Foundation of Cloud Iot Edge ML
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Lecture 03
Introduction to IoT platform

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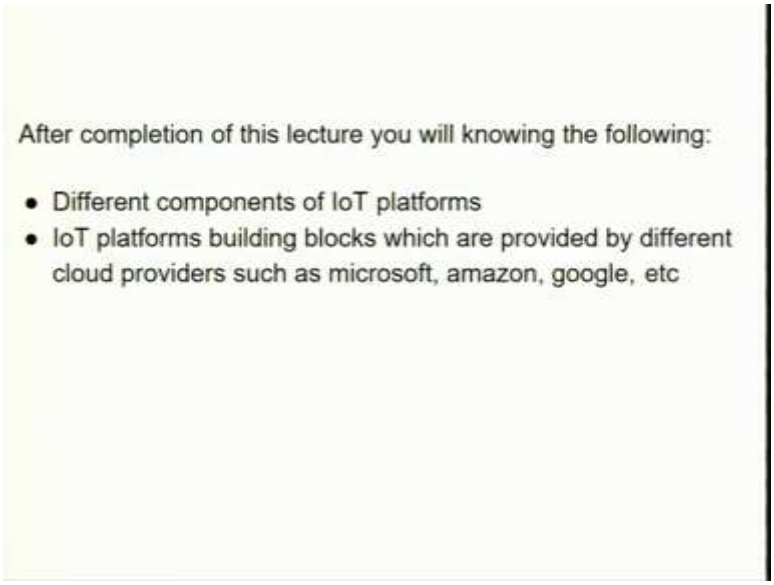

I am Dr. Rajiv Misra IIT Patna, today's topic is introduction to IoT platform. In this lecture, you will be knowing the following concepts. The first one is we will introduce you the different

components of IoT platforms so, then IoT platforms building blocks. So, these building blocks are essential to understand the different IoT platform services which is being offered by different cloud providers such as Microsoft that is known as IoT Azure IoT hub, Amazon's IoT platform is known as IoT Greengrass and Google and there are many other prominent cloud providers, which provides this IoT platform.

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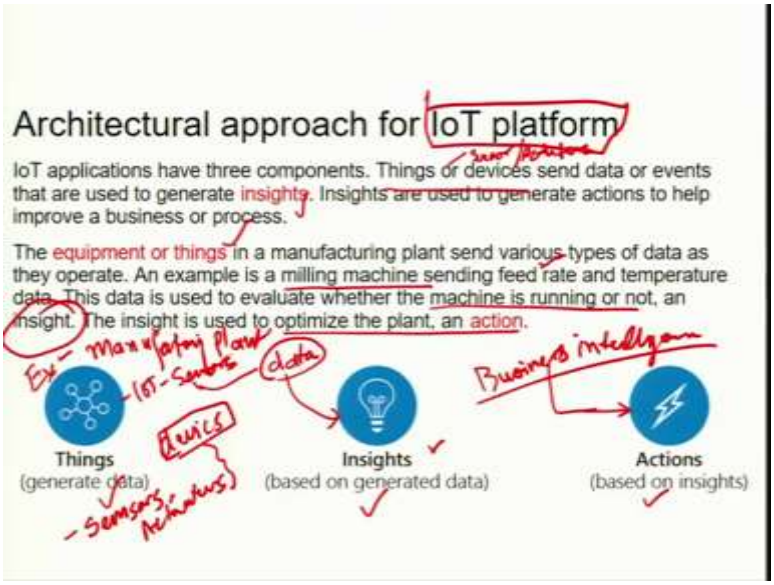

Architectural approach for IoT platforms so, in this particular slide, you can see a broad overview of an IoT platform what comprises why there is a essential need for IoT platform that is IoT applications, how three different main used cases or three different applications, which are categorized as three components. The first one is called things or the devices.

So, these things or devices you may also know by means of sensors or actuators these things or the devices will send the data or the events that are used to generate the insights insights means, that these sensor data when they generate the data, so, it contains the events within it and if you can uncover it, then it is called generating the insights from that particular data.

So, insights are used to generate actions to help improve the business or the process. So, that is all shown over here. So, there are three different components one the first one is called the things sometimes you also know as the sensors are actuators. And together you can say that these are called as things are nothing but they are the devices.

So, the equipments or the things for example, in a manufacturing plant will send various types of data as they operate an example is a milling machine, which sends the feed rate and the temperature data out of their sensors.

Now, this data is used to evaluate whether the machine is running or not and that will become an insight. So, Insight is used to optimize the plant and that is called an action. So, let me say that for example, in a manufacturing plant. So, the machines are having an IoT sensors which monitors the condition of different machines called milling machines, these particular IoT sensors will send the condition of that particular machine and this particular information that is called the data this data is sent for generating that insight about the condition of the machine whether it is running or not.

And out of that insight, you have to now decide that is called the business intelligence that is that particular plant has to decide what an action has to be taken in on a particular conditions which these particular devices are doing it.

Now, these all things whatever is required for automation of any industry for an optimization is requires an IoT platform, which has to be in three different forms. One is that it is to be having the things which generates the data that is called sensor or devices. The second is the data which is generated by these things will contain a rich amount of information or insight.

So, uncovering or getting the details of that, that is the insights which are generated out of the data and then based on these insights, then action has to be taken by this organization. So, this is an overview of an IoT platform architecture.

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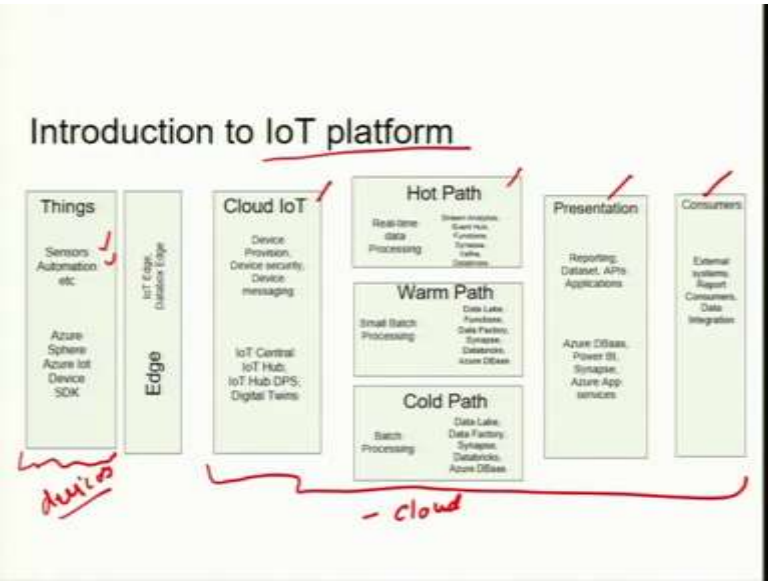

So, to accomplish this architecture, so, let us introduce you with this IoT platform in this particular lecture. So, this particular platform we will explain you in the following things. So, things is an automation that is in the form of sensors and automation and this will form an automation or IoT network.

So, this will be at the device level. And then comes this information with the sensors are generating this has to be sent to the cloud for getting the insight and taking the decisions or actions. So, that is that component in the cloud IoT platform is called the cloud.

So, as far as the cloud is concerned, cloud has the following component under this IoT platform, first one is called Cloud IoT, then we will see that data, how the data is to be processed, under what condition there are different types of analytics or processing path that we will discuss and then finally, we are going to do a presentation of that insight and then finally, the consumers will come to take this action to use it insight and take the action. So, we will explain this IoT platform in more detail.

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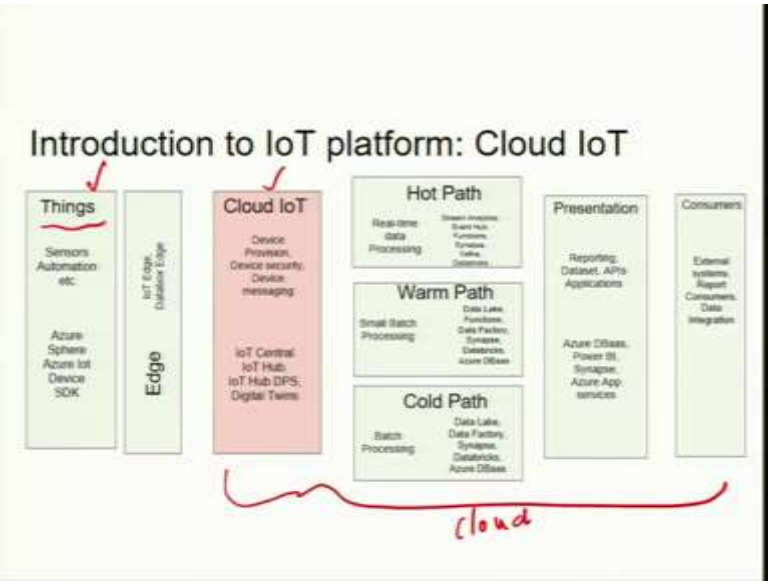

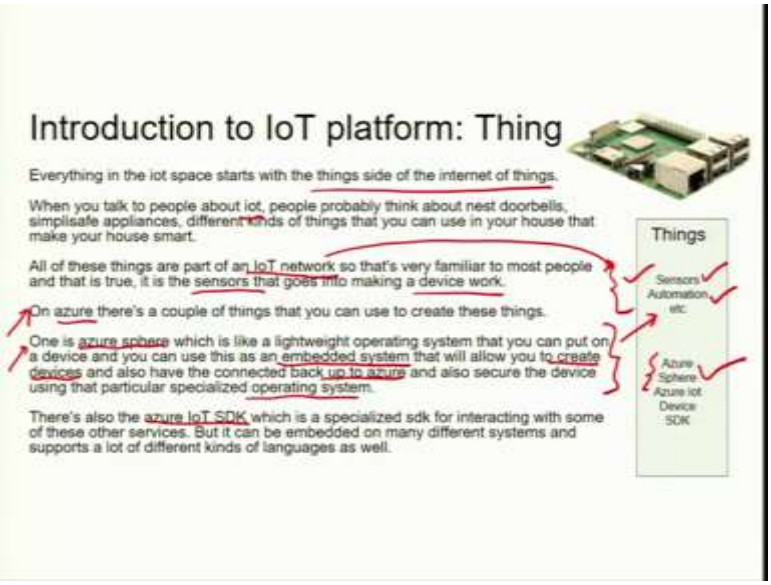

Let us start with the first component that is called the things so, as that this IOT space starts with the thing sight, this is also known as internet of things which comprises of the sensors and other automation devices, which are now deployed at the machines or at the factory level or maybe the smart city. These deployments are called things or the sensors or the automation.

So, when you talk about an IoT, so, people probably think about the home automation, that is they may think about the nest, doorbells are simply safe applications, that is different kinds of

things you are using in your home and to make your home quite smart. So, all of these things are the part of an IoT network.

So, that is very familiar to most of the people and it is nothing but the sensor that goes into making this particular device working. So, when we talk about the things, it means that the sensors and automation, and together it will form an IoT network.

Now, if you take a particular use case, that is a particular platform IoT platform from Microsoft, which is called an Azure, let us see how this particular things are integrated into the Azure. So on Azure, there are a couple of things that you can create through these particular things.

So, they have the offering, which is called azure sphere, which is a lightweight operating system that you can put on a device that runs on the device, and you can use this embedded system that allows you to create the virtual device and also have the connected this particular device to the cloud that is called azure and also secure the device using this particular specialized operating system.

So, that means this device to function as in the IoT platform, you have to now use these software's which is available such as azure sphere, or this and to connect with this Azure IoT or software Development Kit SDK. So, there is also an Azure SDK which is a specialized SDK for interacting with some of these other services. But it can be embedded on many different systems and supports a lot of different kinds of programming languages as well.

So, having understood the things part, in IoT platform, the next important component is at the cloud. And that is called a Cloud IoT. So, let us understand this cloud IoT component in the IoT platform.

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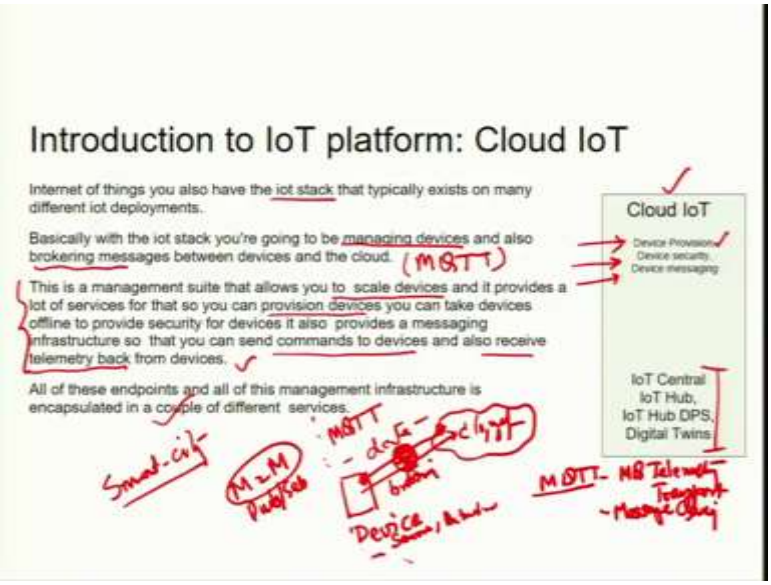

Now, you know that Internet of Things, you have this IoT stack which consists of many different IoT deployments. So, basically the IoT stack, you are going to manage these devices and also these devices when they generate the messages. So, you require a software module which is called the broker.

So, brokering the message between the device and the cloud is very essential, we are not going in detail, but let me explain you that this service which takes this IoT message and transfer it to the cloud is defined by a protocol which is also well known as MQTT. So, MQTT will provide a Message Broker wherein, it will take the messages from these devices which are generating at the last mile of IoT platform and give it to the cloud for getting insight.

So, that is what is the cloud IoT. So, cloud IoT will provide the device provision, it will also ensure the device security and also makes an endpoint for device message. So, you can see from this particular figure, you have a device which is in the form of sensors and actuators and when they are going to connect or take this particular data to the cloud for that, this is a brokering service which runs at both the endpoints.

So, this communication is called machine to machine communication. So, at one end is a device the other end is also a cloud another machine and the protocol, which does this data transmission for these two endpoints that is the device and the cloud sometimes used as MQTT. So, MQTT

stands for MQ telemetry transport so, MQ stands for message queuing telemetry transport is the full form of MQTT.

So, MQTT is a protocol that is machine to machine protocol and it works with a broker. So, a broker sits and run in the form of publice Pub Sub publish and subscribe system. So, the data which is generated by the device will be published and the data at the IoT cloud, cloud IoT will be subscribing it so, this particular management suit allows you to scale the devices it is not only one device, but hundreds and thousands of the devices are deployed.

For example, a smart city environment so, many number of IoT devices are installed. So, how all these devices start communicating with the cloud that is at the cloud IoT. So, this kind of scale is also possible and management suit is required to scale the devices and provides lab services for which you have you can provision the devices you can take the devices offline to provide the security for the device, provides a messaging infrastructure so that so that, that devices can or you can send the command to the devices and also receive the telemetry back from the devices.

So, this particular management, which is provided with the help of these two ends, that is the cloud IoT and the device part is a part of this IoT platform and we are discussing the other end that is the cloud IoT.

So, all of these endpoints and all this management infrastructure is encapsulated in different types of services. So, the services which we have already pointed out as device provision, device security, device messages, so let us see how in particular IoT platform that is given by Microsoft Azure handles this three different aspects in cloud IoT.

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So, on Azure there is a service which is called an Azure central, which is more like a software as a service offering out of a public cloud that encapsulates a lot of functionality for the ability to create the applications in the context of an IoT Central.

Also, it allows multi tenancy with the different devices to scale, not only the devices, but also the downstream components of the Internet of Things, integrating these devices as they are serving up. So, therefore, IoT Central is a software as a service, which runs and which provides this kind of encapsulation functionality to create the applications and also support multi tenancy with different devices so, to skill the other component, which this Microsoft, Azure provides in the form of IoT Hub is a general purpose tool, the Azure provides for managing these devices. This is also important so many devices are there, and these devices are to be managed by the cloud.

So, it has a device provisioning services that we have already mentioned and this particular that is IoT Hub, which is an Azure service, which does this device provisioning, that needs for the scaling up the device for putting up the certificates on the devices, generating those certificate for messaging from the device and for the messaging to the device at the low level functionality, that is all being handled by the IoT Hub.

Now, another important aspect of this particular device provision or device management is done with the help of Azure digital twin. So, for every device, there is a configuration or the state of the device is maintained in the cloud and that is called the digital twin of that particular device.

So, this digital twinning is the ability to manage the device configuration in a suit of software to integrate with the Azure IoT Hub maintains a some kind of state information about the device in the cloud so, if the device is on or off is working at a proper speed at a particular temperature, all this is a part of the configuration and that is called the digital twin of that.

So, instead of going directly to the device, the digital twin which is maintained by the IoT cloud in the form of Azure IoT Hub, this particular configuration is maintained and this makes this particular device managing that particular device and provisioning this particular device from the centralized management control, which is being provided by some of these platforms and for Microsoft it is called as Azure IoT Hub and digital twins.

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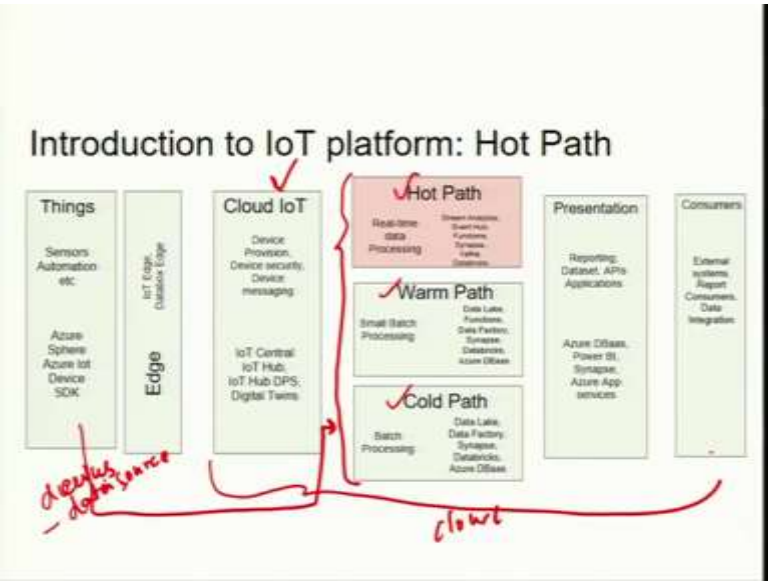

Now, having understood the cloud IoT the next part, we are going to discuss about the data, what are you going to do with the data which is being generated by the devices. So, devices becomes the data source. So, as we have mentioned in the first slide, that these data source has to be brought into the cloud and how they are to be connected that we have already seen in the cloud IoT.

So, this particular different messaging solutions will bring this particular data which is originated by different devices into the cloud system. And there are three different type of way by which these particular data is can be processed one is called hot path. The other two are also called warm path and a cold path, let us understand these different type of analytics or analysis of the data which is brought into the cloud.

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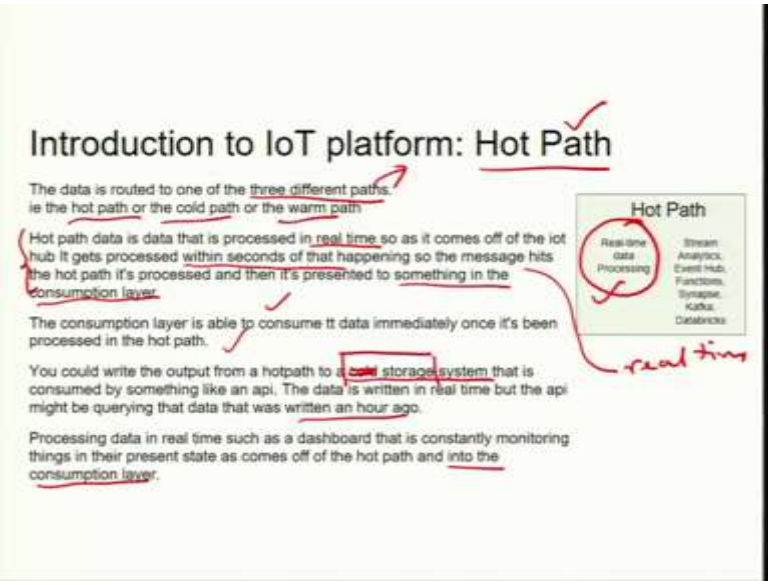

The first one is called the hot path. So, the data that is routed by the device will be processed in three different ways they are called path that is called hot path, cold path or a warm path. So, let us understand about the hot path way of analyzing the data. So, hot path data is the data that is processed in the real time.

So, as the data comes into the system, it will be processed on the fly or immediately. So, as it comes off the IoT hub it gets processed within the seconds of that happening. So, the message hits the hot path and it is processed and it is then presented to some something in the further layers that is called the consumption layer.

So, that is called the hot path, hot path you can also understand by processing that particular data into the real time real time means, as the data is incoming into the system it has to be computed and processed.

So, it is also called as a hot path is also known as the real time data processing. For that, we will be looking at what are the different services, which IoT platform are now doing it for doing the hot path that is real time data processing.

Now, consumption layer is able to consume the data immediately once it is being processed in the hot path. So, that is the other side that is the consumption layer is all the time ready to consume the data which is being processed here in the hot path. Now, you could write the output of the hot path to the cold storage system.

So, cold storage means that you can as well write that the outcomes of the hot path analytics and store somewhere in the storage system and that is why it is called the cold storage. So, that is consumed by some API and the data is written in the real time, but the API might be querying the data after some time and therefore, it has to be stored in another form that is called storage system.

So, processing data in real time, such as a dashboard that is constantly monitoring these things in their present state as comes off the hot path and will be done at the consumption layer. So, so, that monitoring or monitoring of the outcome of this real time data processing or a hot path will be seen in the next layer that is called a consumption layer.

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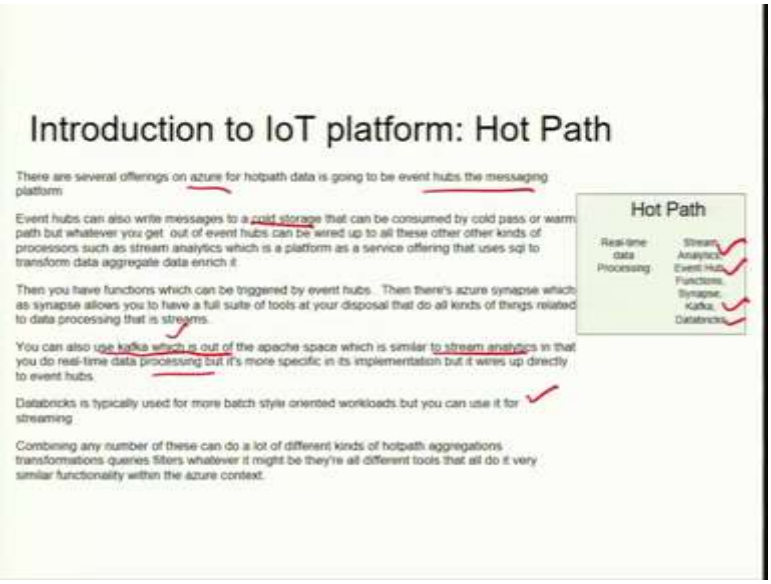

So, let us see about the hot pot in more details. So, there are several offerings by the Azure for the hot path. So, we are going to see these kind of offerings, which this IoT platform provides that is in the form of IoT Cloud for doing this hot path processing that is in the form of messaging platforms.

So, the hubs that is Event Hubs can write these messages into the storage and that storage can be consumed by the cold pass or warm pass whenever you get out of these events that we have already told. Now, you have several functions that which can be triggered and these functions are listed over here that is called stream analytics and this particular event hub that we have talked is synapse, and then Kafka and data bricks.

So, you can understand the use of the Kafka, which is out for out of this Apache space, which is very similar to the stream analytics of in that real time data analytics and is more specific in its implementation.

So, there are various solutions which are available, which can bring the data and do the real time processing and that is one of this particular well known system that is called the Kafka. So, data bricks is typically used for batch style oriented, but you can use for streaming as well. So, that is why it is mentioned over here.

So, this combination of any number of these, that means offerings like whether it is stream analytics, Event Hub functions, synapse, synapse, Kafka, data bricks and the combination any of these combination can do lots of different kinds of hot path aggregation, transformation queries, filters, whatever it might be, and different tools are available very similar functionality is available in the Azure and in other cloud offering as well.

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Now, we are going to see about the cold path what do we mean by the cold path, how that is all done. So, cold path is a batch oriented. So, unlike the hot path, the message will be now accumulated into the system and then it will be processed at a later point of time.

So, here, this accumulated message over a period of time is then typically triggered with a timer and then only it will be processed and that processed data in the form of the batch and this batch oriented processing is called a cold path.

So, this particular data will be write back in some kind of storage and wherever the processing on the data might look like, so, one way of this particularly storage, you can see you can understand is in the form of a data lake, data factory, synapse, data bricks and Azure database as a service. So, these are all different ways by which you can use to store the incoming data so, that you can process in the batch at a later point of time.

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So, this we have already discussed that, Azure database also offers as a service offering is there it uses also you can use SQL databases or you can use Cosmos database and so, on there are many other there are many ways of storing some kind of data into the storage platforms which are being provided and here listed in this particular slide in the form of data lake, data factory, synapse, data bricks and Azure database as a service.

So, Azure database as a service uses different type of database possible and which is used for the storage platforms. Now, you can see about the data factory or software as a service platform. Similarly, you can see synapse, a very similar functionality is integrated in a synapse shoot on the Azure Data bricks also provides the ability to scale and integrates with a lot of other offerings.

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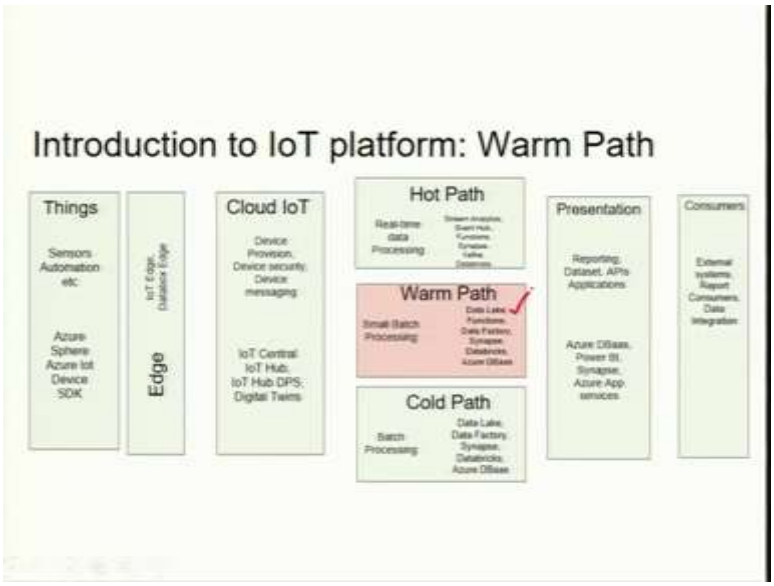

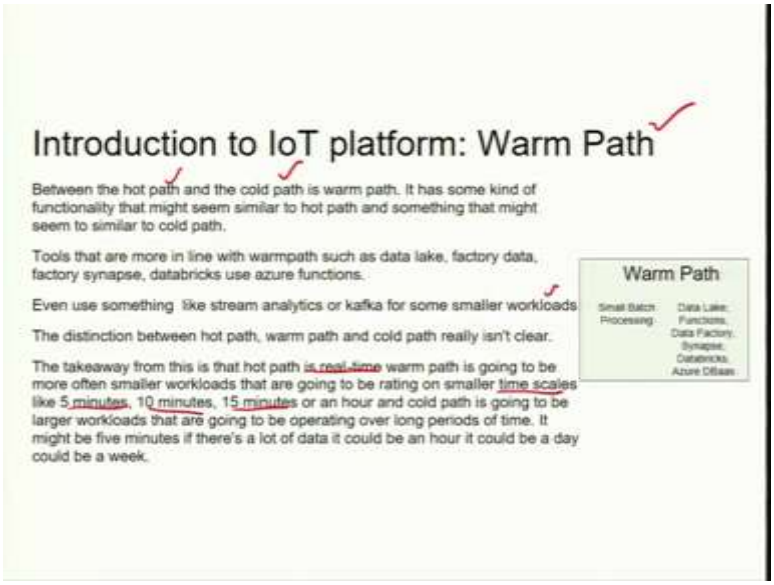

Now, let us understand with the third approach of data processing, which is called warm path. So, in the warm path, which lies between the hot path and a cold path, so, that means, it has some kind of functionality that might seem similar to the hot path and something that might look similar to the cold path. So, it is in between and this is called a warm path.

So, tools are more like more in the line with the warm path such as data lake, factory data, factory synapse, data bricks use the Azure functions and so on. So, that is what we have seen

how are, you can use something like stream analytics or a Kafka, but for a smaller workloads in the warm path.

So, the distinction between warm path, hot path, cold path is not very clear, it depends upon the application. So, the takeaway from this is that the hot path is something which is real time and warm path is going to be more often smaller workloads that are going to be rating on a smaller time scales, let us say that 5 minutes, 10 minutes, 15 minutes, an hour and cold path is going to be a larger workloads that are going to be operating over a long period of time.

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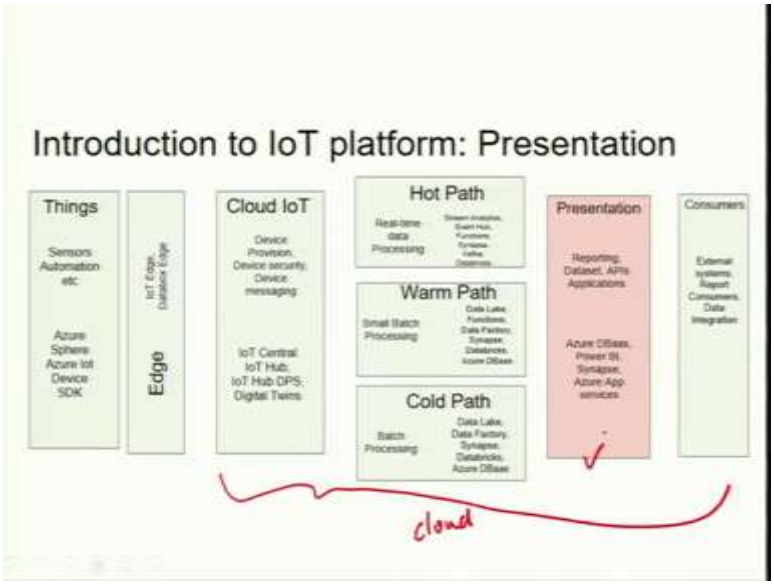

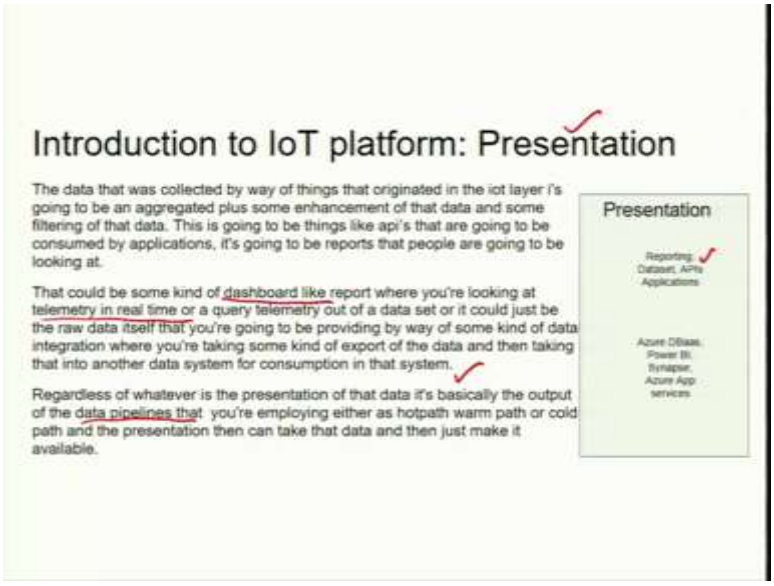

So, we are going to see the next component of an IoT platform in the cloud which is called the presentation. So, as it is mentioned over here, presentation means that you have got the insight done before the presentation now, you required to make a report of that particular insight and different API's and applications you need for that in the presentation layer.

So, the data that was collected by the way of the things that originated in the IoT layer is going to be aggregated some enhancement of that data and filtering of that particular data is a part of that presentation.

So, you required for in this presentation something like a dashboard, which can make you aware or which can summarize that particular result or a report that you are looking at the telemetry in the real time or you can also perform a query for a telemetry out of the data set or it could be just a raw data itself that is going to be providing some kind of data integration with this particular dashboard and some kind of export the data and then taking into another data system for the consumption of that particular data. There are many ways of this doing this presentation.

So, regardless of whatever is the presentation of the data is basically the output of the data pipeline that you are employing either as the hot path, warm path or a cold path, and finally, it comes to the presentation that can take the data and then make it available for the presentation.

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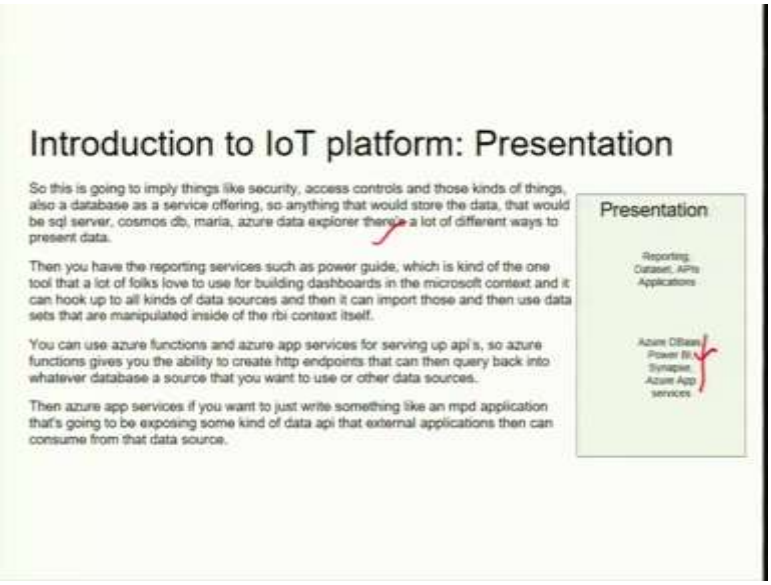

So, it is going to employ the things like security access control, those kinds of things also, the database as a service offering in this particular way, it is not that presentation is to be given based on these access control mechanisms and different mechanisms or different databases are to be accessed on that particular query for the reporting and so on.

So, there are different services which are available, which can be accessed for the presentation that we have already defined, important thing is business intelligence, you have a Power BI is on there are different services which are utilized here in the presentation layer.

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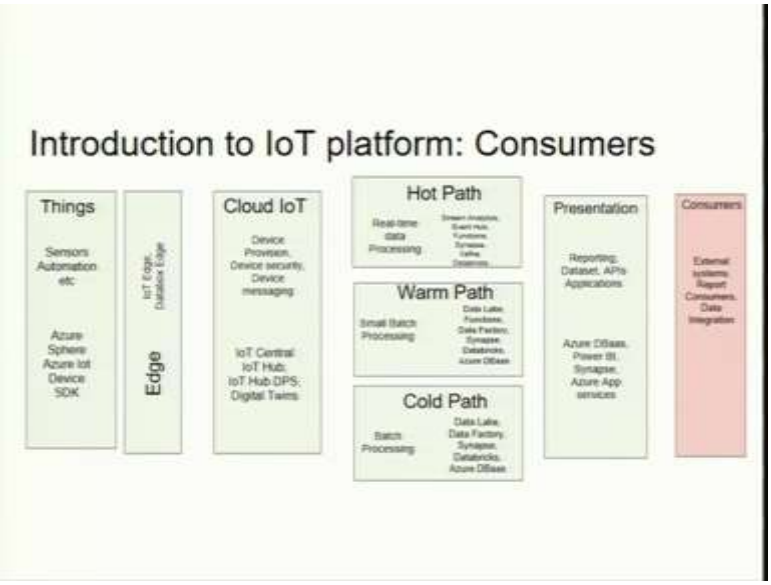

Finally, you have now the consumers or so, consumers is the external systems and the report and the data integration of that. So, let us understand this.

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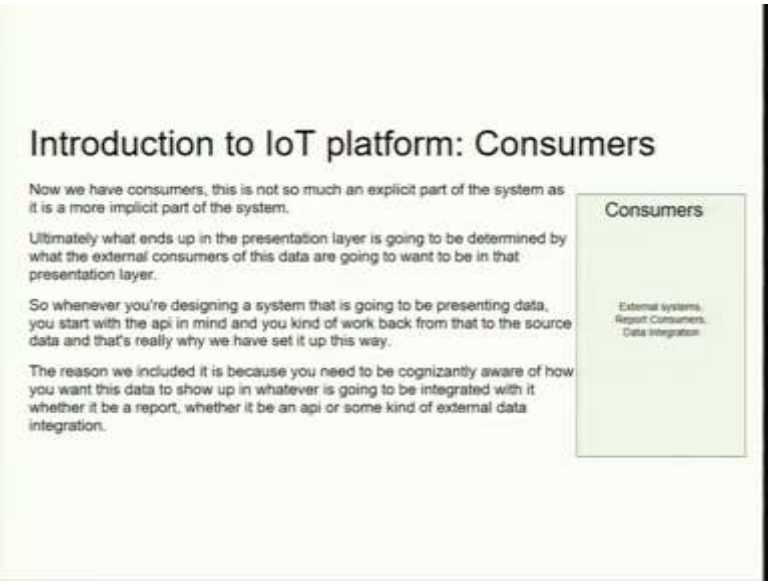

So, now you have the consumers, this is not so much explicit of the system as it is more implicit part of the system ultimately ends up out of that presentation going to be determined what external consumer want out of that particular data through the presentation layer. So, you are designing a system beyond this, as far as the consumers are concerned.

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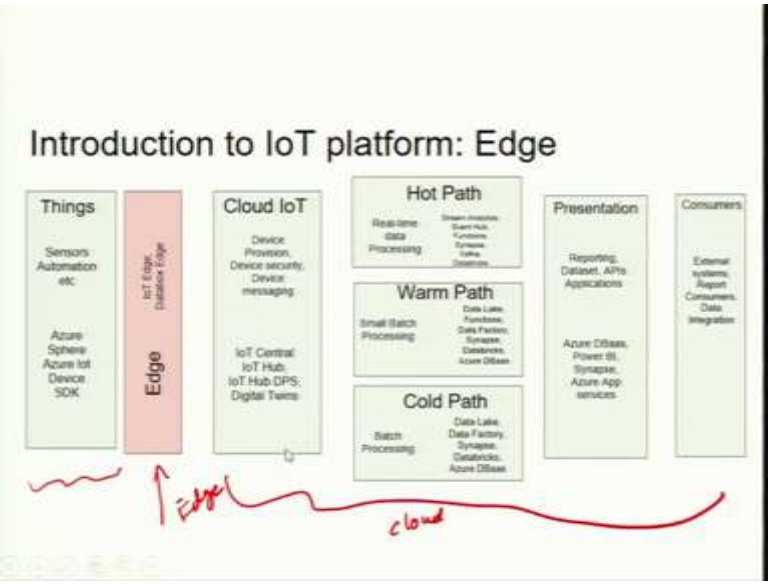

Now, after having seen the things on one end of the spectrum, and there is another end of the spectrum that is called a cloud. Now, it is the time when you have to see in between that is called an edge. So, in IoT platform, what is the role of the edge we are going to see now.

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So, on end of the network, the local area network, a bunch of devices that are emitting the telemetry and the events and doing all kinds of things that they do are ultimately sent back to the cloud.

However, in some situation, some kind of pre processing also if it takes place, so that means all the data need not have to be sent to the cloud that is called some sort of filtering and aggregation and some enhancement on the data which is closer to the devices. So, there comes the necessity of an edge layer.

So, in the sense, the edge is almost the micros of everything that happens in the cloud. So, you have the things you have the message, buses, data pipeline, many other kinds of data enhancement tool exist for pre processing. So, pre processing the data before it goes to the cloud is the part of this particular edge. So, there are two types of services which runs in the edge. And first one is called an IoT Edge.

So, IoT Edge is a platform, which is more of an operating system that can be installed on that appliances, which works very close to the device, and it is based on the Docker containers. So, this particular Docker container will now allow this particular mimics some of the cloud functionality at the edge so that pre processing can be performed before the data can be sent to the cloud.

So, for example, you can do a stream analytics, and your ability to do the message filtering and number of other things is a part of the edge layer and when you install and these applications on the edge using the Docker and container on this IoT Edge.

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So, this particular edge, it offers a message proxy for sending the messages from the devices to the cloud. And so here in the event of internet outage, you can also have the queue of these messages. And when the internet is restored, then you can forward those to the cloud and therefore it mitigates against the things like loss of the message due to the internet outages and so on. So, it has various advantages.

Similarly, there is a local response to the event in a particular context as well as and you can do to build and machine learning on some other kind of event management at IoT Edge. So, there are various tools available to do this called Data Box is very similar service which can do this kind of machine learning type workloads and also will be run at the edge that is the machine learning models.

So, in the context of edge installation, you have to ship all the data back up to the cloud, you can do it more intelligently on the edge. So, it as far as the edge is concerned, it mimics most of these function at the edge and it can do all that things very quickly and does not also rely even the internet connection therefore, it reduces the latency and then now, whatever is very essential will be then sent back.

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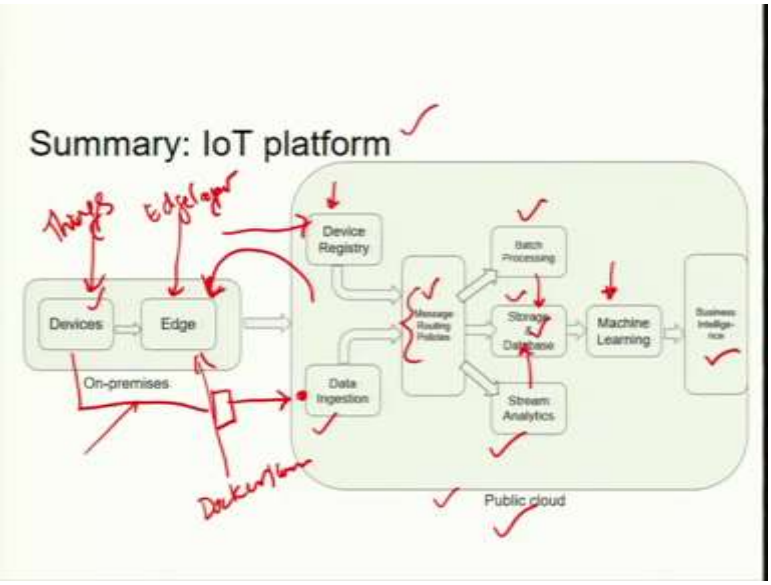

So, let us summarize this IoT platform in the following slides. So, what we have seen as the IoT platform that on premise what you will see, this is the devices and very close by there is an edge.

So, both of these layers, we have mentioned the devices as the things and this is the edge layer and then followed by this is the public cloud.

So, this particular device, which generates the data using some brokering service or messaging, message brokering service will now make a endpoint connection in the public cloud. So, that it will be receiving the data which is means subscribe the data which is being published by the devices. So, these for that these devices need to be recognized in the public cloud for that there is a service running which is called a device registry.

So, as we have already mentioned that in the cloud IoT, this particular component will work that is called a device registry will have the specifications of all the devices which are operating in the system then comes that when these particular devices which are registered when they want to generate the data, so, there should be a service which is called data ingestion service. So, we have already seen some of these important data ingestion service, which will take the data from the devices and put into the cloud system for doing these computations.

So, then comes this particular data ingestion, the once that data is entered into the cloud system, then there will be a message routing policy that means, how the data is to be processed or computed we have seen whether it is to be done by the hot path analytics, hot path data analytics, cold path data analytics or warm path data analytics which will be decided here by the message routing policies, if it is hot path data analytics then you have to do the stream analytics in the real time and if it is the cold path analytics, then you have to do batch processing into the system.

And if you want to make it persistent these batch processing, then you have to use the database and you have to store these data into the database system and stream analytics also you can after computation processing you can store in the database as well that we have already seen once the data is stored, whether it is a process data by the hot path analytics or by the cold path analytics that is by the batch processing or the stream processing the data is stored in the databases.

So, these databases are the databases which can store the unstructured data as well. And this is being offered as a database as a service by different cloud providers. So, that we have already mentioned. So, once the data is available in the database, then you can perform a machine learning using this particular data and then this machine learning will generate some kind of

business intelligence that is the actionable insight which the business intelligence will be doing it.

Now, these particular capabilities which the public cloud is having some of these capabilities are now again is executed on the edge so that you can reduce the latency for that you will be requiring something which is called a Docker container for the virtualization and then you will be running these services on the edge. So, that is what is the summary.

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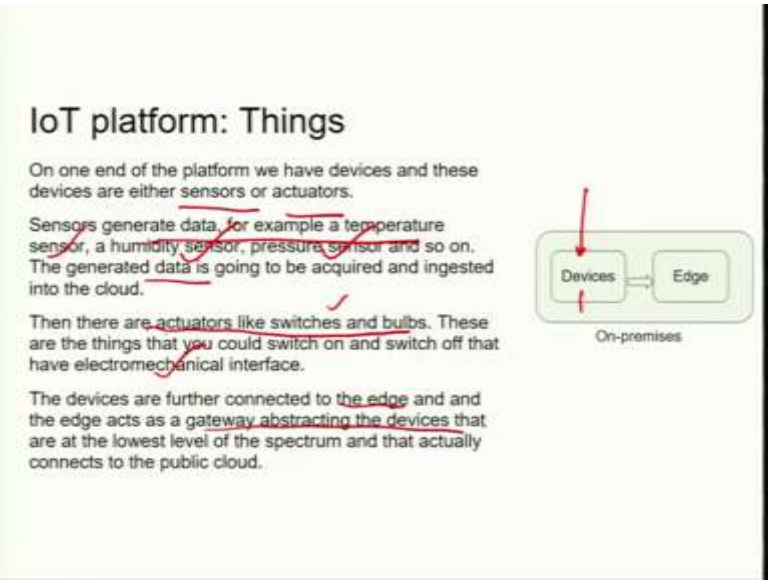

And these things we have again going into summarizing in more detail. So, what we have discussed about the things so things are nothing but they are the sensors and actuators they are the devices which are deployed in the particular scenario and they are generating the data such as the temperature sensor or the humidity sensor or the pressure sensor. It depends upon that application, what kind of sensors are deployed for monitoring the conditions of the factory or the city or the home and so on.

So, these particular sensors which are also called as a devices and actuators also called the devices. So, once they will generate the data it is going to be acquired and ingested in into the cloud. So, as far as the devices are concerned it is not only sensors, but they are the actuators also such as switch and bulbs are called actuators where you have to now send the command for the

switch for example, it is bulb to switch off or switch on these are called so, these are called actuators, electromechanical devices are called the actuators.

So, these are the things that you could switch on and switch off and that have been electromechanical interface. So, these are called things or the devices so, the devices are further connected to the edge and the edge acts at the gateway abstracting the devices that are at the lowest level of the spectrum and that actually connects to the public cloud.

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So, what we have seen is that this particular connection to the other endpoint goes into the cloud through the edge. So, there are two touch points when you go inside the cloud one is called a device registry, the other is called the device ingestion.

So, all the devices in the (sense) sensors and actuators they have to be now, on boarding or they have to be now recognized into the cloud system that they are operating under what conditions. Similarly, the data ingestion. So, so for that, it also uses the digital twin for that, after the doing the device registry for maintaining the conditions of configuration of the device. Then comes the authentication and authorization of the devices that is stored in the device registry.

So, this is very much important why because the authentication, authorization will now check through the security whether these devices are authorized or not. So, this particular way of maintaining the directory of all the devices in the form of device registry, then the next pass is

called and in the IoT pass is called data ingestion point so the devices which are registered when they will generate the data.

So here, the other endpoint will receive it that is called subscribed the data which is being published by the protocol. So, you, it uses some kind of protocol and in an IoT platform, we are not going in detail about the protocol but this particular data ingestion endpoint will perform depends upon what kind of velocity it is, if it is high velocity high throughput endpoint, where the sensor data is getting streamed.

So, for that, you require another tool like Kafka, which could be doing all that similar tools are also available by the other cloud vendors like such as Amazon kinases or Google Cloud publish subscribe. So, it is a pipeline that basically acquires the data and passes on this data processing pipeline.

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Now, the third important thing is the insight that I have already told that for once the data is ingested into the cloud, then it has to be processed to get the insight out of the data which that devices has ingested. So it has to be done through the policy that is called message routing policy.

So, message routing policy will define how this particular data is going to be split between the batch processing and the real time processing and how this raw data is to be stored and

processed, is going to be stored all this is defined in the message routing policies that we have already explained the different types of policies so, that is to be configured here in an IoT platform under the category called insight.

So, for example, some data needs to be batch process. So, you have to first collect and then then aggregate it and then process at a later point of time, and in some cases, you need to process it in the real time that we have already done.

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So, therefore, there are three different ways one is called cold path analytics, a hot path analytics, and these are all we have already covered and discussed.

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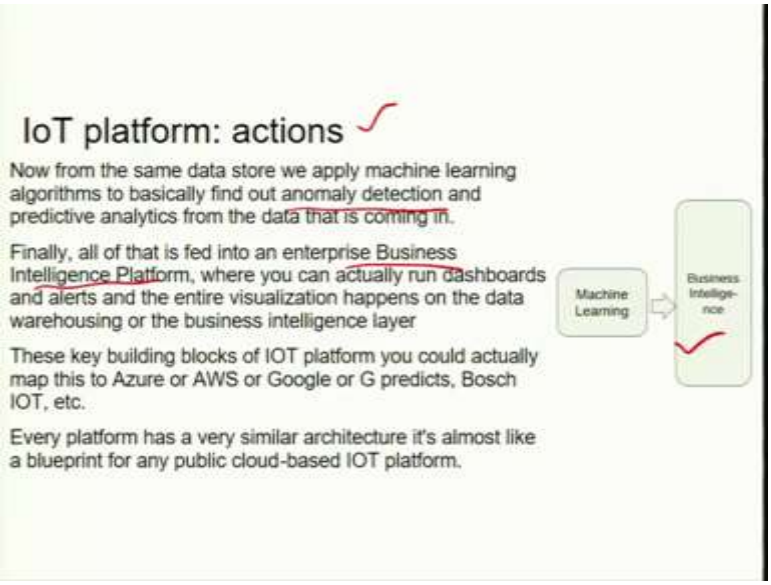

Finally, the data which is ingested and decided to be processed under different policies now finally, it is a time when you have to take the actions for that you have to apply the machine learning to find out the anomaly which is to be detection and for that and using the predictive analytics actions from the data which is incoming so for that, you know that you require business Intelligence platform.

So, Business Intelligence platform requires the input from the machine learning and then it will do this visualization and also apply their data warehouse and so on. So, therefore, the key building blocks of an IoT platform could actually map this to either Azure IoT Hub or AWS, that is called AWS IoT or a Google or a Bosch, IoT and so on.

So, all these platforms, which are being provided by different companies, that is very similar to what we have covered here as IoT platform. So, we have covered very generic and functionalities of this IoT platform and this architecture is quite similar to what these cloud providers are providing.

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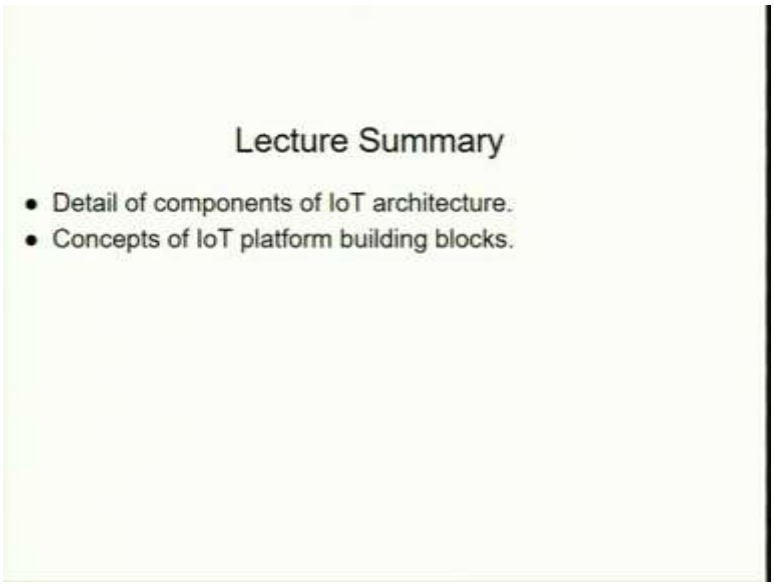

So, let us summarize what we have so far discussed. So, today we have discussed the IoT platform that is the details of all the components of an IoT architecture. We have also given you the concept of IoT platform building blocks. Thank you.