Introduction to Internet of Things

Week 7

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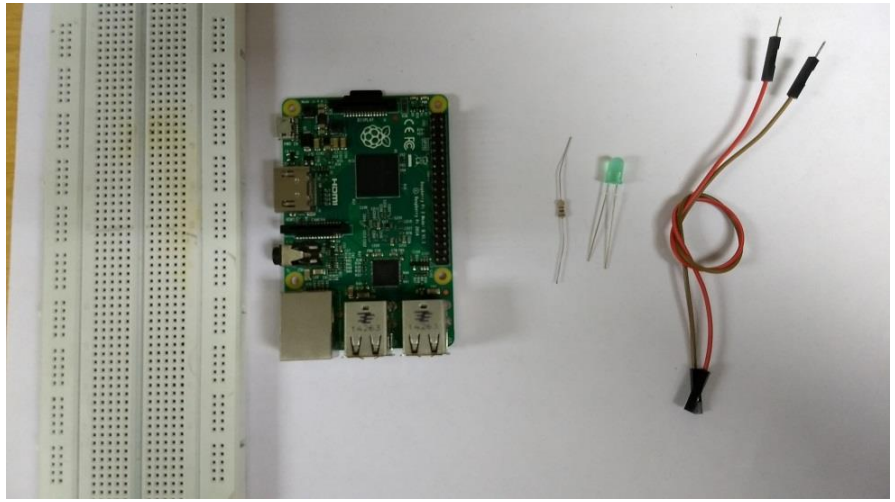
IoT: Remote Data Logging

Internet Of Things

- Creating an interactive environment
- Network of devices connected together



Remote data logging

- Collect data from the devices in the network
- Send the data to a server/remote machine
- Control the network remotely

System Overview 1

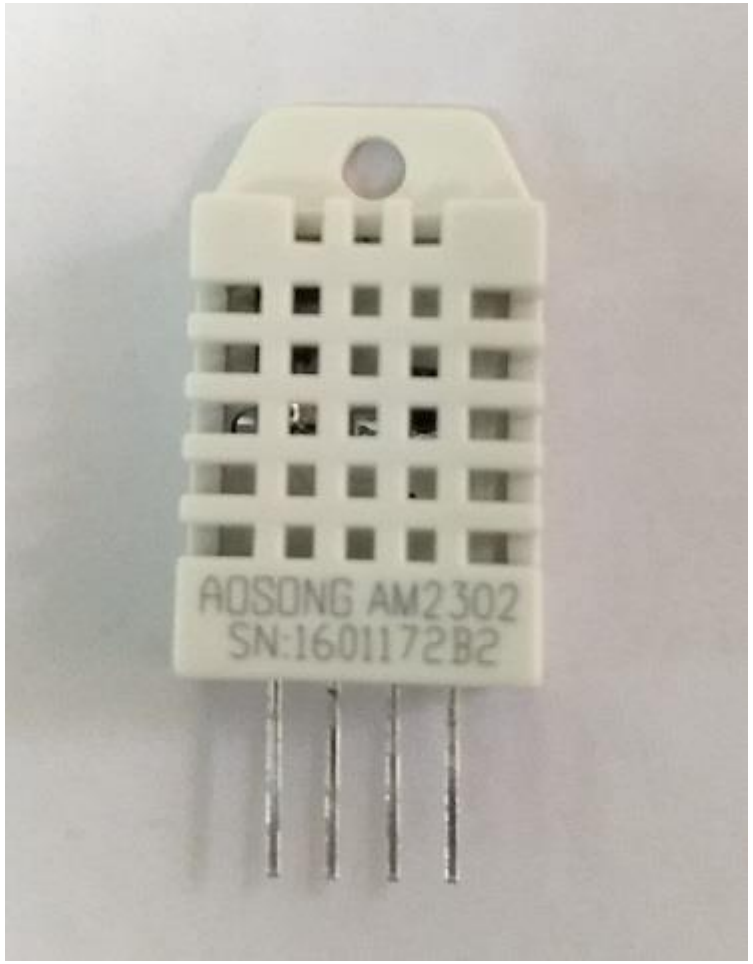
- A network of Temperature and humidity sensor connected with Raspberry Pi
- Read data from the sensor
- Send it to a Server
- Save the data in the server

Requirements

- DHT Sensor
- 4.7K ohm resistor
- Jumper wires
- Raspberry Pi

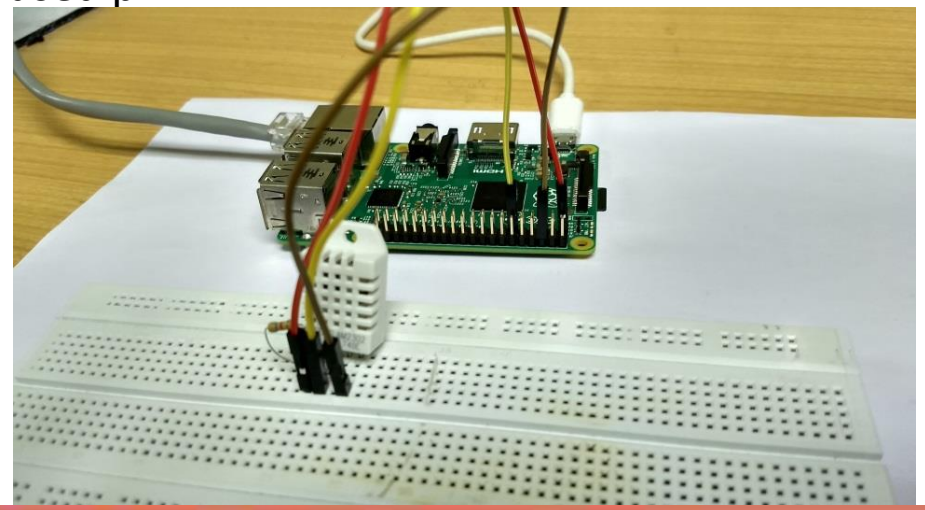
IoT: DHT

- Digital Humidity and Temperature Sensor (DHT)
- PIN 1, 2, 3, 4 (from left to right)
  - PIN 1- 3.3V-5V Power supply
  - PIN 2- Data
  - PIN 3- Null
  - PIN 4- Ground



Sensor-Raspberry Pi Interface

- Connect pin 1 of DHT sensor to the 3.3V pin of Raspberry Pi
- Connect pin 2 of DHT sensor to any input pins of Raspberry Pi, here we have used pin 11
- Connect pin 4 of DHT sensor to the ground pin of the Raspberry Pi



Read Data from the Sensor

- Adafruit provides a library to work with the DHT22 sensor
- Install the library in Raspberry Pi
- Use the function Adafruit_DHT.read_retry() to read data from the sensor

```
 GNU nano 2.2.6                    File: IOTSR.py

import RPi.GPIO as GPIO
from time import sleep

import Adafruit_DHT

GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)

sensor = Adafruit_DHT.AM2302  # create an instance of the sensor type

print ('Getting data from the sensor')

#humidity and temperature are 2 variables that store the values received from the sensor
humidity, temperature = Adafruit_DHT.read_retry(sensor,17)

print ('Temp={0:0.1f}*C humidity={1:0.1f}%'.format(temperature, humidity))
```

```
pi@raspberrypi:~ $ python IOTSR.py
Getting data from the sensor
Temp=26.1*C humidity=65.9%
pi@raspberrypi:~ $
```

Sending Data to Server

Socket Programming:

- Creates a two-way communication between two nodes in a network
- The nodes are termed as Server and Client
- Server performs the task/service requested by the client

Sending data to Server using network protocols

- Create a server and client
- Establish connection between the server and the client
- Send data from the client to the server

Creating a socket:

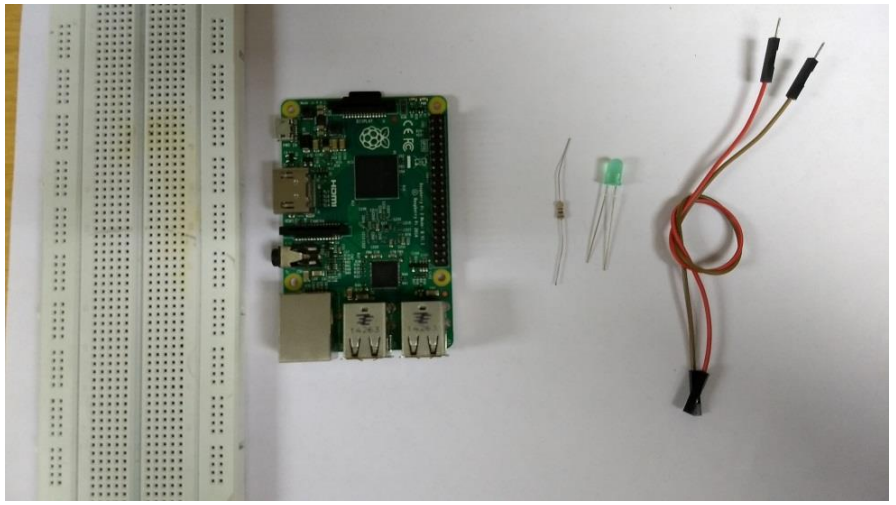
s = socket.socket (SocketFamily, SocketType, Protocol=0)

- SocketFamily can be AF_UNIX or AF_INET
- SocketType can be SOCK_STREAM or SOCK_DGRAM
- Protocol is set default to 0

IoT: Remote Data Logging

System Overview 2

- A network of Temperature and humidity sensor connected with Raspberry Pi
- Read data from the sensor
- Send it to a Server
- Save the data in the server
- **Data Splitting**
- **Plot the data**



- Create interface as followed in previous overview.
- Use the Adafruit library for DHT22 sensor to read the sensor data.
- Sending data to server using socket programming
- Data from the client needs to be processed before it can be used further
  - Data splitting/filtering
  - Data plotting

Data Processing

Data splitting/filtering:

- Data from the client is saved in a text file
- The values are separated by a comma(‘ , ’)

message = str(h)+','+str(t)

- Split() function can be used to split a string into multiple strings depending on the type of separator/delimiter specified.

Example:

Data= ‘sunday,monday,tuesday’ **Data.split(“,”)** **[‘sunday’,’monday’,’tuesday’]**	#Data is a string with 3 words separated by a comma # split the data whenever a “,” is found # Gives 3 different strings as output

Data Processing

Plotting the data:

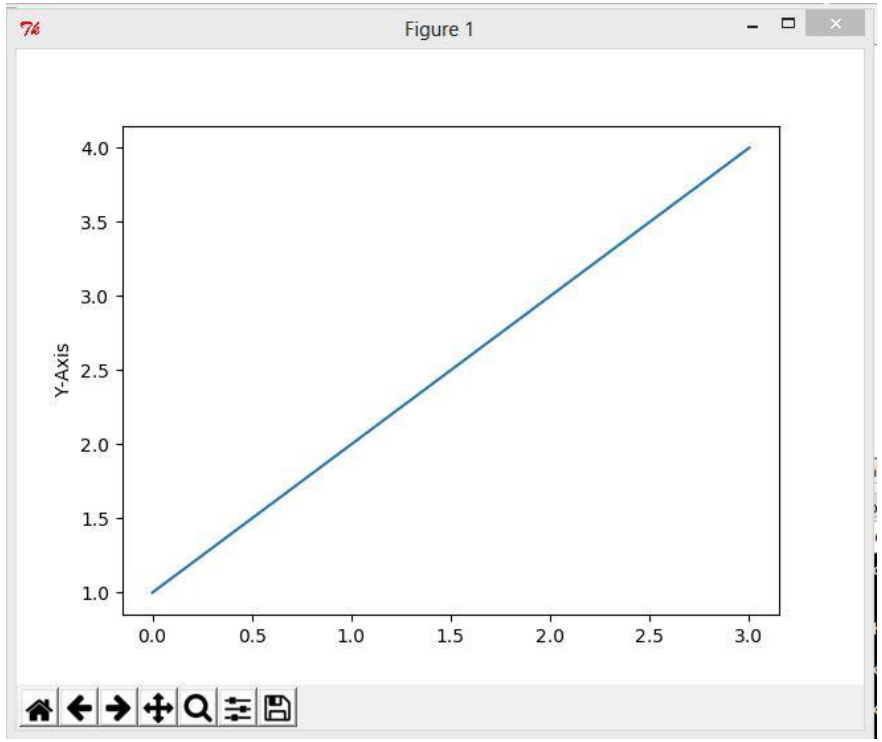
- MATPLOTLIB is a python library used to plot in 2D
- Plot(x,y): plots the values x and y
- xlabel('X Axis'): Labels the x-axis
- ylabel('Y Axis'): Labels the y-axis
- title("Simple Plot"): Adds title to the plot

```
import matplotlib.pyplot as myplot
myplot.plot([1,2,3,4])
myplot.ylabel("Y-Axis")
myplot.show()
```

Plotting the data:

import matplotlib.pyplot as myplot
myplot.plot([1,2,3,4])
myplot.ylabel('Y-Axis')
myplot.show()

By default the values are taken for y-axis, values for x-axis are generated automatically starting
from 0



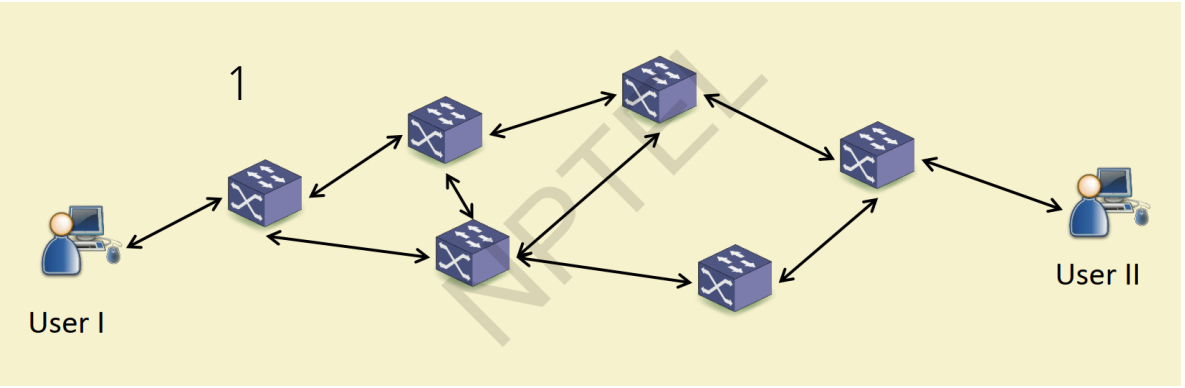
Functions Used in Plotting Data

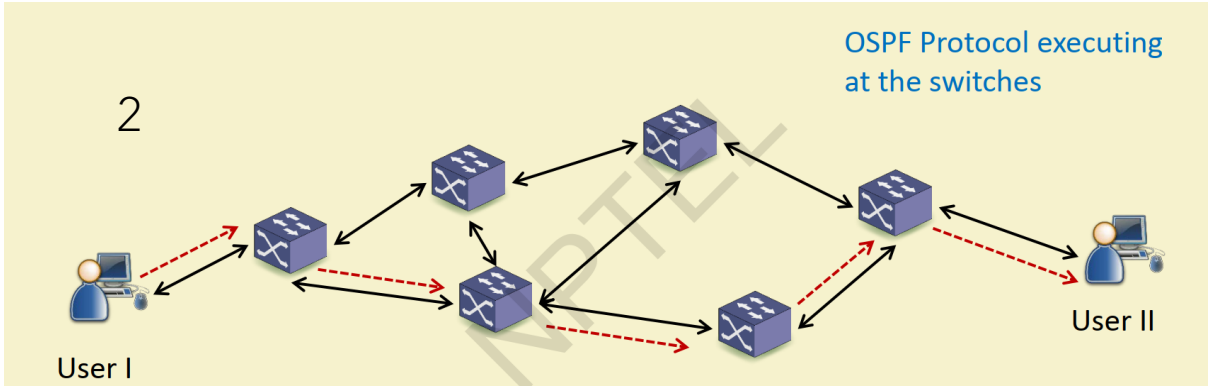
Some other common functions used in plotting:

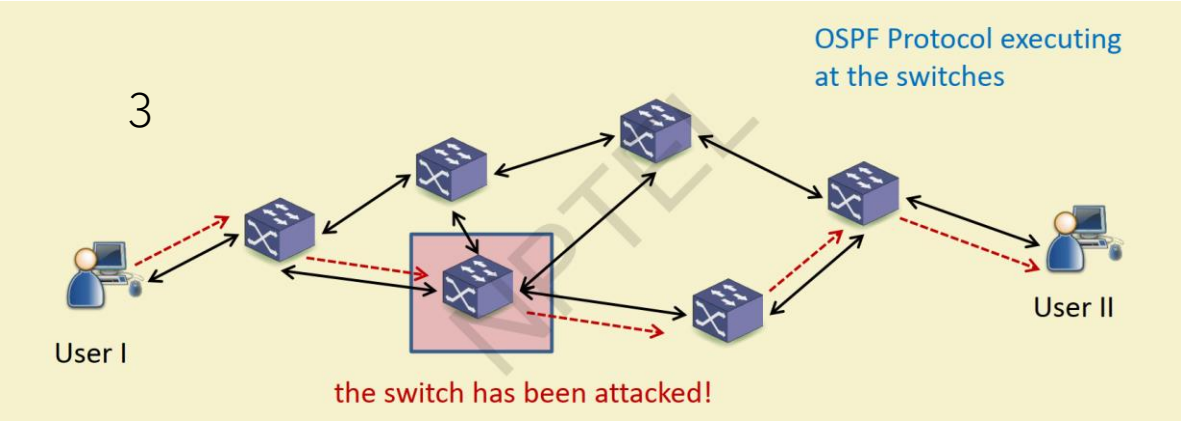
- figure(): Creates a new figure
- grid(): Enable or disable axis grids in the plot
- ion(): turns on the interactive mode
- subplot(): Adds subplot in a figure
- Close(): Close the current figure window
- Scatter(): make a scatter plot of the given points

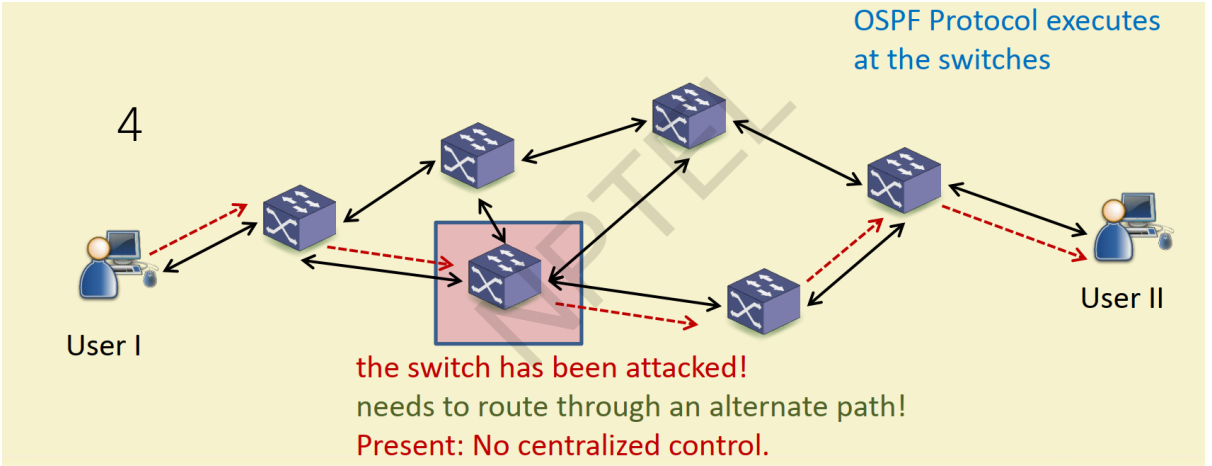
Software Defined Networking

Overview of current Network





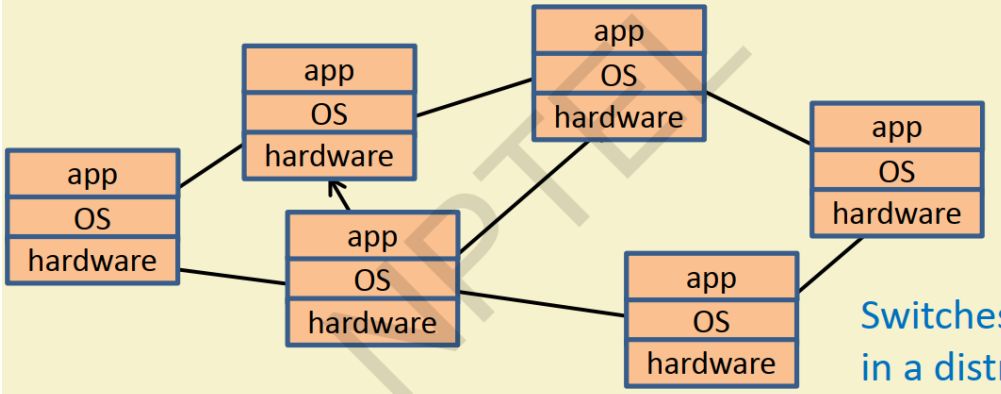




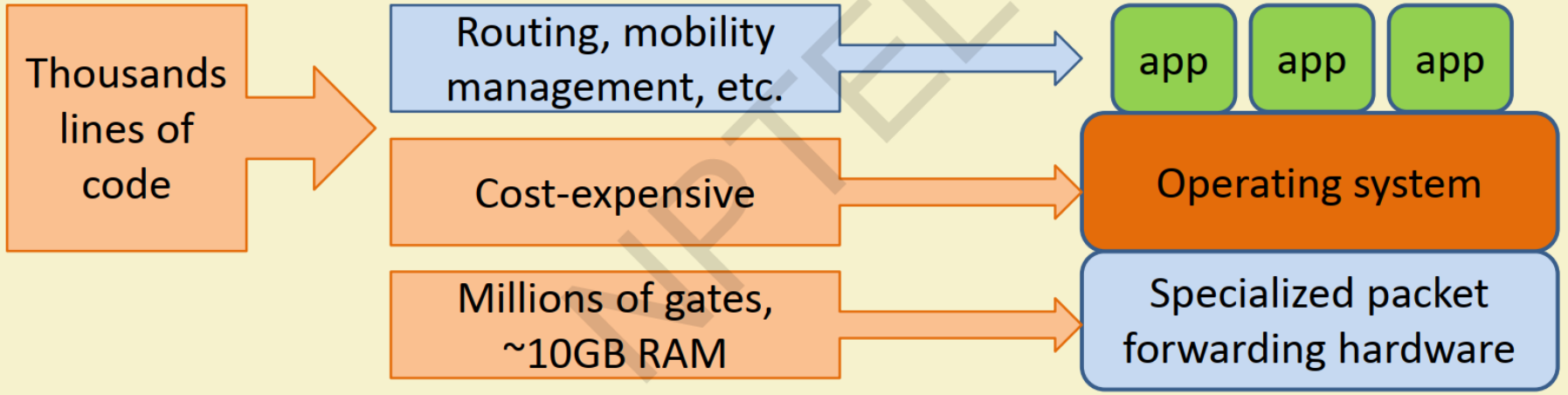
Software Defined Networking

Limitations of current Network

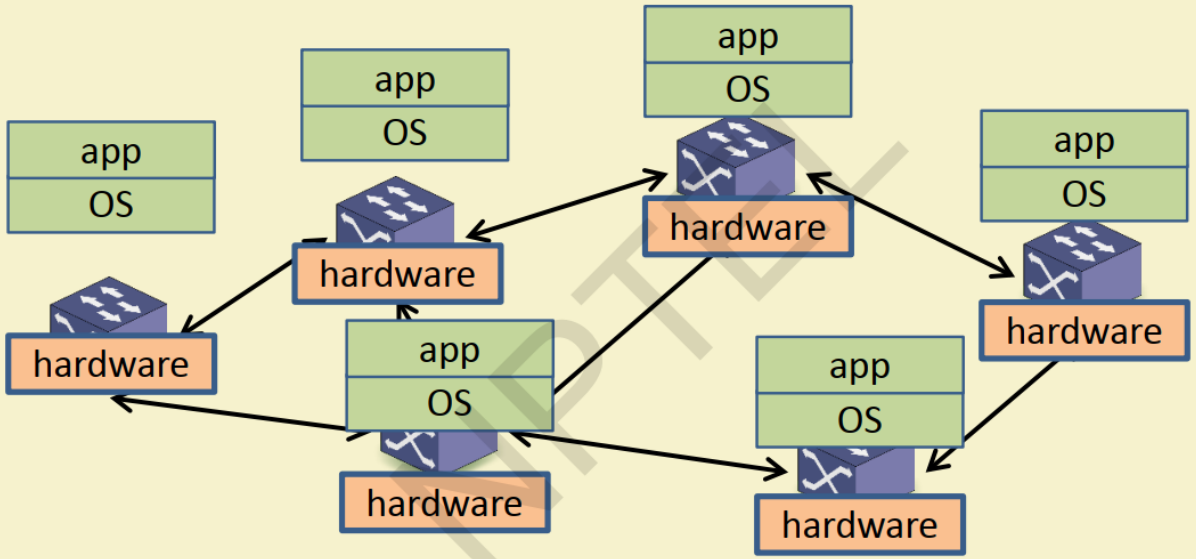
- ✓ Vendor-specific architecture of switches limits dynamic configuration according to application-specific requirements.
- ✓ Switches are required to configure according to the installed operating system (OS).
- ✓ Centralized control is not feasible in traditional network.

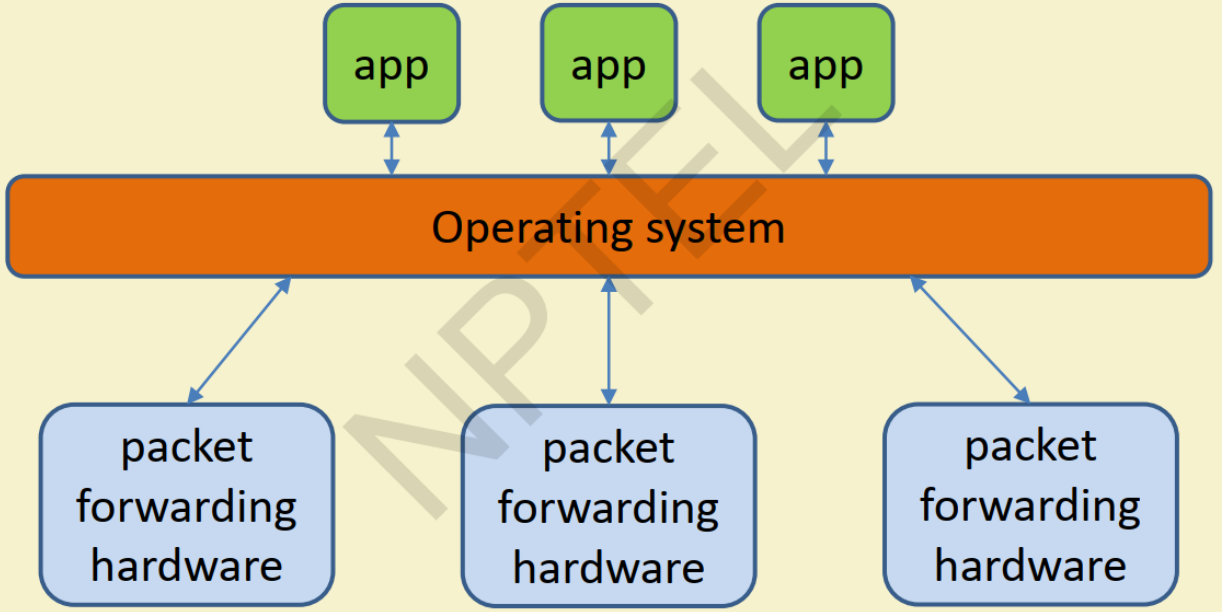


Switches forward traffic in a distributed manner. They do not have a global view of the network



Current Network to Software Defined Networking





Origin of Software Defined Networking

✓ 2006: At Stanford university, a team proposes a clean-slate security architecture (SANE) to control security policies in a centralized manner instead of doing it at edges.

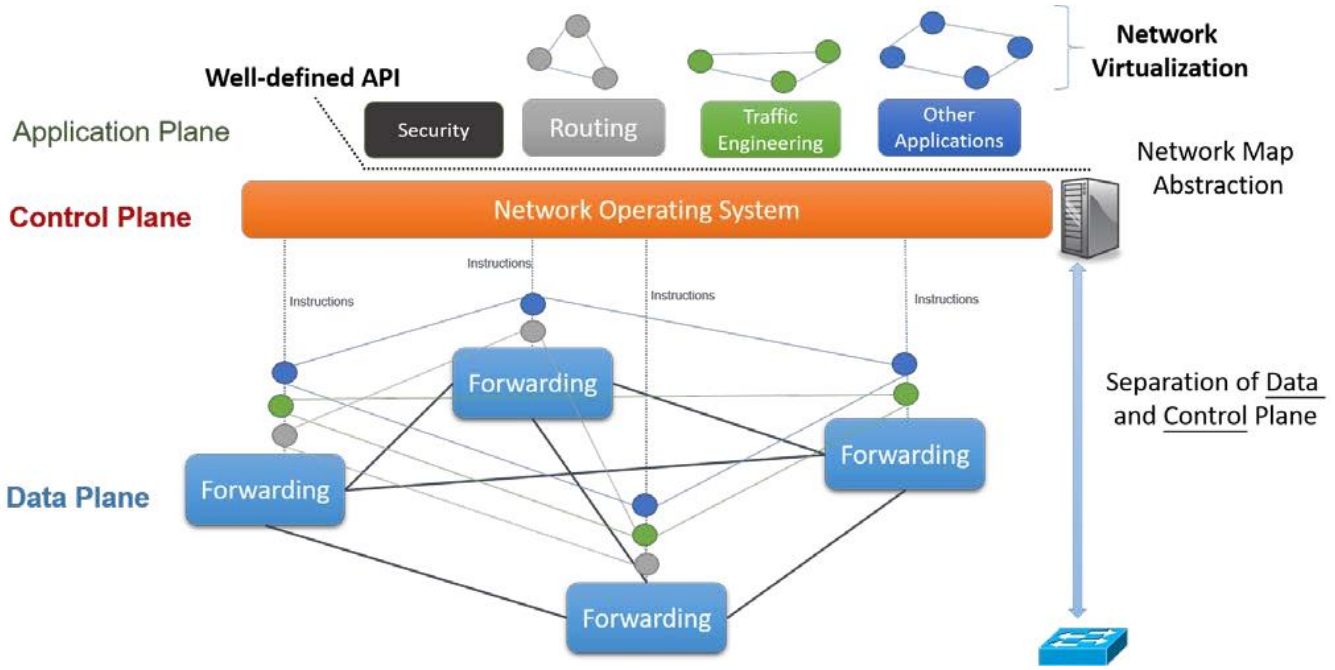
✓ 2008: The idea of *software-defined network* is originated from OpenFlow project (*ACM SIGCOMM 2008*).

✓ 2009: Stanford publishes OpenFlow V1.0.0 specs.

✓ June 2009: Nicira network is founded.

✓ March 2011: Open Networking Foundation is formed.

✓ Oct 2011: First Open Networking Summit. Many Industries (Juniper, Cisco announced to incorporate.



SDN Architecture

Basic Concept of Software Defined Networking

- ✓ Separate control logic from hardware switches
- ✓ Define the control logic in a centralized manner
- ✓ Control the entire network including individual switches
- ✓ Communication between the application, control, and data planes are done through APIs

Components/Attributes of SDN

- ✓ Hardware switches
- ✓ Controller
- ✓ Applications
- ✓ Flow-Rules
- ✓ Application programming interfaces (APIs)

Current Status of SDN

- ✓ Companies such as Google have started to implement SDN at their datacenter networks.
- ✓ It is required to change the current network with SDN in a phased manner.
- ✓ Operational cost and delay caused due to link failure can be significantly minimized.

Challenges

- ✓ Rule placement
- ✓ Controller placement

Rule Placement

Rule Placement

- ✓ Switches forward traffic based on a rule – 'Flow-Rule' – defined by the centralized controller.
  - Traditionally, Routing Table in every switch (L3 switch/router). SDN maintains Flow Table at every switch.
  - Flow-Rule: Every entry in the Flow Table.
- ✓ Each rule has a specific format, which is also defined by a protocol (e.g., OpenFlow).

Match SDN Applications First and Use Normal For Unmatched Packets (Hybrid Default Forwarding)

Priority	Ingress Port	MAC Source Address	MAC Destination	Protocol	Vlan ID	IP Source Address	IP Destination	Source Port	Destination Port	Instructions
10000	*	*	*	TCP	*	*	10.1.1.20/32	*	80	Forward to Port 1
5000	*	*	*	*	*	*	10.1.1.0/24	*	*	Forward to Port 2
300	*	*	*	*	2600	*	*	*	*	Send to Controller
0	*	*	*	*	*	*	*	*	*	OF Normal

Challenges in Rule Placement

Challenge 1

✓ Size of ternary content-addressable memory (TCAM) is limited at the switches.

- Limited number of rules can be inserted.

✓ Fast processing is done using TCAM at the switches.

✓ TCAM is very cost-expensive.

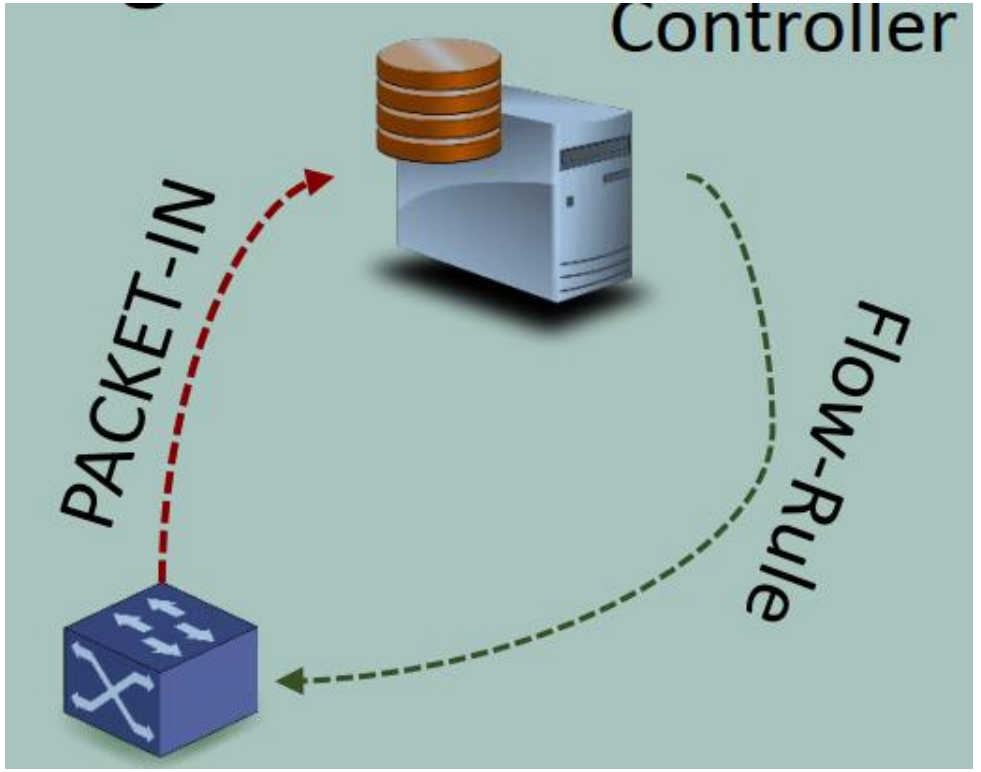
Challenge 2

✓ On receiving a request, for which no flow-rule is present in the switch, the switch sends a *PACKET-IN* message to the controller.

✓ The controller decides a suitable flow-rule for the request.

✓ The flow-rule is inserted at the switch.

✓ Typically, 3-5ms delay is involved in a new rule placement



Rule Placement

- ✓ How to define/place the rules at switches, while considering available TCAM.
- ✓ How to define rules, so that less number of *PACKET-IN* messages are sent to controller.

Open Flow Protocol

Open Flow Protocol

✓ Only one protocol is available for rule placement – OpenFlow.

✓ It has different versions – 1.0, 1.1, 1.2, 1.3, etc. – to have different number of match-fields.

✓ Different match-fields

- Source IP
- Destination IP
- Source Port
- Priority
- etc.

Match SDN Applications First and Use Normal For Unmatched Packets (Hybrid Default Forwarding)

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0	*	*	*	*	*	*	*	*	*	OF Normal

Open Flow Protocol

How much time a flow-rule is to be kept at the switch?

✓ **Hard timeout**

- All rules are deleted from the switch at hard timeout.
- This can used to reset the switch.

✓ **Soft timeout**

- If NO flow is received associated with a rule for a particular time, the rule is deleted.
- This is used to empty the rule-space by deleting an unused rule.

✓ SDN is NOT OpenFlow

- SDN is a technology/concept
- OpenFlow is a protocol used to communicate between data-plane and control-plane.
- We may have other protocols for this purpose. However, OpenFlow is the only protocol present today

OpenFlow Switch Software

- ✓ **Indigo:** Open source, it runs on Mac OS X.
- ✓ **LINC:** Open source, it runs on Linux, Solaris, Windows, MacOS, and FreeBSD.
- ✓ **Pantou:** Turns a commercial wireless router/access point to an OpenFlow enabled switch. OpenFlow runs on OpenWRT.
- ✓ **Of13softswitch:** User-space software switch based on Ericsson TrafficLab 1.1 softswitch.
- ✓ **Open vSwitch:** Open Source, it is the MOST popular one present today.

APIs in SDN

✓ **Southbound API**

- Used to communicate between control layer and infrastructure layer.
- OpenFlow protocol is used.

✓ **Northbound API**

- Used to communicate between control layer and application layer.
- Standard APIs are used.

✓ **East-Westbound APIs**

- Used to communicate among multiple controllers in the control layer.

Controller Placement

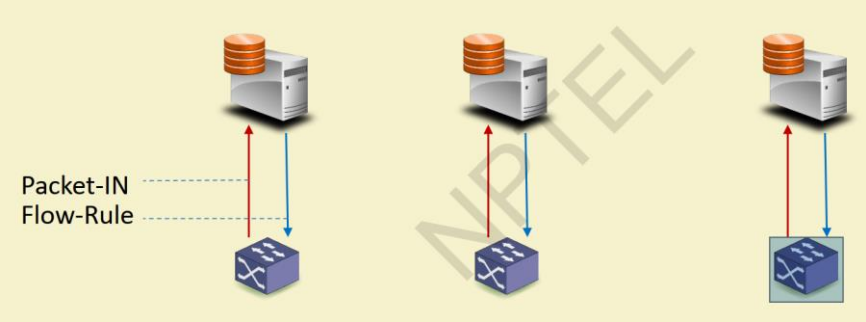
Controller Placement 1

- ✓ Controllers define flow-rule according to the application specific requirements.
- ✓ The controllers must be able to handle all incoming requests from switches.
- ✓ Rule should be placed without incurring much delay.
- ✓ Typically, a controller can handle 200 requests in a second (through a single thread).

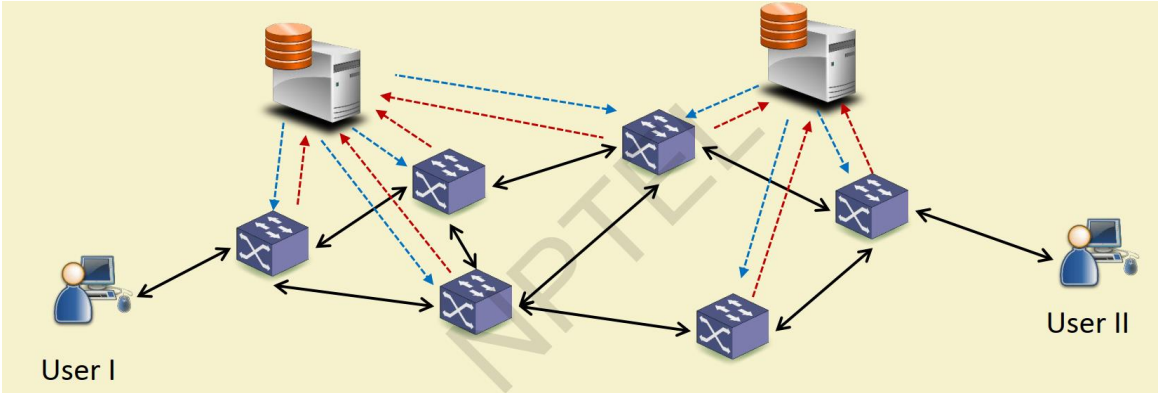
Controller Placement 2

- ✓ The controllers are logically connected to the switches in one-hop distance.
- ▪ Physically, they are connected to the switches in multi-hop distance.
- ✓ If we have a very small number of controllers for a large network, the network might be congested with control packets (i.e., PACKET-IN messages).

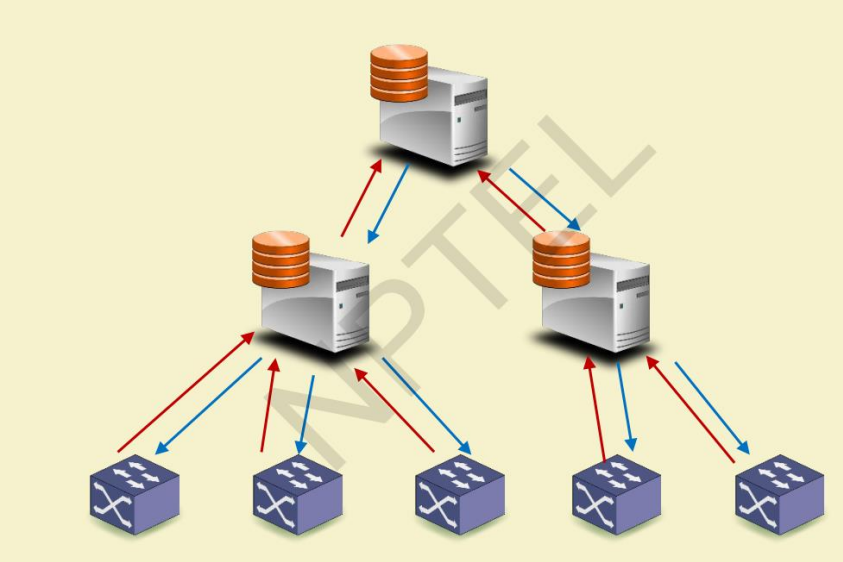
Architecture



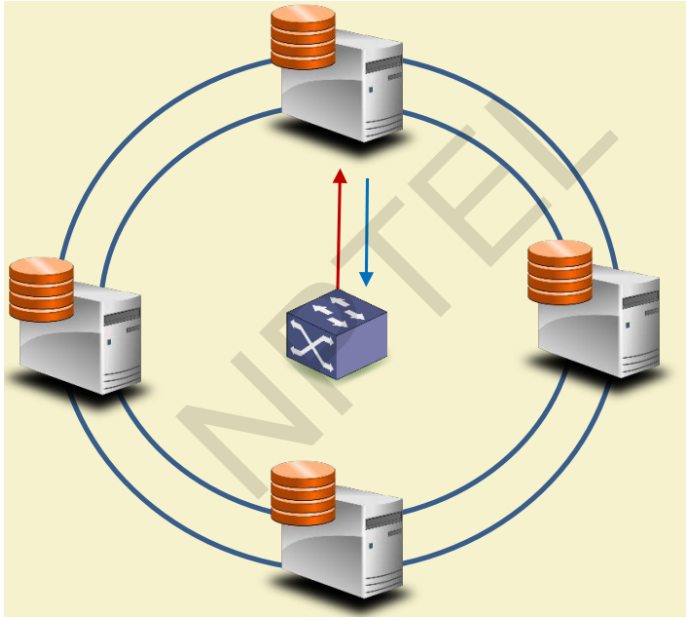
Flat Architecture



Mesh Architecture



Tree Architecture



Ring Architecture

Control Mechanism

✓ **Distributed**

- The control decisions can be taken in a distributed manner
- Ex: each subnetwork is controlled by different controller

✓ **Centralized**

- The control decisions are taken in a centralized manner.
- Ex: A network is controlled by a single controller.

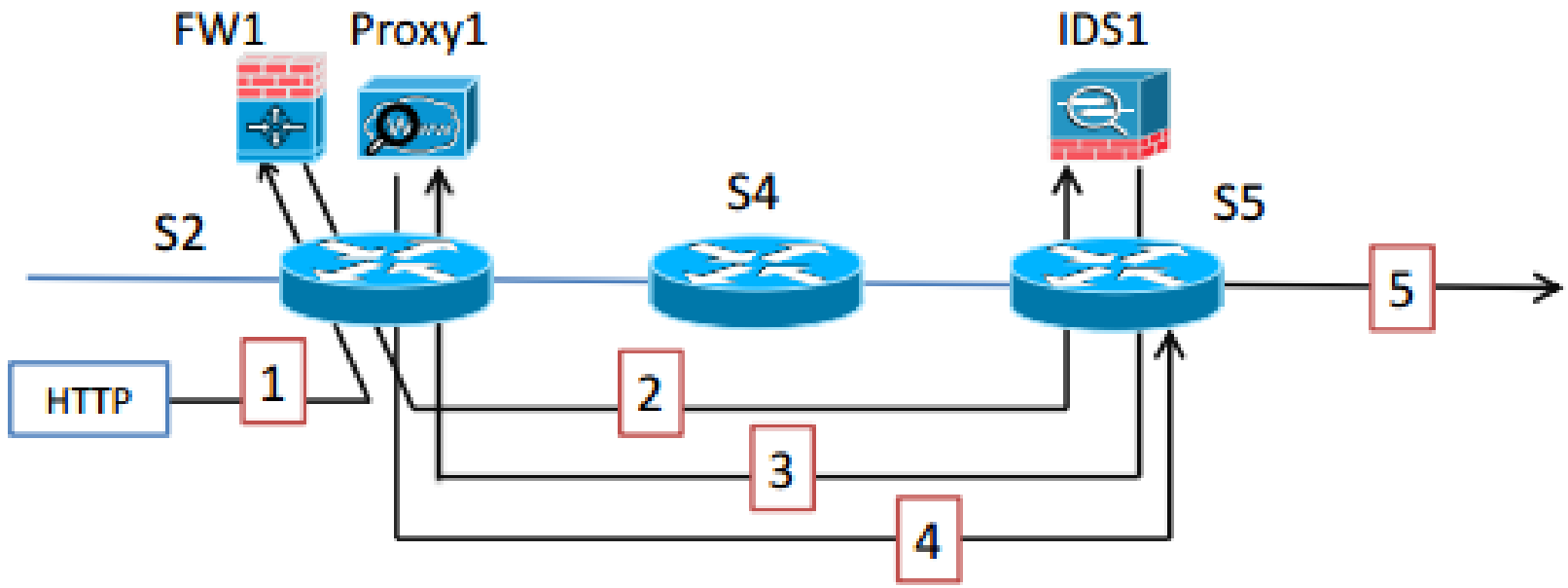
Backup Controller

✓ If a controller is down, what will happen?

- Backup controller is introduced
- Replica of the main controller is created
- If the main controller is down, backup controller controls the network to have uninterrupted network management.

Security using SDN

- ✓ Enhanced security using SDN
- Firewall
- Proxy
- HTTP
- Intrusion detection system (IDS)



Experimenting with SDN

✓ Simulator/Emulator

- Infrastructure deployment – MUST be supported with OpenFlow
- Controller placement – MUST support OpenFlow
  - Remote – controller can be situated in a remote place, and communicated using IP address and port number
  - Local

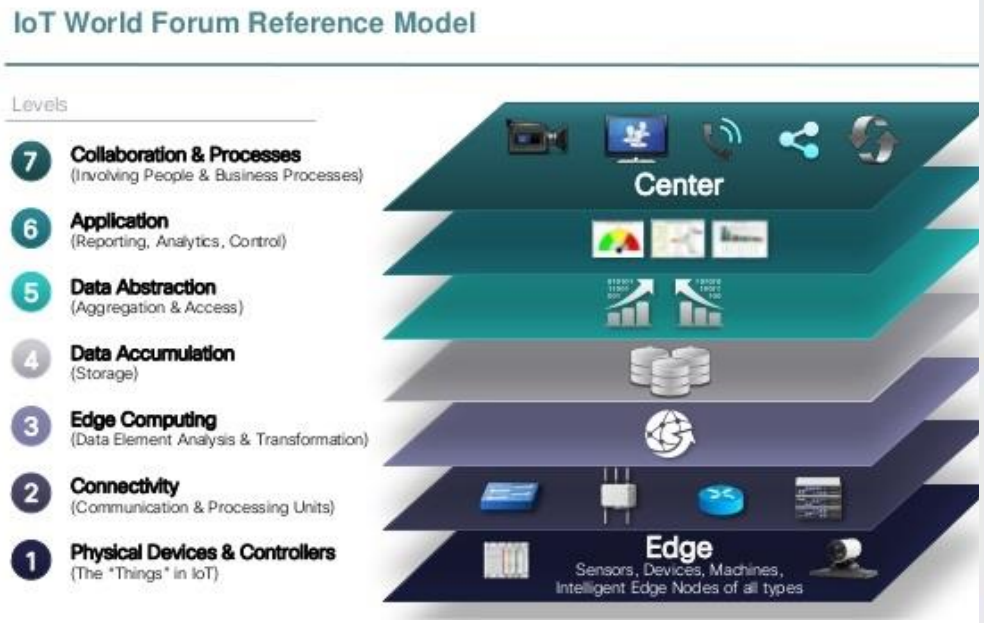
Switch Deployment

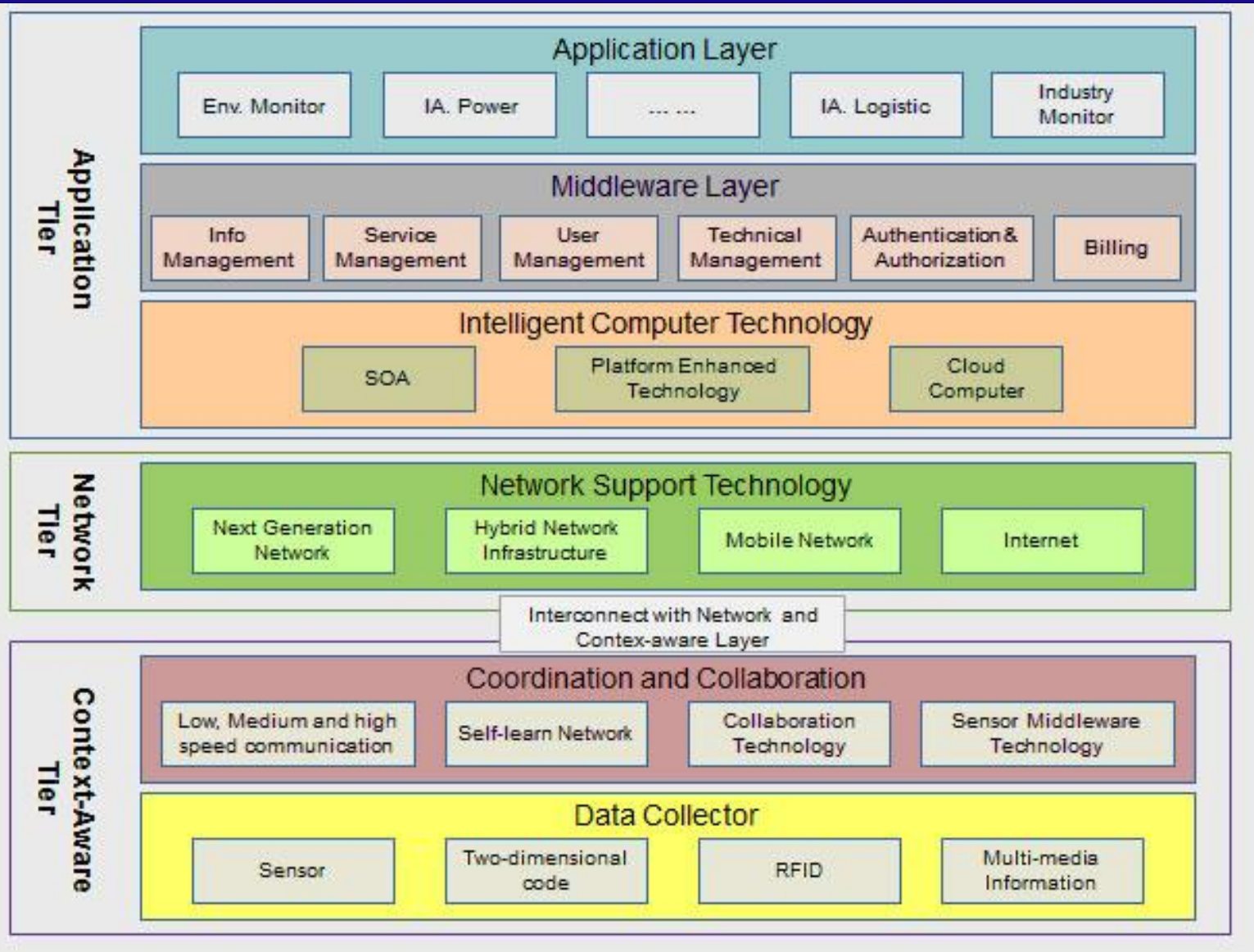
- ✓ Mininet
  - Used to create a virtual network with OpenFlow-enabled switches
  - Based on Python language
  - Supports remote and local controllers

Controller Configuration Software

- ✓ Pox
- ✓ Nox
- ✓ FloodLight
- ✓ OpenDayLight [Popular!]
- ✓ ONOS [Popular!]

IoT Architecture

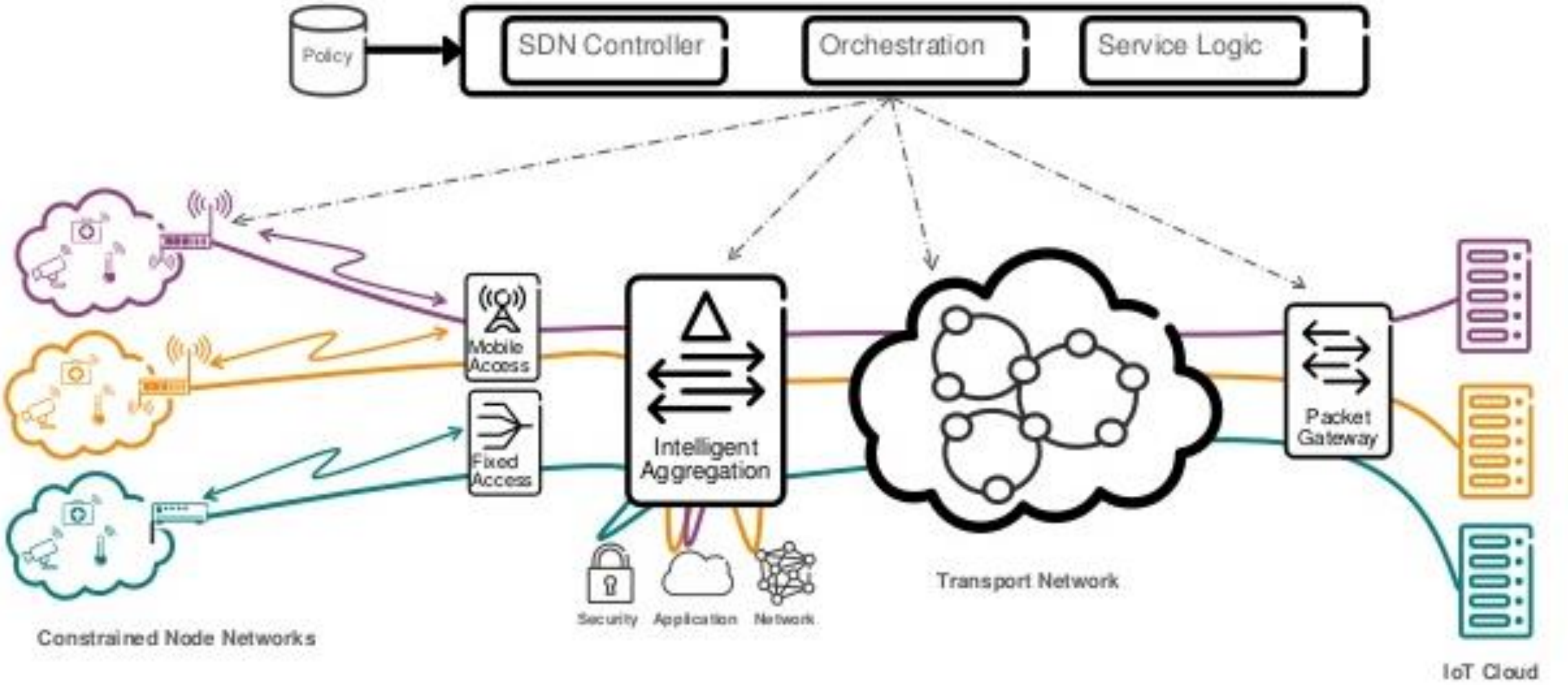




Benefits of Integrating SDN in IoT

- ✓ Intelligent routing decisions can be deployed using SDN
- ✓ Simplification of information collection, analysis and decision making
- ✓ Visibility of network resources – network management is simplified based on user, device and application-specific requirements
- ✓ Intelligent traffic pattern analysis and coordinated decisions

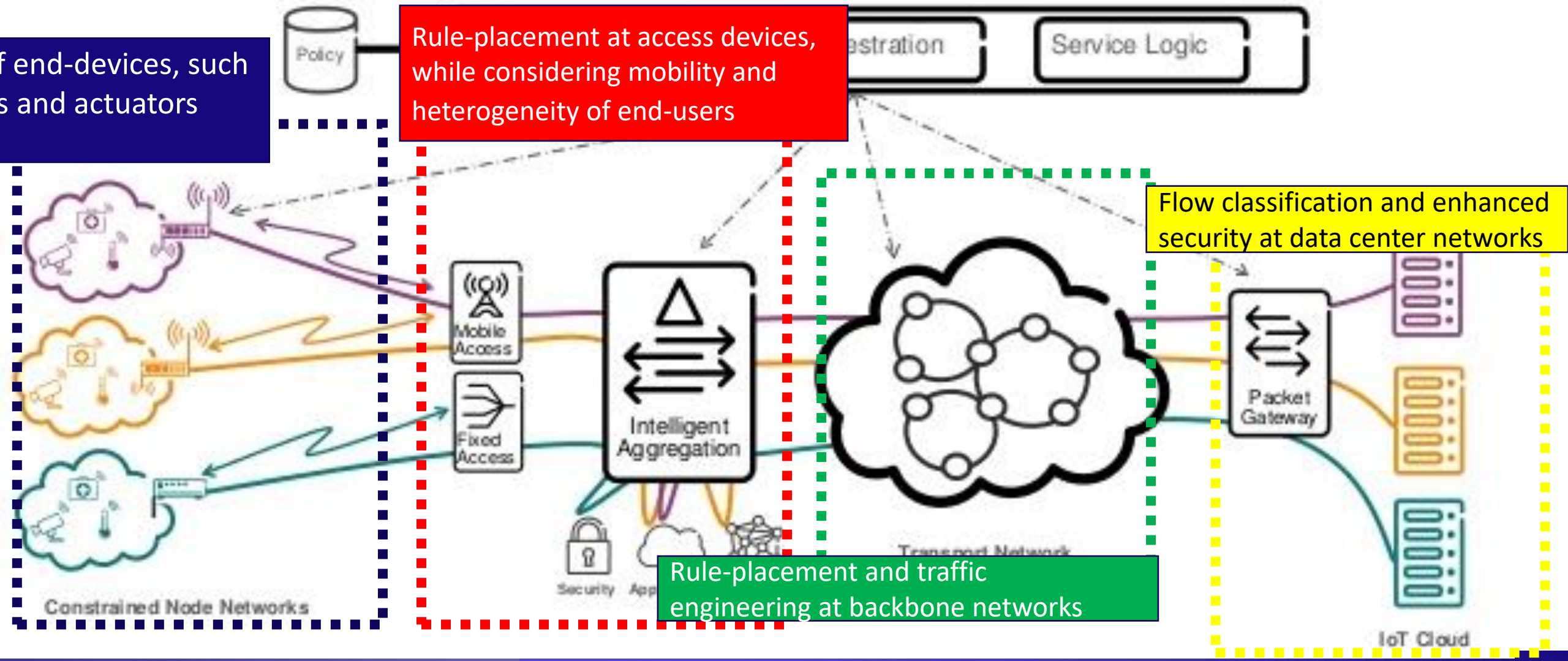
Benefits of Integrating SDN in IoT



Benefits of Integrating SDN in IoT

f end-devices, such
s and actuators

Rule-placement at access devices, while considering mobility and heterogeneity of end-users



Flow classification and enhanced security at data center networks

Rule-placement and traffic engineering at backbone networks

Challenges of Integrating SDN in IoT

- Real-time programming of sensor nodes
- Vendor-specific architecture
- Resource constrained – heavy computation cannot be performed
- Limited memory – cannot insert too many control programs

Opportunities of Integrating SDN in IoT

- Can we program the sensor nodes in real-time?
- Can we change the forwarding path in real-time?
- Can we integrate different sensor nodes in a WSN?

Software Defined WSN

✓ Sensor OpenFlow (Luo et al., IEEE Comm. Letters ’12)

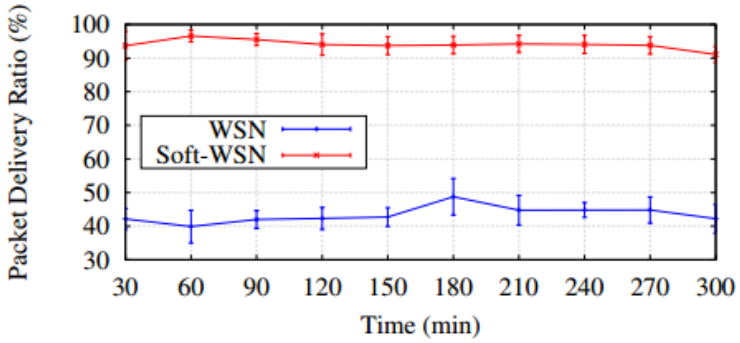
- Value-centric data forwarding
  - Forward the sensed data if exceeds a certain value
- ID-centric data forwarding
  - Forward the sensed data based on the ID of the source node

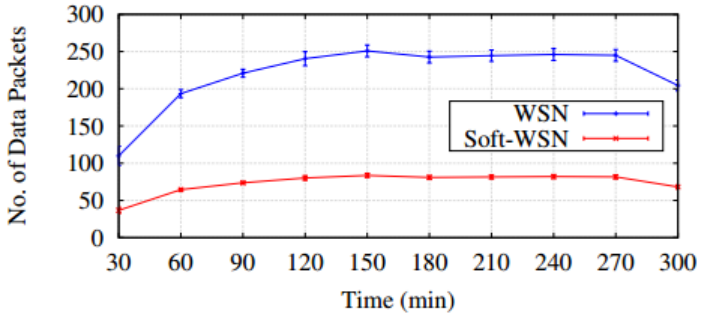
✓ Soft-WSN (Bera et al., IEEE SJ ’16)

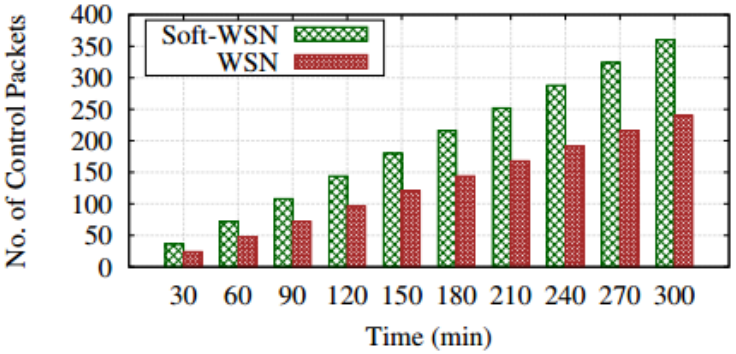
- Sensor Device Management
  - Sensor management
    - Multiple sensors can be implemented in a single sensor board
    - Sensors can be used depending on application-specific requirements
  - Delay management
    - Delay for sensing can be changed dynamically in real-time
- Active-Sleep Management
    - States of active and sleep mode can be changed dynamically

Software Defined WSN

- ✓ Soft-WSN
- Topology Management
  - Node-specific management – forwarding logic of a particular sensor can be modified
  - Network-specific management
    - Forward all traffic of a node in the network
    - Drop all traffic of a node in the network







Question No: 1

In Socket programming, the parameter AF_INET stands for _____.

a. Unix protocols
b. Internet Protocol (IP)
c. File sharing
d. Time slicing

Question No: 1

In Socket programming, the parameter AF_INET stands for _____.

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c. File sharing
d. Time slicing

The AF_INET specifies the rules and standards of the Internet protocol, hence the socket acts as an IP socket.

Question No: 2

During remote server access by a Raspberry Pi, where the Raspberry Pi acts as a client, the client needs the following?

a. Only IP address of server
b. Only port number
c. Both server IP address and port number
d. Client’s IP address

Question No: 2

During remote server access by a Raspberry Pi, where the Raspberry Pi acts as a client, the client needs the following?

a. Only IP address of server
b. Only port number
c. Both server IP address and port number
d. Client's IP address

A client can communicate with a server only if both IP address and port numbers are known.

Question No: 3

If you are using Raspberry Pi to connect IoT sensors (such as DHT temperature sensors), which of the following python-based libraries lets you configure the sensors and read data from them?

a. Adafruit
b. Matplotlib
c. Numpy
d. Socket

Question No: 3

If you are using Raspberry Pi to connect IoT sensors (such as DHT temperature sensors), which of the following python-based libraries lets you configure the sensors and read data from them?

a. Adafruit
b. Matplotlib
c. Numpy
d. Socket

The Adafruit library provides the necessary functions to configure sensors and read data from them to a Raspberry Pi.

Question No: 4

You can store and log the different sensor data for processing in text (.txt) files but not comma separated value (.csv) files.

a. True
b. False

Question No: 4

You can store and log the different sensor data for processing in text (.txt) files but not comma separated value (.csv) files.

a. True
b. False

The sensor data can be logged in any format as is suitable and appropriate, as long the data does not get corrupted.

Question No: 5

Consider the following python script using the split() function, what will be the correct print output (SEE the options VERY carefully including the quotation marks)

```
dat = 'Apple,Guava#Banana'
var = dat.split(""#"")
print(var)
```

a. ['Apple','Guava','Banana']
b. ['Apple','Guava']
c. ['Guava','Banana']
d. ['Apple,Guava','Banana']

Question No: 5

Consider the following python script using the split() function, what will be the correct print output (SEE the options VERY carefully including the quotation marks)

```
dat = 'Apple,Guava#Banana'
var = dat.split(""#"")
print(var)
```

a. ['Apple','Guava','Banana']
b. ['Apple','Guava']
c. ['Guava','Banana']
d. ['Apple,Guava','Banana']

The split('#') method splits the string into two parts with respect to the '#' character.

Question No: 6

In SDN, the central controller defines all the paths, flows and behavior of the network in a centralized manner.

a. True
b. False

Question No: 6

In SDN, the central controller defines all the paths, flows and behavior of the network in a centralized manner.

a. True
b. False

SDN is a centralized networking scheme where the central controller has full global control over the network.

Question No: 7

OpenFlow is a protocol that is used for traditional distributed OSPF based networking.

a. True
b. False

Question No: 7

OpenFlow is a protocol that is used for traditional distributed OSPF based networking.

a. True
b. False

OpenFlow is the most popular protocol that implements concepts of SDN, where SDN is the theoretical framework and is different from traditional networks

Question No: 8

In SDN _____ tables in switches describe the rules that the switch must follow for packet forwarding and are configured by the controller.

a. network
b. distance
c. hop
d. flow

Question No: 8

In SDN _____ tables in switches describe the rules that the switch must follow for packet forwarding and are configured by the controller.

a. network
b. distance
c. hop
d. flow

Flow tables are configured in SDN switches by the controller that determine its packet forwarding behavior.

Question No: 9

In a network architecture one logical hop between two nodes can actually be composed of multiple physical hops in the physical network.

a. True
b. False

Question No: 9

In a network architecture one logical hop between two nodes can actually be composed of multiple physical hops in the physical network.

a. True
b. False

A logical connection between two nodes can actually contain several physical hops

Question No: 10

What among the following is a challenge while designing SDN architecture?

a. Control Placement only
b. Both Rule and control placement
c. Rule placement only
d. Switch placement.

Question No: 10

What among the following is a challenge while designing SDN architecture?

a. Control Placement only
b. Both Rule and control placement
c. Rule placement only
d. Switch placement.

Both rule and control placements are issues in SDN

Question No: 11

PACKET_IN type of messages are associated with which of the following directional APIs?

a. Eastbound APIs
b. Southbound APIs
c. Westbound APIs
d. Northbound APIs

Question No: 11

PACKET_IN type of messages are associated with which of the following directional APIs?

a. Eastbound APIs
b. Southbound APIs
c. Westbound APIs
d. Northbound APIs

Southbound APIs are for communication between the controller and the switches and PACKET_IN is used by the switches to send a new packet to the controller.

Question No: 12

For an SDN switch flow rule, the soft timeout is set to 2 minutes and the hard timeout is set to 6 minutes. After 6 minutes and 10 seconds since the flow rule was initialized, what will be the status of the flow be in the switch?

a. The flow will be surely deleted
b. The flow will be deleted if it receives no packet for 4 minutes.
c. The flow will remain intact.
d. The flow will remain intact with a random probability.

Question No: 12

For an SDN switch flow rule, the soft timeout is set to 2 minutes and the hard timeout is set to 6 minutes. After 6 minutes and 10 seconds since the flow rule was initialized, what will be the status of the flow be in the switch?

a. The flow will be surely deleted
b. The flow will be deleted if it receives no packet for 4 minutes.
c. The flow will remain intact.
d. The flow will remain intact with a random probability.

Hard timeout signifies the time after which the flow rule will no longer be valid in any situation.

Question No: 13

It is a good idea to keep a backup controller in an SDN architecture along with the main controller.

a. True
b. False

Question No: 13

It is a good idea to keep a backup controller in an SDN architecture along with the main controller.

a. True
b. False

The backup controller is useful for storage and recovery in case the primary controller fails. It makes the network resilient.

Question No: 14

Software Defined IoT solves the challenge of _____ that is prevalent in traditional IoT networks.

a: uniformity
b: deployment
c: homogeneity
d: heterogeneity

Question No: 14

Software Defined IoT solves the challenge of _____ that is prevalent in traditional IoT networks.

a: uniformity
b: deployment
c: homogeneity
d: heterogeneity

SDIoT can be used to solve the prevalent heterogeneity challenges in traditional IoT networks.

Question No: 15

Sensor OpenFlow, Soft-WSN and SDN-WISE are examples of _____.

a. Traditional routing protocols.
b. Various SDN protocols for wired LANs
c. Various implementations of the concept of Software Defined IoT
d. Traditional IoT protocol examples.

Question No: 15

Sensor OpenFlow, Soft-WSN and SDN-WISE are examples of _____.

a. Traditional routing protocols.
b. Various SDN protocols for wired LANs
c. Various implementations of the concept of Software Defined IoT
d. Traditional IoT protocol examples.

The given names are all examples of various implementations of different concepts of Software Defined IoT by various research groups across the world.

Question No: 16

You have an IoT temperature sensor that is sensing temperature from a particular location and sending the data over the network to a server situated far away in another city for storage. This is an example of remote data logging.

a. True
b. False

Question No: 16

You have an IoT temperature sensor that is sensing temperature from a particular location and sending the data over the network to a server situated far away in another city for storage. This is an example of remote data logging.

a. True
b. False

Remote data logging refers to the process of sending data and information from a client/sensor over the network to a remote server located somewhere else.

Question No: 17

For a two-way communication between a client and server, i.e both the client and the server send data to each other, it is important that both of them knows about the following about each other

a. Only the IP address of server
b. Only the port number of client
c. Both the IP address and port number
d. Neither the IP address nor the port number

Question No: 17

For a two-way communication between a client and server, i.e both the client and the server send data to each other, it is important that both of them knows about the following about each other

a. Only the IP address of server
b. Only the port number of client
c. Both the IP address and port number
d. Neither the IP address nor the port number

Since it is a two-way communication, the client and server should both know about the IP address and the port number of each other in order to communicate.

Question No: 18

If you are using Raspberry Pi (RPi) to connect standard IoT sensors (such as DHT temperature sensors), which among the following components of the Raspberry Pi do you use connect your Pi to your sensor for data transfer.

a. HDMI port of the RPi
b. MicroSD card slot of the RPi
c. Ethernet LAN port of the RPi
d. General Purpose Input Output (GPIO) pins of the RPi

Question No: 18

If you are using Raspberry Pi (RPi) to connect standard IoT sensors (such as DHT temperature sensors), which among the following components of the Raspberry Pi do you use connect your Pi to your sensor for data transfer.

a. HDMI port of the RPi
b. MicroSD card slot of the RPi
c. Ethernet LAN port of the RPi
d. General Purpose Input Output (GPIO) pins of the RPi

The GPIO pins of the RPi board is responsible for connecting the RPi to any external sensor/actuator.

Question No: 19

It is possible to connect a single DHT temperature sensor with a suitable number of connection wires with two Raspberry Pis acting as a client for the same sensor.

a. True
b. False

Question No: 19

It is possible to connect a single DHT temperature sensor with a suitable number of connection wires with two Raspberry Pis acting as a client for the same sensor.

a. True
b. False

You can connect any number of RPis to the same sensor, with each Rpi acting as a separate client, provided you have suitable number of connection wires.

Question No: 20

Which among the following denotes the correct connection order for a standard 4-PIN DHT sensor with the order of PIN numbers taken as 4,3,2,1 (from right to left)

a. Data, Null, Ground, Power
b. Ground, Data, Power, Null
c. Ground, Null, Data, Power
d. Power, Data, Null, Ground

Question No: 20

Which among the following denotes the correct connection order for a standard 4-PIN DHT sensor with the order of PIN numbers taken as 4,3,2,1 (from right to left)

a. Data, Null, Ground, Power
b. Ground, Data, Power, Null
c. Ground, Null, Data, Power
d. Power, Data, Null, Ground

Question No: 21

Using the matplotlib library in Python, you are plotting a graph of pressure values versus time, with pressure taken in the vertical axis and time taken in the horizontal axis. While writing the code to plot the graph, which among the following is the correct parameter (denoted by '??') that you can write within the function "ylabel(??)"

a. Time
b. Pressure
c. Length
d. Mass

Question No: 21

Using the matplotlib library in Python, you are plotting a graph of pressure values versus time, with pressure taken in the vertical axis and time taken in the horizontal axis. While writing the code to plot the graph, which among the following is the correct parameter (denoted by '??') that you can write within the function "ylabel(??)"

a. Time
b. Pressure
c. Length
d. Mass

Question No: 22

Lack of centralized control is a problem and limitation of traditional network architectures without Software Defined Networking (SDN) support

a. True
b. False

Question No: 22

Lack of centralized control is a problem and limitation of traditional network architectures without Software Defined Networking (SDN) support

a. True
b. False

Traditional networks do not have a central authority over them, therefore many issues take time to get resolved with distributed algorithms.

Question No: 23

Detaching the physical hardware from the overlying software components, such as the Operating System (OS) and applications forms an important aspect of transitioning to SDN

a. True
b. False

Question No: 23

Detaching the physical hardware from the overlying software components, such as the Operating System (OS) and applications forms an important aspect of transitioning to SDN

a. True
b. False

Question No: 24

Flow rules are stored within SDN switches that run the OpenFlow protocol in the following format.

a. Images
b. Files
c. Tables
d. None of these

Question No: 24

Flow rules are stored within SDN switches that run the OpenFlow protocol in the following format.

a. Images
b. Files
c. Tables
d. None of these

Question No: 25

Among the following, which is the most unlikely to be considered as a suitable candidate for a match-field for flow rules in SDN

a. Source port number of the packet
b. Destination IP address of the packet
c. Temperature of the switch motherboard
d. Destination MAC address.

Question No: 25

Among the following, which is the most unlikely to be considered as a suitable candidate for a match-field for flow rules in SDN

a. Source port number of the packet
b. Destination IP address of the packet
c. Temperature of the switch motherboard
d. Destination MAC address.

Question No: 26

In SDN, the central controller of one network can communicate with the central controller of another SDN network through which of the following directional APIs

a. East-West bound APIs
b. Southbound APIs
c. Westbound APIs
d. None of these

Question No: 26

In SDN, the central controller of one network can communicate with the central controller of another SDN network through which of the following directional APIs

a. East-West bound APIs
b. Southbound APIs
c. Westbound APIs
d. None of these

Question No: 27

Suppose in SDN, there are two switches S1 and S2. The same packet P arrives in both the switches, S2 does not have the appropriate flow rule to forward this particular packet, whereas S1 has. Then with respect to the two switches, what is the correct action that is taken.

a. S1 sends PACKET_IN to controller, S2 forwards the packet
b. S2 sends PACKET_IN to controller, S1 forwards the packet
c. Both S1 and S2 send PACKET_IN to controller
d. Both S1 and S2 forward the packet.

Question No: 27

Suppose in SDN, there are two switches S1 and S2. The same packet P arrives in both the switches, S2 does not have the appropriate flow rule to forward this particular packet, whereas S1 has. Then with respect to the two switches, what is the correct action that is taken.

a. S1 sends PACKET_IN to controller, S2 forwards the packet
b. S2 sends PACKET_IN to controller, S1 forwards the packet
c. Both S1 and S2 send PACKET_IN to controller
d. Both S1 and S2 forward the packet.

Question No: 28

No matter how big an SDN network becomes, we can never have more than one SDN controller.

a. True
b. False

Question No: 28

No matter how big an SDN network becomes, we can never have more than one SDN controller.

a. True
b. False

Question No: 29

With Software Defined IoT, it is possible to control the individual physical sensor and actuator nodes as well as rule placement of the backbone network remotely by suitable orchestration and software.

a. Yes
b. No

Question No: 29

With Software Defined IoT, it is possible to control the individual physical sensor and actuator nodes as well as rule placement of the backbone network remotely by suitable orchestration and software.

a. Yes
b. No

Question No: 30

Soft-WSN that has been proposed as one of the solutions to Software Defined IoT achieves the following

a. Only Device Management
b. Only Topology Management
c. Both Device and Topology Management
d. Neither Device nor Topology Management

Question No: 30

Soft-WSN that has been proposed as one of the solutions to Software Defined IoT achieves the following

a. Only Device Management
b. Only Topology Management
c. Both Device and Topology Management
d. Neither Device nor Topology Management

Soft-WSN that has been proposed by Bera et. Al (IEEE SJ'16) achieves both device and topology management efficiently.

Question No: 31

The switches in a non-Software Defined Network (SDN) environment do not have a global view of the network.

a. True
b. False

Question No: 31

The switches in a non-Software Defined Network (SDN) environment do not have a global view of the network.

a. True
b. False

Question No: 32

Which of the following is not a function of the Application Pane in Software Defined Network architecture?

a. Business Logic implementation
b. Security
c. Traffic Engineering
d. Forwarding

Question No: 32

Which of the following is not a function of the Application Pane in Software Defined Network architecture?

a. Business Logic implementation
b. Security
c. Traffic Engineering
d. Forwarding

Question No: 33

In Socket programming, the parameter AF_INET stands for _____.

a. Unix protocols
b. Internet Protocol (IP)
c. File sharing
d. Time slicing

Question No: 33

In Socket programming, the parameter AF_INET stands for _____.

a. Unix protocols
b. Internet Protocol (IP)
c. File sharing
d. Time slicing

Question No: 34

During remote server access by a Raspberry Pi, where the Raspberry Pi acts as a client, the client needs the following?

a. Only IP address of server
b. Only port number
c. Both server IP address and port number
d. Client’s IP address

Question No: 34

During remote server access by a Raspberry Pi, where the Raspberry Pi acts as a client, the client needs the following?

a. Only IP address of server
b. Only port number
c. Both server IP address and port number
d. Client’s IP address

Question No: 35

Controllers in SDN receive requests from the _____.

a. End users
b. Gateways
c. Switches
d. Routers

Question No: 35

Controllers in SDN receive requests from the _____.

a. End users
b. Gateways
c. Switches
d. Routers

Question No: 36

During remote server access using socket programming what is the utility of the <socket_name>.listen() function?

a. To create a new socket
b. To bind the socket to connection
c. To wait for clients to connect
d. To close the connection

Question No: 36

During remote server access using socket programming what is the utility of the <socket_name>.listen() function?

a. To create a new socket
b. To bind the socket to connection
c. To wait for clients to connect
d. To close the connection

Question No: 37

With respect to client-server model of socket programming, in which of the following does the function <socket_name<.bind() reside?

a. Client
b. Server
c. Both client and server
d. None of client and server

Question No: 37

With respect to client-server model of socket programming, in which of the following does the function <socket_name<.bind() reside?

a. Client
b. Server
c. Both client and server
d. None of client and server

Question No: 38

Which among the following are valid data processing activities

a. Data Splitting
b. Data filtering
c. Data plotting
d. All of the given

Question No: 38

Which among the following are valid data processing activities

a. Data Splitting
b. Data filtering
c. Data plotting
d. All of the given

Question No: 39

Which among the following is the correct direction for PACKET_IN type messages in SDN?

a. From controller to switch
b. From switch to controller
c. Between two switches
d. Between two controllers

Question No: 39

Which among the following is the correct direction for PACKET_IN type messages in SDN?

a. From controller to switch
b. From switch to controller
c. Between two switches
d. Between two controllers

Question No: 40

Suppose a particular flow-rule has a soft time-out of 5s and a hard time-out of 3s. Is this association correct?

a. Yes
b. No

Question No: 40

Suppose a particular flow-rule has a soft time-out of 5s and a hard time-out of 3s. Is this association correct?

a. Yes
b. No

Question No: 41

In SDN Backup Controllers are required for which among the following?

a. To act as backup of the main controller all the time
b. To act as backup when the main controller fails
c. To replace the main controller all together
d. None of the stated.

Question No: 41

In SDN Backup Controllers are required for which among the following?

a. To act as backup of the main controller all the time
b. To act as backup when the main controller fails
c. To replace the main controller all together
d. None of the stated.

Question No: 42

Which of the following is true?

a. Traditional Network: Routing Table, Software Defined Network: Routing Table
b. Traditional Network: Flow Table, Software Defined Network: Routing Table
c. Traditional Network: Routing Table, Software Defined Network: Flow Table
d. Traditional Network: Flow Table, Software Defined Network: Flow Table

Question No: 42

Which of the following is true?

a. Traditional Network: Routing Table, Software Defined Network: Routing Table
b. Traditional Network: Flow Table, Software Defined Network: Routing Table
c. Traditional Network: Routing Table, Software Defined Network: Flow Table
d. Traditional Network: Flow Table, Software Defined Network: Flow Table

Question No: 43

What are the benefits of using SDN over IoT?

a. Management of device heterogeneity
b. Management of end-device mobility and dynamic flow rules
c. Software control of end-devices, i.e sensors and actuators
d. All of the given

Question No: 43

What are the benefits of using SDN over IoT?

a. Management of device heterogeneity
b. Management of end-device mobility and dynamic flow rules
c. Software control of end-devices, i.e sensors and actuators
d. All of the given

Question No: 44

Sensor OpenFlow, Soft-WSN and SDN-WISE are examples of _____.

a. Traditional routing protocols.
b. Various SDN protocols for wired LANs
c. Various implementations of the concept of Software Defined IoT
d. Traditional IoT protocol examples.

Question No: 44

Sensor OpenFlow, Soft-WSN and SDN-WISE are examples of _____.

a. Traditional routing protocols.
b. Various SDN protocols for wired LANs
c. Various implementations of the concept of Software Defined IoT
d. Traditional IoT protocol examples.

Question No: 45

Consider the following python script using the split() function, what will be the correct print output (SEE the options VERY carefully including the quotation marks)

```
dat = `Apple,Guava#Banana`
var = dat.split(‘#’)
print(var)
```

a. [`Apple`,`Guava`,`Banana`]
b. [`Apple`,`Guava`]
c. [`Guava`,`Banana`]
d. [`Apple,Guava`,`Banana`]

Question No: 45

Consider the following python script using the split() function, what will be the correct print output (SEE the options VERY carefully including the quotation marks)

```
dat = `Apple,Guava#Banana`
var = dat.split(‘#’)
print(var)
```

a. [`Apple`,`Guava`,`Banana`]
b. [`Apple`,`Guava`]
c. [`Guava`,`Banana`]
d. [`Apple,Guava`,`Banana`]

Question No: 46

No matter how big an SDN network becomes, we can never have more than one SDN controller.

a. True
b. False

Question No: 46

No matter how big an SDN network becomes, we can never have more than one SDN controller.

a. True
b. False

Question No: 47

With Software Defined IoT, it is possible to control the individual physical sensor and actuator nodes as well as rule placement of the backbone network remotely by suitable orchestration and software.

a. Yes
b. No

Question No: 47

With Software Defined IoT, it is possible to control the individual physical sensor and actuator nodes as well as rule placement of the backbone network remotely by suitable orchestration and software.

a. Yes
b. No

Question No: 48

Consider that only the following match field based flow rule is installed within an OpenFlow enabled SDN switch and no other flow rules are present, [Ingress port: 90, Source IP address: 10.15.16.20 ==> Egress port: 100]. It means that if a packet with source IP address 10.15.16.20 arrives at port 90, then the switch should forward it to port 100.Now a packet with source IP address 10.56.78.100 arrives at port 40. Which among the following will be the correct action by the switch

a. Switch drops the packet
b. Switch sends PACKET_IN message to controller
c. Switch forwards the packet to port 100
d. Switch forwards the packet to port 90

Question No: 48

Consider that only the following match field based flow rule is installed within an OpenFlow enabled SDN switch and no other flow rules are present, [Ingress port: 90, Source IP address: 10.15.16.20 ==> Egress port: 100]. It means that if a packet with source IP address 10.15.16.20 arrives at port 90, then the switch should forward it to port 100.Now a packet with source IP address 10.56.78.100 arrives at port 40. Which among the following will be the correct action by the switch

a. Switch drops the packet
b. Switch sends PACKET_IN message to controller
c. Switch forwards the packet to port 100
d. Switch forwards the packet to port 90

Question No: 49

Which of the following best determines the SDN controller-switch architecture?

a. Centralized
b. Decentralized
c. Distributed
d. Does not matter

Question No: 49

Which of the following best determines the SDN controller-switch architecture?

a. Centralized
b. Decentralized
c. Distributed
d. Does not matter

Question No: 50

What nature of decisions are enabled on integrating SDN with IoT?

a. Centralized
b. Coordinated
c. Distributed
d. Decentralized

Question No: 50

What nature of decisions are enabled on integrating SDN with IoT?

a. Centralized
b. Coordinated
c. Distributed
d. Decentralized

Question No: 51

What is the full form of TCAM in SDN switches?

a. Temporary content-addressable memory
b. Transmission content-addressable memory
c. Transfer content-addressable memory
d. Ternary content-addressable memory

Question No: 51

What is the full form of TCAM in SDN switches?

a. Temporary content-addressable memory
b. Transmission content-addressable memory
c. Transfer content-addressable memory
d. Ternary content-addressable memory

Thank You