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STUDY AND COMPARISION OF VARIOUS INTERNET OF THINGS PROTOCOLS

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Abstract---*The Internet of Things is the developing area in the field of Information and Communication Technology, where we have various devices in the world that are connected with each other and to the Internet. The protocols play an important role in implementation of the IoT, with which Devices can communicate with each other. In this paper, we will discuss about the basic protocols of the IoT technology used to connect this devices. The protocols are classified into three parts as Home and Private network protocols, Internet Protocols, Web transfer and Application based protocols. The comparison of protocols in light of various parameters is done. By comparison we can point to the best combination of protocols to implement working IoT solution. We can justify that which protocol is better or the combination of which protocol can be used together to get the best way for the implementation of IoT.*

Keywords-- *IoT, Protocols, Smart Devices.*

I. INTRODUCTION

The internet of things is the modification of the Internet Technology used earlier. In IoT, we are trying to accommodate each and every thing in the world and connect them with each other using older infrastructure of the Internet. As we are just modifying the existing infrastructure of Internet, So the initial cost of Implementation will be very low and beneficial.

We know many existing technologies such as Zigbee, Bluetooth, Wi-Fi, 2G/3G/4G Cellular etc. that are already in use, along with it there are many newer technologies which can be used to develop a system of Internet of Things. Depending on the range, data requirement, security, battery usage, availability, cost and many more factors of various protocols, we can select the best which suites our applications [1].

So, to understand protocols in better ways with respect to its domain and work done, we divide the protocols into three Parts as follow:

Home and private Network protocols: This is the protocols which are used at the network layer by the consumer. This protocol is used between the devices, to transmit the data or information. This part consists of the various protocols like Bluetooth [2], Zigbee [2], Z-Wave [2], Wi-Fi [2], NFC [2], Sigfox [3], Nuel [2], LoRaWAN [2].

Internet Protocols: These protocols are used on the external network to transfer the data between the device and the internet and vice versa. Here we use the various infrastructure of current Internetwork and develop our applications on it by just modifying some of the component functions which we require to change and work, as per our need. The protocols based on this part are IPv6 [1, 2, 4], 6LoWPAN [2], UDP [1,2], Thread[2], Cellular[2].

Web Transfer and Application Protocols: In this part we will discuss about, how the messages are transferring from one application to another and about the security aspect of that message. The protocol used for this part are COAP [4,5] for web based transfer of data from one end to another, DTLS[5] for providing security to our data, REST[6] based protocol for web service type of applications, XMPP[2] and MQTT[2] are the messaging protocols, Web socket[7] and SOAP[8,9] are used to provide a framework for transferring of data and messages between the devices.

The paper further, is arranged as follow, section 2 discuss about detailed description of Home and Private Network based protocols, section 3 about Internet protocols, section 4 about Web and Application based protocols, then in section 5 we compare various protocols into their particular domains, then in section 6 we discuss the proposed case studies of the IoT protocols that how to use them, at last we conclude the paper[2].

II. HOME AND PRIVATE NETWORK PROTOCOLS

These protocols are working on private networks where we can transfer a data and information between the devices example of it are home network, office networks etc.The protocols used for this kind of operation and suitable for it are:

2.1 Bluetooth

It is a short Range device which is very important for the development of IoT Systems as it is popular in the market. We can use it as a key for the wearable product, as we can connect it to the Smartphones using IoT Abeit. The newer Bluetooth Low Energy (BLE) is also become popular as it gives similar range to Bluetooth but the advantage is that it consumes much low power as compare to ordinary Bluetooth technology, however it has a disadvantage that it is not designed for file transfer.
Devices that consist Bluetooth smart features has Bluetooth core specification version 4.0 or higher (latest is 4.2) with combined basic data rate and low energy core specification for RF Trans receiver, baseband and protocol stack. Version 4.2 supports features that allow smart sensors to connect internet through 6LowPAN, with which we can use existing IT Infrastructure to manage Bluetooth smart edge devices.

2.2 Zigbee

Like Bluetooth Zigbee pro and Zigbee Remote Control usesIEEE 802.15.4 protocol which is industry based standard forwireless network technology, operating at 2.4 GHZ, whichexchange data at low data rate where restricted and within100m range either within a home or building.

Zigbee has much advantage in complex system with lowpower operation, high security, robustness and high scalabilitywith high node count. It is better option to take placeof wireless and sensor network in M2M and IoT Applications.The Latest version is 3.0 which is the combination ofall previous standards of Zigbee.

2.3 Z-Wave

It is low power RF Communication Technology designed forhome automation products. It is used for reliability and lowlatency communication for transferring small packet and ata rate of 100kbits/s. It works in the 1GHz band. It supportthe mesh network type topology, hence it require no coordinator.It also supportsup to 232 devices. It is the simplestprotocol than others so development of it is faster, but theproblem is that the developer of chip for this technology isthe only sigma developer. So, the production is slower thanother technology development.

2.4 Wi-Fi

It is the most popular technology used now a day within thehome environment and within LANs. It has a wide existinginfrastructure as well as it supports fast and quality datatransfer.The most common standard used for today is 802.11n whichprovide a throughput of hundreds of megabits per secondwhich is good for data transfer but the disadvantage is thatit is too power consuming which is not suitable for the IoTDevices. The RS Development kit used for development ofWi-Fi is provided by RS.

2.5 NFC

It is a simple contact less two way communication technologybetween electronic devices especially Smartphones. It allowvarious contact less operation like amount transfer, digitalcontent and contact of electronic devices like card withoutany contact. It work within the area of 4-10 cm. It has apower consumption of less than 15mA.

2.6 Sigfox

It is a wide range technology. Its range comes between Wi-Fiand Cellular network. It works in the ISM band which isfree for the data transfer without the need for any kind ofpermission between the connected devices. Many M2M devicesrun on small battery and if we use Wi-Fi then its rangeis short and cellular network is power consuming so wecan use Sigfox. It runs in ultra-narrow band(UNB)witha low data transfer rate of 10 to 1000 bits per second andwith only 50 Microwatt as compare to 5000 Microwatt incase of Wi-Fi. So it has standby time of 20 years with 2.5mAhbattery as compare to 2 years for cellular.

It provides a power efficient and scalable network with a millionof devices connected in a several square kilometers. Itis suitable for various smart application like smart meters,patient monitors, security devices, street lightning. It usessilicon from EZRadiopro wireless trans-receiver lab. It operatesin 1 GHz band wireless network applications.

2.7 Nuel

It is similar to Sigfox, operating in sub-1GHz band and alsouses TV whitespace spectrum to have high scalability, highcoverage, low power and low cost wireless network. It usesiceni chip to communicate in white space UHF band. It isa weightless technology especially designed for IoT and alsoit competes with GPRS, 3G, CDMA, LTE WAN

solutions.Data rates can be of any range from few kbps to 100kbpsfor same link and can consume very less battery as 20 to 30mA batteries can run upto 10 to 15 years.

2.8 LoRaWAN

It is also used for WAN, same like Sigfox and Nuel. It useslow power WAN to support low cost mobile secure bidirectionalcommunication in IoT, M2M, Smart city and industrialapplication. With low power consumption, it supportlarge network with millions and millions devices with datarate of 0.2 kbps to 50 kbps. Battery consumption is 10mAand battery life increases to 10 years.

III. INTENET PROTOCOLS

These are the protocols that are used to transfer the datato and from internet and devices. These are the long rangetechnologies than the network protocols. The protocols that come under this part are:

3.1 6LoWPAN

It is the IP-based technology (IPv6 based low energy wirelesspersonal area network). It is a network protocol which definesthe header and encapsulation compression mechanism.It is freedom in this technology to use it on the physical layerand it can be used across multiple platforms like Ethernet,Wi-Fi, 802.15.4, and many more. We just need that IPv6is included in it, which is very important introduction to beused for development of IoT.

IPv6 is capable of enabling a unique IP address to each personin the world and connect it to the internet. It provides acomplex system to connect each and every device with a lowpower consumption and cost effective manner. It providesalmost 5x1028 address to every person in the world.

6LowPAN is designed to send packet over IEEE802.15.4 andit uses the protocol like UDP, COAP, MQTT, TCP, HTTPto send and receive packets or data to and from the internetand device. It has a mesh type network structure which isself-healing, scalable and robust. The advantage of it is thatthough the host devices are sleeping for long time it remainsconnected with them.

3.2 Thread

It is a new IPv6 based networking protocol targeted basicallyfor the home appliances. It is not a protocol similarto 6LowPAN, Bluetooth or Zigbee. But it can be used asa substitute for Wi-Fi as it can be work better for homeautomation setup, which is the limitation of Wi-Fi.

It is launched in 2014 by thread group; it works on currentIEEE 802.15.4 protocol with the existing chip technologyprovided by free scale and silicon lab. It is a mesh networkand uses IEEE 802.15.4 radio trans-receiver and supportsupto 250 nodes with a high security(Authenticationand encryption).

3.3 IPv6

In the usage of IPv6 in IoT the major problem is adoption ofIPv6 but this problem will be solved because of the limitationof IPv4 that it does not support more number of devicesattached with it. Whereas in term of scalability IPv6 supportbillions and billion devices per square millimeter.IPv6solve the issue of NAT Barrier of end to end connection.

IPv6 provides a facility that devices work as a web servicesusing the COAP and REST Architecture. It also providesa mobility of end nodes as well as routing nodes of the network.Also IPv6 is self-configurable so the devices can configurethemselves automatically. Also we can make a smartnetwork of our own in IPv6 and connect it to the rest of theworld.

3.4 UDP

Due to the requirement of lower handshake protocols theUDP reduces the network traffic and hence the workload.We can transfer more data over the network within less timeperiod. Another advantage is that we can send data with asfast rate as the device is capable of transferring the data.

COAP is dependent on the UDP to achieve deterministicand real time operation. The UDP layer of the internet isusing the concept of COAP and its various functions whichis discussed later in the COAP.

3.5 Cellular

The transmission of IoT data to the longer distance can bedone by GSM/3G/4G, as cellular network provides a longdistance and high data rate transfer over the internet withthis technology, but the power consumption of the devicesis more in this network. It provides sensor based low bandwidthdata project with low power consumption and lowdata transfer over the internet. The main component in thistechnology is SquareEE and CELL1.0 low cost developmentboard and shield connecting board with Raspberry Pi andArduino platform.

IV. WEB BASED AND APPLICATION PROTOCOLS

This are protocols which are used to transfer the data on theinternet by using some kind of applications and the securityaspect of the data should also be taken into consideration,so that the people trust on this technology. The protocol that comes under this are:

4.1 COAP

It is a Constrained based Application Protocol which is developedby the Constrained RESTful Environment (CORE)workgroup of IETF. COAP is based on the REST Architecturefor communicating with the constrained devices.

COAP is lightweight protocol and is based on the UDP network.Since we are using this protocol for our future usein IoT, we should primarily run this protocol on IPv6.But since IPv6 is not accepted by all service providers, sowe have to provide a support for both IPv6 and Ipv4.

The features of COAP that makes him possible to use forIoT are that it fulfill the requirement of the M2M communicationwith the security provided by DTLS, it provides URIand content support with low overhead and parsing complexity,Asynchronous Message transfer, it support unicastand multicast operation with UDP bindings, it has a facilitythat COAP can be used same as HTTP using the StatelessHTTP mapping.

COAP supports two layers:

- **Message Layer:** Supports four types of message that is: CON (Confirmable), NON (Non confirmable), RST(Reset), ACK (Acknowledgement).
- **Request/Response Layer:** This support the backand forth of messages between client and server. Accordingto the above message format the types of responseis being send and receive.

4.2 DTLS

DTLS is used for providing the security for transfer of messageamong devices. It is providing end to end communicationin application layer. It avoid cryptographic overheadproblem occur in low layer security protocol.

DTLS Contain two layers:

- The Bottom layer contain Record Protocol,
- The Top one contain three protocol Alert, Handshakeand application Data.

DTLS has a problem to implement because of its requirementof larger memory which is not possible for the IoTdevices. Also we require a handshake between the devices,so it is difficult to implement.

4.3 XMPP

Extensible messaging and presence protocol (XMPP) is aopen source messaging protocol which provides a lot of facilitylike video call, Multi-Party chat, voice call, etc. and itis lightweight middleware, content syndicator and providerouting of XML data.

It provide human to machine communication(H2M). Thebenefits of XMPP are that it provides a server less messagetransfer using the P2P communication and DNS Server.

XMPP use various device classes to communicate betweenthings over the internet. It uses mDNS(multicast) and DNSSD(ServiceDiscovery)protocols to communicate rather thansever based protocols that are used by other M2M communicationgateways.

In H2M communication we have a problem of interoperabilityand discovery, Self configuration, and informationfiltering.

4.4 MQTT

MQTT stands for the MQ Telemetry Transport. It is alightweight messaging protocol which use publish/subscribefacility with low Bandwidth and high Latency. This protocolis designed so that the content delivery failure is minimumand network bandwidth requirement will also be minimum.These protocols provide a facility of Machine to Machinecommunication.

This protocol is ideal for IoT devices and for mobile applicationwhere the bandwidth and battery power requirementare at minimum use.

The security concern of this protocol is provided with username and password. Also the Encryption is done with SSLsecurity protocol specially designed for the MQTT.

4.5 REST

REST(Representational State Transfer) is software thatprovides architectural style for building Scalable web service.REST provides a constrained for designing the componentin the distributed environment that leads to high performingand more maintainable architecture. REST sometimesmakes use of HTTP verbs(GET, POST,PUT, DELETE etc.)to communicate over the internet.

The Constrained RESTful Environment(CORE) sees a RESTarchitecture in a suitable form for the most constrainednodes(e.g. microcontrollers with limited memory) and networks(e.g.IPv6, 6LoWPAN etc.). CORE is aimed at M2M(Machineto Machine) communication which is the base of our IoTbased applications.

The REST architecture with the help of the CORE, helpus to transfer a message over the internet and also in thepersonal network(M2M)using various constraints of the architectureand also use the HTTP methods for it. So withthe help of REST we can develop a web services, transfera message from one end to another, better security(SSL,HTTPS etc.). This is the best architecture on the applicationlayer where we are provided with all kind of components and constraints required for the implementation of the IoT.

4.6 WebSocket

WebSocket provides a two-way communication between aclients running a untrusted code to the remote host that tryto communicate from that code. The security to this typeof communication is provided by the origin-based securitymechanism used by the web browsers. This method providesa message framing over the TCP connection. This applicationused where we require two-way communication withserver without opening multiple HTTP connections.

This protocol consists of two parts Handshake and Data Transfer.First of all the handshake is carried on between a clientand a server(Request, status and response). After the handshakecomplete between the server and client then the messagepassing is carried on between them.

So, in the context of IoT in the smart home, the devices connectedto the home server can use this protocol for two-waycommunication. That is when server receive some messagefrom outside the network it transfer that message to devices,and Devices when communicate with each other they cantransfer message via server. So server and client can easilydo two-way communication with the help of WebSocket.

4.7 SOAP

SOAP (Simple object access protocol) is a Messaging basedprotocol which can be written using the XML language andis working in the wide variety of distributed models. It definesmessage formats and we can use variety of messagepatterns like RPC, Asynchronous, and Synchronous etc.

SOAP is just used for formatting the message and is usingthe WSDL for describing the content of message. The messagecreated in the SOAP can be transferred using any ofthe techniques like web services, BEEP (Block ExtensibleExchange Protocols), NETCONF (Network Configurationprotocol), JS etc.

So in the respect of IoT we can use SOAP for transmittingthe message between M2M using good security mechanismand with better formatting in order. Since we have differentoption with which we can send a SOAP message from oneend to another, so we can use the method which is preferable for us. But the disadvantage of SOAP is that, it will besomewhat heavy weight and the power consumption will bemore. But, we can use the SOAP based transfer in theinternet protocol based layer over the IPv6, 6LoWPAN,etc.

So, SOAP is not suitable for application in the lower layerlike private network or home network, but is the most suitablefor the internet layer in the terms of security as wellas the efficiency and the chance of failure of the messagedecreases.

V. COMPARISION

The Comparison is done between protocols based on thevarious parameters. The comparison tables below are usedfor the purpose of selection of protocols that suites best forour application.

TABLE-I Shows the comparison of the network basedprotocols where it has many parameters for the comparisonlike Standards, Frequency, Range, Data rate, Power Consumption,Payload, header size and Error checksum.

TABLE-II contains two part where Part-A contains the protocolcomparison of the Internet Protocol where it is comparedbased on the parameters like power consumption anddata rate. Part-B contains the application based protocolswhere it shows that which type of protocol is it and for whichpurpose it is used.

Table-1.Home and Private Network protocols comparison

	Stan-dard	Range (in m)	Data Rate (in kbps)	Power Consumption	Payload (in bytes)	Header Size (in bytes)	Error Check-sum
Bluetooth	Bluetooth 4.2 core specification	50-150	1000	High	0 - 343	6.75	1/3 FEC, 2/3FEC, ARQ
Zigbee	IEEE 802.15.4	10-100	250	Moderate	116	15	XOR
Z-Wave	Z-Wave Alliance	30	9.6/ 40/ 100	Moderate	n	-	XOR
Wi-Fi	802.11n	50	600 x 1000	High	2346	54-74	FCS,CRC-32
NFC	ISO/IEC 18000-3	0.1	100 – 420	V-Low	Variable	-	Re-Request data
Cellular	2G, 3G, 4G	35000, 200,000	35 – 10,000	High	10 – 60 millisecond.	As per n/w	CRC-16, CRC-32
Sigfox	Sigfox	30,000	0.01 – 1	V-Low	12	4	-
Nuel	Nuel	10 km	BPS-KBPS	Low	-	-	-
LoRaWAN	LoRaWAN	2000 5000	0.3 – 5	Low	64,000	2	-

Table-2 Other Comparisons

A. Internet Protocols

Protocols	Power Consumption	Data Rate
6LoWPAN	Low	Low
UDP	Moderate	High
Cellular	High	Very High
Thread	Low	Moderate
IPv6	High	High

B. Application Protocols

Protocols	Type
COAP	Simplified HTTP
DTLS	Privacy
REST	Constraint Based
Web Socket	Socket Based
MQTT	Messaging
XMPP	Messaging
SOAP	Web Service

VI. CASE STUDIES

Based on the protocols discussed above in this paper, variouskinds of case studies are proposed in which we can use these protocols. The protocols which we use depend on the typeof application and on the parameter of the protocol.

6.1 Smart Living

Figure 1: Smart room with connected devices[10]

In older days when we are sitting in a room and we have toswitch on or off TV, Fan, Light etc., we have to physically operateit using the electric switch board. But after the inventionof IoT, we can just operate all the things by sitting ona sofa or bed just with our Smartphones and laptops(PCs).As shown in figure-3 all the devices are connected throughthe Wi-Fi, Zigbee, Bluetooth, and NFC etc. We can operate allthe devices with our Laptop or Smartphone, as shown. Alldevices are connected with the central Server and all the requestresponse are transacted from that Server to devicesand operating instrument.

The mechanism work as follow, When we are sitting in aroom watching TV and we want the AC to be on and light tobe deem then we give a command to Server through Smartphoneusing user interface, through Wi-Fi to server, thenserver gives it to devices through Bluetooth or some otherprotocols. Here we can use any home networking protocolswhichever we like and satisfied with[10].

6.2 Smart Home

Figure 2: Home with connected systems[11]

Here we will discuss about the home with all the componentsconnected with each other and also with, home centralserver. Here we can control each and every device from ourgarden sprinkler to our energy meter along with electronicdevices.

As shown in figure-2 our smart home consist smart gridto control the electricity consumption, the pool sensor and garden sprinkler system to control pool temperature andsprinkle water after measuring the moisture of garden. We also have automatic lightning which sense our presence withthe help of body heat sensors, also it can sense our activitylike working or sleeping and adjust the lightning accordingly.The security system is also connected with this to protectour home from unauthorized access.

We can connect this all devices using the Wi-Fi, Zigbee, Sigfox,etc. And we can use WLAN(Wireless LAN)/HAN(HomeArea network)gateway to handle communication betweenthese components [11].

6.3 Crowd control during Emergencies and Events

Here the authorities are helpful in controlling crowd andtheir activities during the events and emergencies. In this wehave to install app in the mobile devices and this is effectiveonly if the location of the device is on. Here we will trackthe location of the people and can estimate the numbers inparticular event. And notice their activities with the helpof street camera, motion sensors and officers on duty. Usinglocation based technology like GPS, Wi-Fi, and cellular wecan create a heat map of Crowd. In case of emergencieswe can guide the response team to handle the situation andwhich route to take to control the situations. So with thehelp of IoT technology we can reduce the damage in case ofany kind of disaster and emergencies[12].

6.4 Smart City

Smart Cities are those that have better infrastructure andmake use of IoT technology to improve and manage power,resources and urban planning. Here we are leading to thefuture in which we have micro-controller and Trans-receiversfor digital communication and we become an integral part ofthe Internet. Smart city is the combination of many smartthings and technologies like water system, power grids, noisemonitoring, traffic congestion, health maintenance, smartlightning, automation and stability of public buildings andso on.

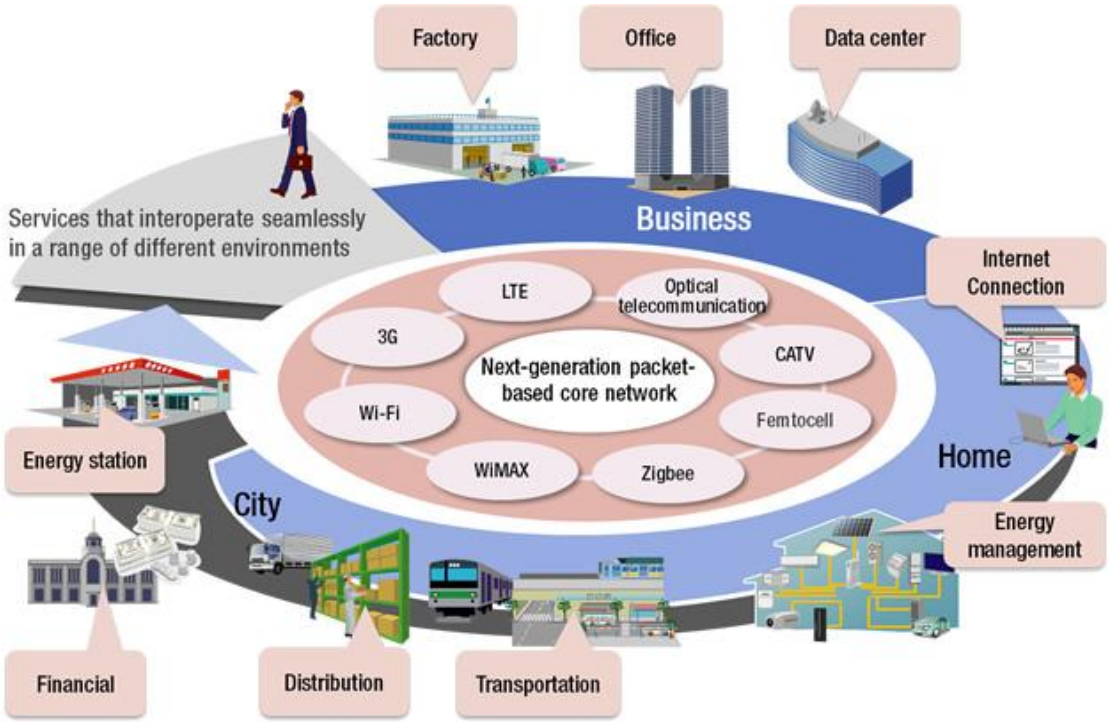

Figure 3: Structure of smart city network [13]

As per our discussion on protocols we can see all the protocolsare useful for the Smart cities. Like Structural health uses Wi-Fi and Ethernet to integrate and realize, waste management uses Wi-Fi, 3G and 4G for detecting and transferringwaste level to the authority, air quality monitoring is donewith Bluetooth and Wi_ using gas sensors. So we can usemany protocols like 6LoWPAN, Zigbee, Z-wave etc. for communicatingand transferring between the devices and theauthorized centers.In smart cities the important thing is the internet connectivityin each and every part of the city

should be compulsorilyavailable. This can bemake done with the help of Wi-Fi andother cellular network connectivity[14].

VII. CONCLUSION

From the paper discussed above we can conclude that the divisionof protocols to various parts is useful for us to identifythe protocols and to choose best protocol according to the application we want to develop. The table shown above shows the comparisonof various protocols against various parameters which help us to choose the protocolwhich suites best for our application.

Table-1 shows us that at network level with the low rangeand power which technology suites best for the Implementationof IoT. Table-2 (A) shows us that at the Internet basedprotocols which suites best for us to communicate over theInternet. Table-2 (B) shows us that at application basedprotocols which protocol, to be used, so that we can easilyimplement it as per the need of our application.

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