual data transfer takes place over Bluetooth.

2.6.3 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 machine allow user preferences to be remembered and the learnt with the time when a user moves from one vending machine to the other and pass the smart phone with the vending machines using specific interface is presented.

Users can save their preferences and favorite products sensor in a smart vending machine monitor its operations and send the data to the cloud which can be used for predictive maintenance. Smart vending machines can communicate with other vending machines in there vicinity and share their inventory levels so that the customers can be routed to the nearest machines in case product goes out of stock in a machine

2.7 Logistics

2.7.1 Route Generation and Scheduling

Modern transportation systems are driven by data collected from multiple sources which is process to provide a new services to the stockholders. By collecting large amount of data from various sources and processing the data into Useful information data driven.

Transportation system can provide new services such as advanced route guidance dynamic vehicle routing anticipating customer demand for pickup and delivery problem, for instance route generations and scheduling systems candidate end-to-end using combinations of road patterns and transportation smooth and feasible schedule based on the availability of vehicles.

2.7.2 Fleet Tracking

Vehicle fleet tracking system using GPS technology to track the locations of vehicle in real time. Cloud based fleet tracking systems can be scaled up on-demand to handle large number of vehicles.

Alerts can be generated in case of deviation in planned routes. The vehicle locations and routes data can be aggregated and analyzed for detecting bottlenecks in the supply chain such as a traffic conditions or route of elements and generations of alternative route and supply chain Optimization in a fleet tracking system for commercial vehicle is described the system can analyze messages sent from the vehicles to identify unexpected incidence and descriptions is between the actual and applied data.

2.7.3 Shipment Monitoring

Shipment monitoring solutions for Transportation systems allow monitoring the conditions inside container. For example, containers carrying Fresh Food produce can be monitored to prevent spoilage of food.

IoT based shipment monitoring system you sensor such as temperature pressure and humidity for instance to monitor the conditions inside the container and send the data to the cloud where it can be analyzed to detect food spoilage.

The analysis and interpretation of the data in the environmental conditions in the container and food truck positioning can enable more effective routing decisions and their time therefore it is possible to take remedial measures such as the food that has a limited time budget before it get rotten can be rerouted to a closer destinations, alerts can be raised to the driver and the distributor about the transit conditions, such as container temperature exceeding the allowed limit, humidity levels going out of the allowed limit.

For instance, and corrective actions can be taken before the food gets damaged. A Cloud-based frame work for real time fresh Food Supply tracking and monitoring was proposed . For fragile products vibrations levels during shipment can be tracked using accelerometer and gyroscope sensors attached to IoT device.

A system for monitoring container in integrity and operating conditions described. The system monitors the vibrations patterns on their container and its contents to reveal information related to its operating environment and integrity during transport handling and storage.

2.7.4 Remote Vehicle Diagnostics

Remote vehicle diagnostic systems can detect faults in the vehicles warn of impending fault. These Diagnostic system use on-board IoT devices for collecting data on vehicle operation such a speed, engine RPM, coolant temperature, fault code number ,and status of the various vehicle subsystem such data can be captured by integrating on-board diagnostic systems with IoT devices using protocols such as CAN bus.

Modern commercial vehicles support on-board diagnostics OBD standards such as OBD-II. OBD system provides real time data status of vehicle subsystems and diagnostic trouble code which Allow rapidly identifying the fault in the vehicle. IoT based vehicle diagnostic system can send the vehicle data to centralized serves or the cloud where it can be analyzed to generate alerts and suggest remedial actions.

2.8 Agriculture

2.8.1 Smart Irrigation

Smart irrigation systems can improve crop yield while saving water. Smart irrigation system using IoT devices with soil moisture sensors to determine the amount of moisture in the soil and realize the flow of water through the irrigation pipe only when the moisture level goes below a predefined threshold. Smart irrigation systems also collect Moisture level measurements on a server or in the cloud where they collected data can be analyzed to plant watering schedule.

2.8.2 Green House Control

Green house structures with glass or plastic roofs that provide conducive environment for growth of plants. The Climatologically conditions inside a Greenhouse can be monitored and controlled to provide the best conditions for growth of plants. The temperature, humidity, soil moisture, light and carbon dioxide levels are monitored using sensors and their climatologically conditions are controlled automatically using actuation devices.

IoT system plays an important role in greenhouse controlled 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.

The system uses wireless sensor network to monitor and control the agriculture parameters like temperature and humidity in real time for better management and maintenance of Agricultural production

2.9 Industry

2.9.1 Machine Diagnosis and Prognosis

Machine prognosis refers to predicting the performance of a machine by analyzing the data and the current operating conditions and how much deviations exist from the normal operating conditions. Machine diagnosis refers to determining the causes of a machine fault.

IoT plays a major role in both the prognosis s and Diagnostics of industrial machines. Industrial machines have a large number of components that must function correctly for the machine to perform its operations. Sensors in machine can monitor the operating conditions such as temperatures and vibrations levels. The sensor data measurements are done on time scale of few milliseconds to few seconds, which leads to generations of the massive amount of the data.

Case-based reasoning (CBR) is a commonly used method that finds solutions to new problem based on past experience. This past experience is organized and represented as case in a case base. CBR is an effective technique for problem solving in the field in which it is hard to establish a quantitative mathematical model, such as machine Diagnostics and prognosis.

Since foe each machine, data from a very large number of sensors is collected using search high-dimensional data for creation of a case library reduce the case retrieval efficiency. Data reduction and feature extraction methods are used to find the representatives set of ability as the of features.

2.9.2 Indoor Air Quality Monitoring

Monitoring indoor air quality in factories is important for health and safety of the workers. harmful and toxic gas such as carbon monoxide, nitrogen monoxide and Nitrogen dioxide etc t can cause serious health problems .IoT based gas monitoring system can help in monitoring the indoor air quality using various gas sensors. The indoor air quality can vary for different locations. Wireless sensor networks based IoT devices can identify the other hazardous zones, so that corrective measures can be taken to ensure proper ventilation

2.10 Health and Lifestyle

2.10.1 Health and fitness monitoring

Wearable IoT devices that are low non invasive and continuous monitoring of physiological parameters can help in continuous health and fitness monitoring. These wearable devices may be able to be in various forms such as built under wrist bands.

The wearable devices from a wireless sensor networks called body area networks in which the measurements from a number of wearable device are continuously send to a master nodes such as a smart phone which then send the data to the server or a cloud end for analysis and achieving. Healthcare providers can analyze the collected Healthcare data to determine any health conditions or anomalies.

2.10.2 Wearable Electronics

Wearable Electronics such as smart watches smart glasses wristband and fashion electronics (with electronic integrated in clothing and accessories ,example Google glass for Moto 360 smart watches provide various functions and future to assist us in our daily activities and making as lead healthy Lifestyle .

Smart watches the user can search the internet a play audio video file make calls with or without paired mobile phones, play games and use various kinds of mobile applications smart classes allow users to take photos and record videos ,get map directions check flight status and search the internet by using voice commands

2.11 IoT and M2M

2.11.1 M2M

Machine to machine (M2M) refers to networking of Machines for the purpose of remote monitoring and control and data exchange. The end-to-end architecture for M2M systems comprising of M2M area networks, Communications Network and application domain.

An M2M area network comprises of machines which have embedded hardware module for sensing actuation and communication. Various Communication protocols can be used for M2M local area network such as Zigbee, Bluetooth, Modbus M –bus, wireless, power LINE Communication, 6LoWPAN.

These Communications protocols provide connectivity between M2M nodes within and M2M area network. The Communications Network provides connectivity to remote m2m area network. Communication network can use wired or wireless network. The M2M area network use either proprietary or non IP based protocol.

The communication between the M2M nodes and the M2M Gateway is based on the communication protocol. M2M Gateway protocol translation to enable IP connectivity for M2M. M2M Gateway acts as a proxy performing translation from / to native protocol to M2M area network.

M2M data is gathered into point solution such as enterprise applications, service management application for remote monitoring applications. M2M has various application domain such as smart metering, Home Automation, industrial Automation, smart grid.

2.11.2 Difference between IoT and M2M

The difference between M2M and IoT are described as follows:

Communication protocols:

M2m and IoT can differ in how the communication between the machines is device happens. M2M uses other proprietary or not IP based communication protocol for communication within the M2M area networks. Commonly uses M2m protocol include Zigbee, Bluetooth, Modbus, wireless M-Bus, power line communication.

The focus of communication in M2M is usually on the protocols below the network layer. Focus of communication in IoT is usually a protocol in network layer such as http web sockets, MQTT, XMPP, DDS, and AMQP.

Machines in M2M vs. Things in IoT:

The “things “in IoT refers to physical objects that have unique identifier and can sense and communicate with the external environment or their internal physical status. Machines in M2M will be homogenous whereas Things in IoT will be heterogeneous. IoT system can include IoT devices of various types such as fire alarms, door alarms, lighting control devices.

Hardware versus software emphasis

While the emphasis of M2M is more on hardware with embedded modules, the emphasis of IoT is more on software.

Data collection and analysis

M2M data is collected in point solutions and often in on-premises storage infrastructure. The data in IoT is collected in the cloud (can be public, private or hybrid cloud).

Applications

M2M data is collected in point solutions and can be accessed by on premises application diagnosis applications, service management applications, and on-premises enterprise application.

IoT data is collected in the cloud and can be accessed by cloud applications such as analytics applications, enterprise applications, remote diagnosis and management applications, etc.

2.12 SDN and NFV for IoT

Software defined networking (SDN) and the network function virtualization (NFV) and their applications for IoT.

2.12.1 Software Defined Networking (SDN)

Software-Defined Networking (SDN) is a networking architecture that separates the control plane from the data plane and centralizes the network controller. Software-based SDN controllers maintain a unified view of the network and make configuration, management and provision simpler.

Key Elements of SDN

Centralized network controller

With Decoupled control and the data plan and centralized network controller, the network administrator can rapidly configure the network. SDN applications can be deployed

Programmable open API. These speeds have innovation as the network status no longer need to wait for other device vendors to embed features in their proprietary hardware.

Programmable open APIs

SDN architecture supports programmable open APIs for interface between the SDN application and control layers (Northbound interface).

Standard Communication Interface (Open Flow)

SDN architecture uses a standard communication interface between the control and infrastructure layers (Southbound interface). Open Flow, which is defined by the Open Networking Foundation (ONF) is the broadly accepted SDN protocol for the South bound interface.

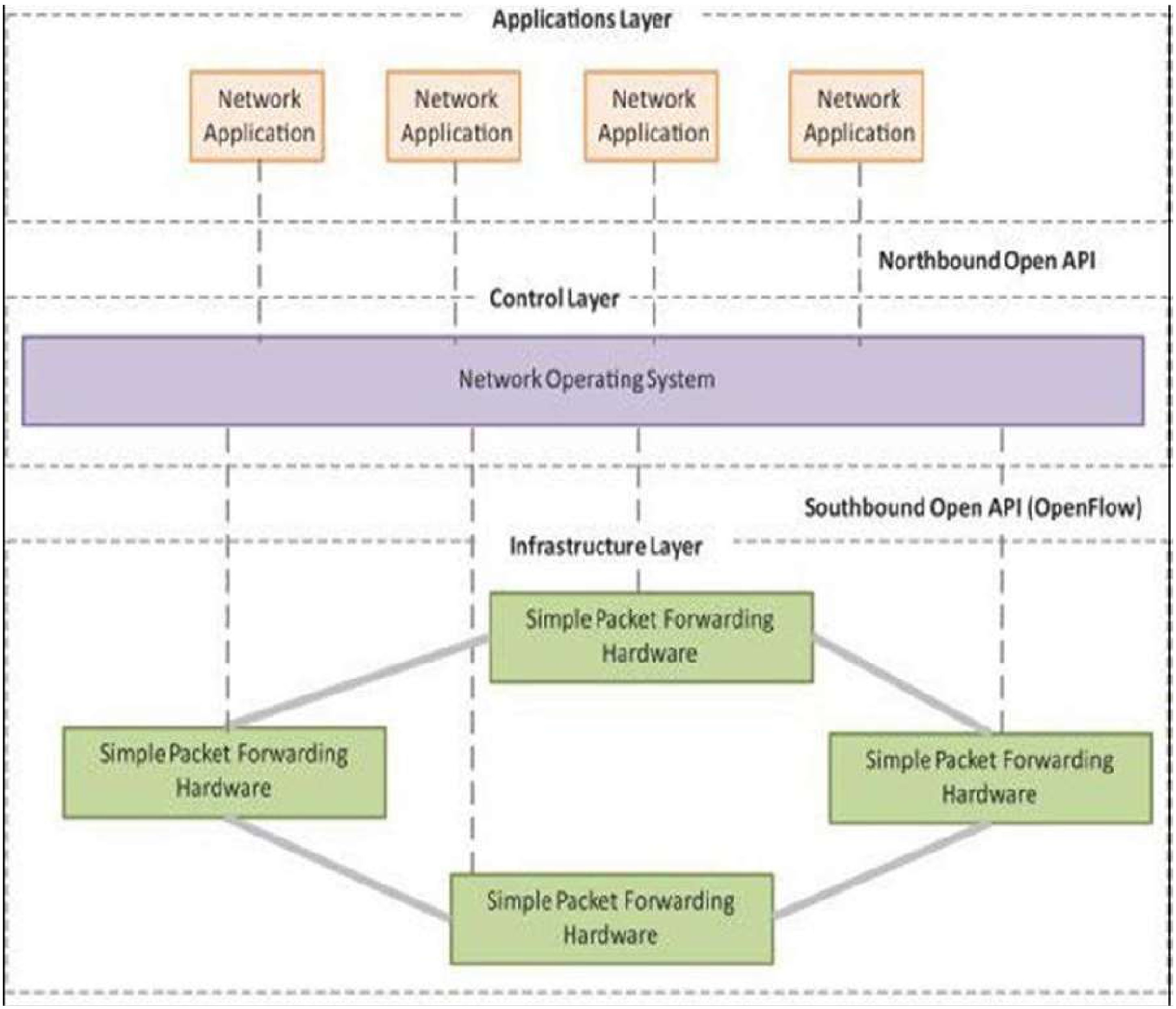

Fig 2.1 SDN Architecture

2.12.2 Network function virtualization:

Network functions virtualization (NFV) is the concept of replacing dedicated network appliances such as routers and firewalls with software running on general-purpose CPUs or virtual machines, operating on standard servers.

• NFV provides the infrastructure on which SDN can run. NFV and SDN are mutually beneficial to each other but not dependent.

• NFV replaces proprietary hardware network elements (NEs) with software running on standard servers, SDN deals with the replacement of standardized networking protocols with centralized control

The key elements of NFV architecture are:

1. NFV infrastructure (NFVI): NFV infrastructure layer consists of different layers such as hardware resources like computing resources (RAM, servers), storage resources (hard-disc), and network resources (routers, switch, and firewalls). Second layer is Virtualization layer which separates hardware and replaces it with software and third layer is virtualized resources such as virtual compute, network and storage

2. Virtualized network function (VNF): VNF is a software implementation is a network function which is capable of running over the NFV infrastructure (NFVI). Example: - vFirewall, vRouters

3. NFV management and orchestration: It has three parts

a. Virtualized infrastructure manager: It controls and manages network functions with NFVI resources and monitors virtualization layer.

b. VNF manager: It manages the life cycle of VNF such as initialize, update, query, scale, terminate etc.

c. Orchestrator: It manages the life cycle of network services which includes policy management, performance measurement and monitoring.

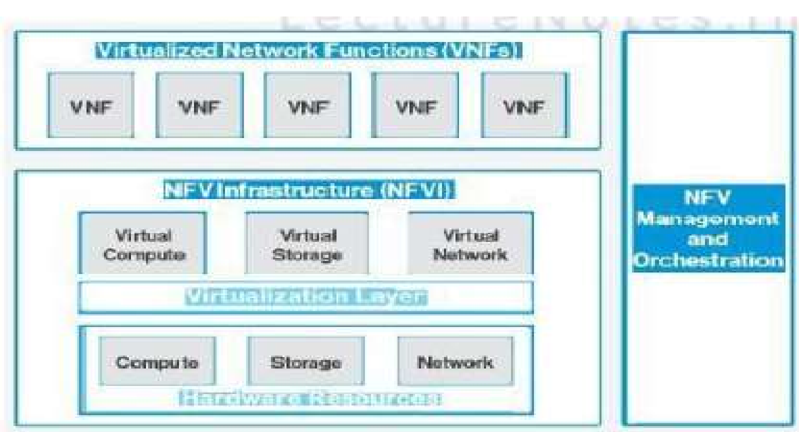

Fig 2.2 NFV Architecture

2.13 Need for IoT Systems Management

Managing multiple devices within a single system requires advanced management capabilities.

1) Automating Configuration: IoT system management capabilities can help in automating the system configuration.

2) Monitoring Operational & Statistical Data: Management systems can help in monitoring operational and statistical data of a system. This data can be used for fault diagnosis or prognosis.

3) Improved Reliability: A management system that allows validating the system configurations before they are put into effect can help in improving the system reliability.

4) System Wide Configurations: For IoT systems that consist of multiple devices or nodes, ensuring system wide configuration can be critical for the correct functioning of the system.

5) Multiple System Configurations: For some systems it may be desirable to have multiple valid configurations which are applied at different times or in certain conditions.

6) Retrieving & Reusing Configurations: Management systems which have the capability of retrieving configurations from devices can help in reusing the configurations for other devices of the same type.

NETCONF:

Network Configuration Protocol (NETCONF) is a session-based network management protocol. NETCONF allows retrieving state or configuration data and manipulating configuration data on network devices.

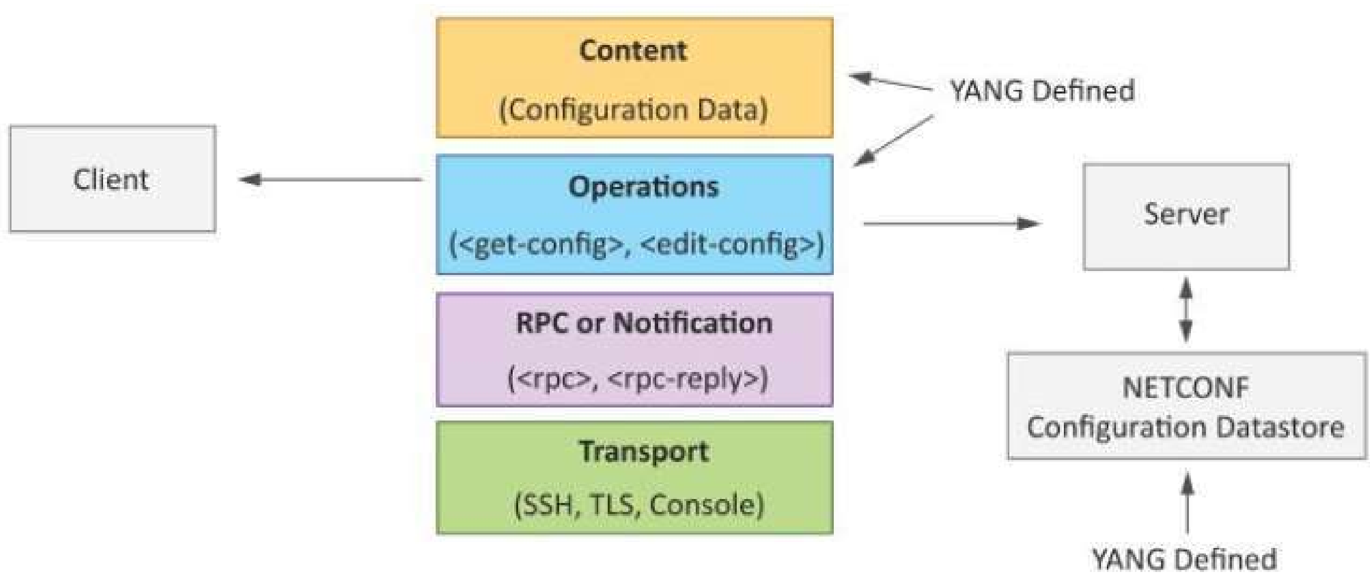

Fig 2.3 NETCONF protocol layers

- NETCONF works on SSH transport protocol.
- Transport layer provides end-to-end connectivity and ensure reliable delivery of messages.
- NETCONF uses XML-encoded Remote Procedure Calls (RPCs) for framing request and response messages.
- The RPC layer provides mechanism for encoding of RPC calls and notifications.
- NETCONF provides various operations to retrieve and edit configuration data from network devices.
- The Content Layer consists of configuration and state data which is XML-encoded.
- The schema of the configuration and state data is defined in a data modeling language called YANG.
- NETCONF provides a clear separation of the configuration and state data.
- The configuration data resides within a NETCONF configuration data store on the server.

YANG:

- YANG is a data modeling language used to model configuration and state data manipulated by the NETCONF protocol
- YANG modules contain the definitions of the configuration data, state data, RPC calls that can be issued and the format of the notifications.
- YANG modules define the data exchanged between the NETCONF client and server.
- A module comprises of a number of 'leaf' nodes which are organized into a hierarchical tree structure.
- The 'leaf' nodes are specified using the 'leaf' or 'leaf-list' constructs. Leaf nodes are organized using 'container' or 'list' constructs.
- A YANG module can import definitions from other modules.
- Constraints can be defined on the data nodes, e.g. allowed values.
- YANG can model both configuration data and state data using the 'config' statement.

2.14 IoT Systems Management with NETCONF-YANG

YANG is a data modeling language used to model configuration and state data manipulated by the NETCONF protocol.

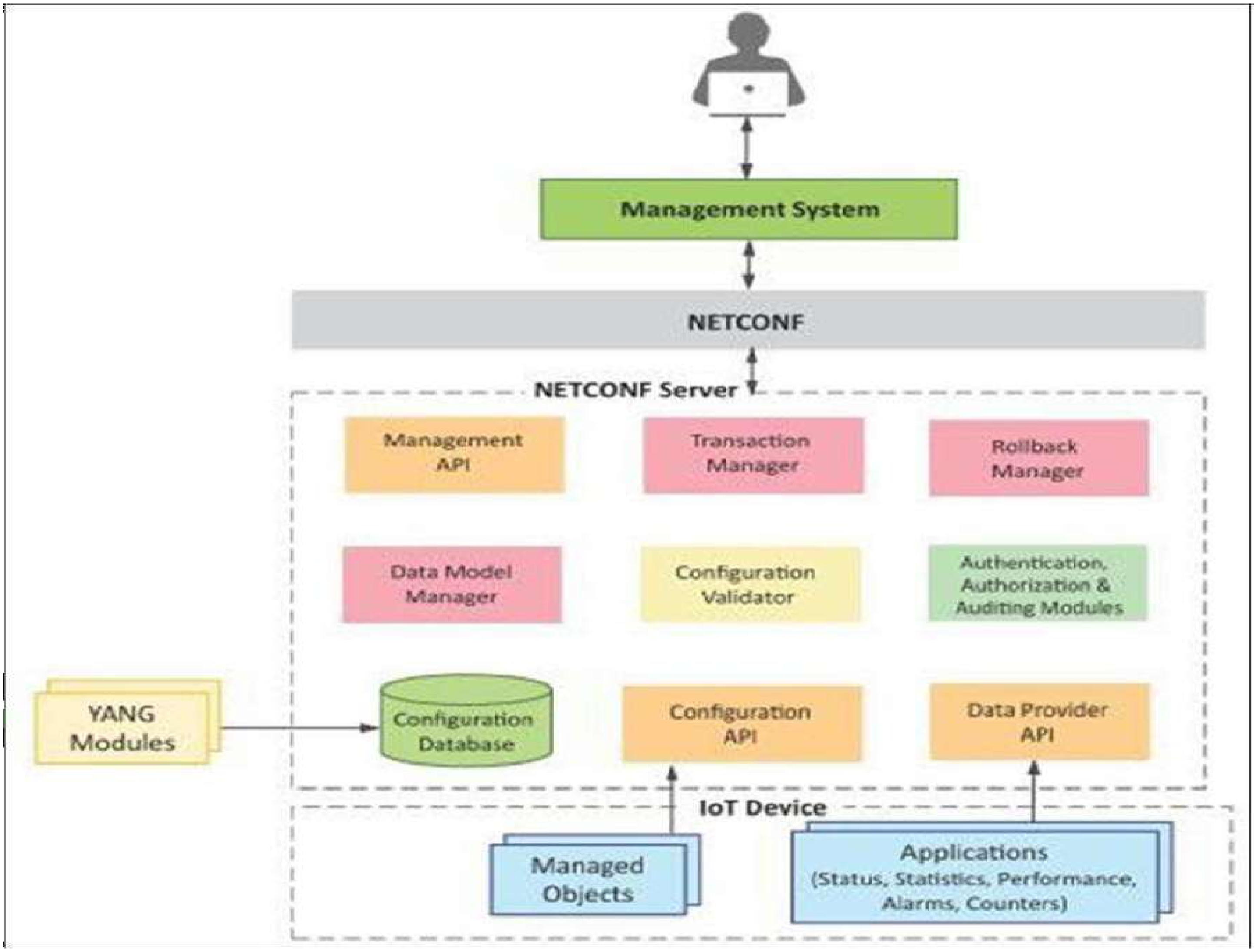

Fig 2.4 IoT Device Management with NETCONF-YANG – A Generic Approach

The generic approach of IoT device management with NETCONF-YANG. Roles of various components are:

1) Management System
2) Management API
3) Transaction Manager
4) Rollback Manager
5) Data Model Manager
6) Configuration Validator
7) Configuration Database
8) Configuration API
9) Data Provider API

1) Management System: The operator uses a management system to send NETCONF messages to configure the IoT device and receives state information and notifications from the device as NETCONF messages.
2) **Management API:** allows management application to start NETCONF sessions.
3) **Transaction Manager:** executes all the NETCONF transactions and ensures that ACID properties hold true for the transactions.
4) **Rollback Manager:** is responsible for generating all the transactions necessary to rollback a current configuration to its original state.
5) **Data Model Manager:** Keeps track of all the YANG data models and the corresponding managed objects. Also keeps track of the applications which provide data for each part of a data model.
6) **Configuration Validator:** checks if the resulting configuration after applying a transaction would be a valid configuration.
7) **Configuration Database:** contains both configuration and operational data.
8) **Configuration API:** Using the configuration API the application on the IoT device can be read configuration data from the configuration data store and write operational data to the operational data store.
9) **Data Provider API:** Applications on the IoT device can register for callbacks for various events using the Data Provider API. Through the Data Provider API, the applications can report statistics and operational data.

Steps for IoT device Management with NETCONF-YANG
1) Create a YANG model of the system that defines the configuration and state data of the system.
2) Complete the YANG model with the _Inc tool'which comes with Libnetconf.
3) Fill in the IoT device management code in the Trans API module.
4) Build the callbacks C file to generate the library file.
5) Load the YANG module and the TransAPI module into the Netopeer server using Netopeer manager tool.
6) The operator can now connect from the management system to the Netopeer server using the NetopeerCLI.
7) Operator can issue NETCONF commands from the Netopeer CLI. Command can be issued to Change the configuration data, get operational data or execute an RPC on the IoT device.