Introduction to Industry 4.0 and Industrial Internet of Things

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Lecture – 30
Key Enables of Industrial IoT: Connectivity – Part 3

In the previous 2 lectures on Connectivity, we were primarily focusing on legacy protocols, which have been around for offering industrial communication of high quality, high grade, having specific, industry specific requirements of reliability, low latency, low jitter, and so on, but there are many different protocols that could be used in the industrial contexts. Many different protocols have evolved over the years many different protocols have evolved over the years particularly with the advent of wireless communication, low power wireless communication, IoT based communication and so on.

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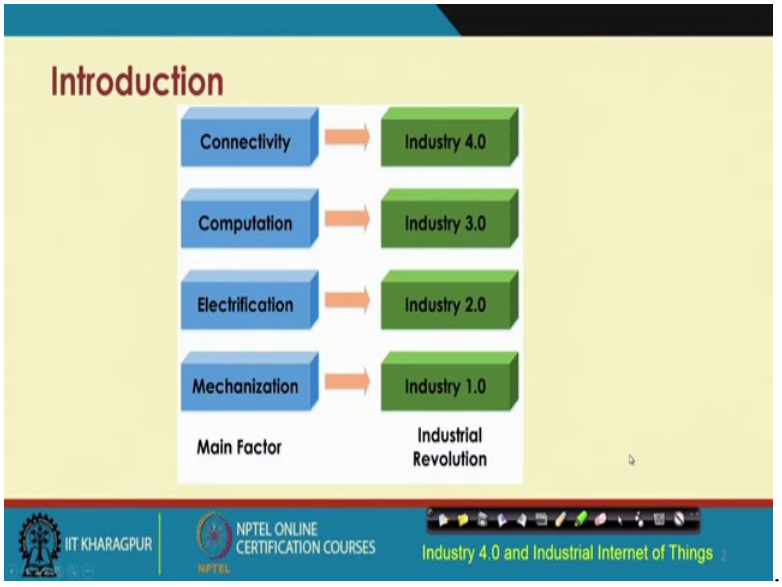

So, if we look at present we are talking about Industry 4.0. So, industrial revolution has happened through different generations of 1, 2, 3 and at present we are talking about 4.0 where the focus is on connectivity.

Now, in this particular context there are different IoT technologies that have come up which can help cater to the requirements of supporting Industry 4.0, protocols such as the

ones that we have discussed in the introductory section on IoT at the outset of this particular course we talked about different IoT protocols. Protocols such as AMQP, MQTT, and many others that we have gone through so far could all be used in addition to these legacy industrial communication protocols, that we have discussed in the previous lectures.

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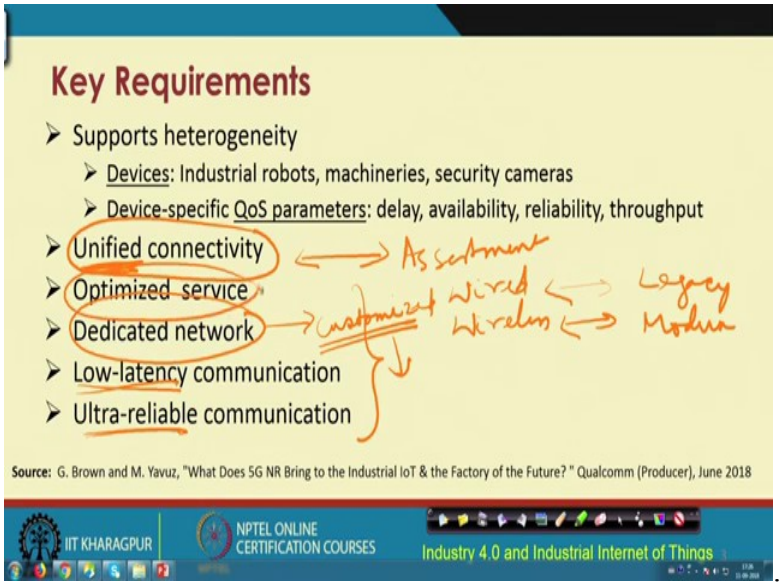

In addition we could use different other advanced protocols particularly protocols belonging to different wireless communication technologies could be used in order to provide connectivity between different devices such as the industrial machines, different types of industrial machines, robotics, robotic machines, robotic devices between the security, cameras in the industry, and so on, and supporting different quality of service parameters of the networks, that are being built in terms of delay, availability, reliability, throughput and so on.

Overall what is desirable is to have unified connectivity even if you are using an assortment of different protocols which may be wired or, wireless or which could be the legacy ones or, the modern ones, what is important is to be able to offer unified connectivity, unified connectivity.

Unified connectivity means what, that seamless connectivity users would not know how which protocol depending on the specific requirements, scenarios, instances, circumstances and so on, which protocols are being used and they are getting shuffled,

reshuffled and at the back end. Users basically get the services and behind the scene there is an unified connectivity architecture, that basically helps in sending data from one point to another catering to the specific industrial requirements that are there.

So, these legacy protocols have been there modbus TCP, RTU, these fieldbus, profibus, inter bus and so on. So, all these protocols have been there plus you have new protocols such as MQTT, AMQP and many others which have become popular in the IOT era. Plus there are few others that we are going to discuss now, which are like 5G tactile internet etcetera which have become very popular, in the recent times. They could also be used they could be integrated together to offer an unified kind of platform supporting different protocols they could be used and unified connectivity can be offered.

What is next important is the optimized service, optimized service, dedicated network communication, low - latency communication, ultra - reliable communication, these are the different other industry specific requirements that will all have to be care to. So, this low latency communication is understood, ultra reliable communication is also understood.

What is this dedicated network? customised requirements, basically customized requirements will have to be fulfilled, in addition, to the because different industry, the particularly different industrial sectors have specific in, customized requirements. Those dedicated network solutions will have to be used in order to fulfil to the customized requirements plus optimized, together with fulfilling these customers requirements optimized service offerings will have to be made.

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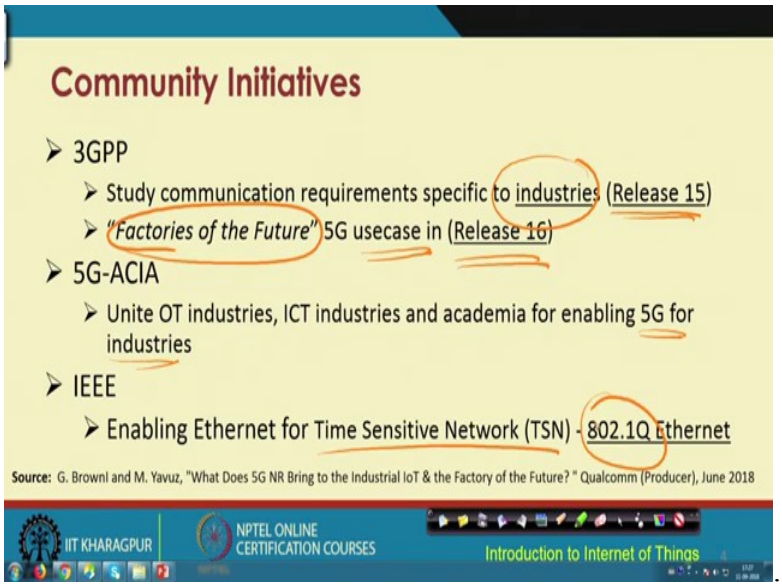

So, we will look at different protocols there have been different community initiatives for example, the 3GPP which has different religious catering to industrial requirements is this release 15, release 15 basically caters to the industry specific requirements.

Release 16 basically talks about the factories of the future so smart factories and so on. So, different use cases supporting the factory smart factory requirements and then you have the 5G – ACIA, which basically unites the OT industry OT means operational technology industries with the ICT industries information and communication technology industries and academia for enabling 5G for industries. So, basically this is talking about 5G for industries 5G- ACIA and IEEE, has different protocols like the TSN supporting the 802.1Q Ethernet protocol.

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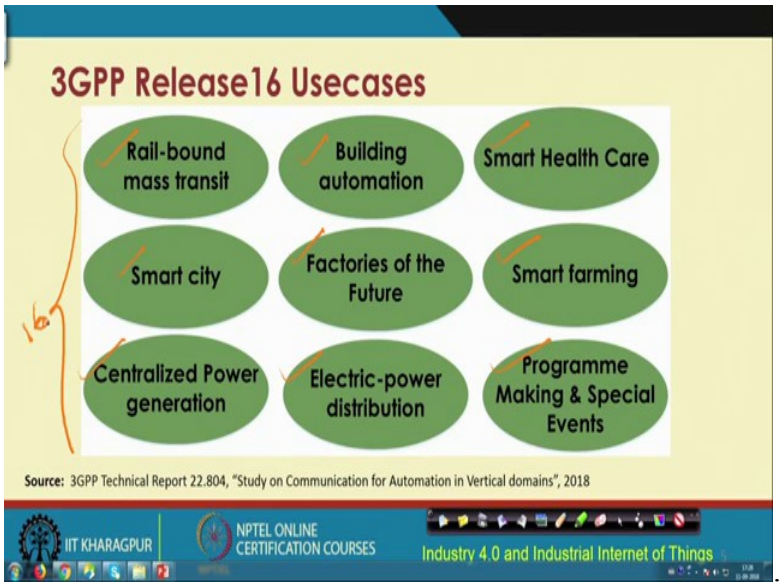

So, 3GPP released 16 has these different use cases has support for different use cases, these are the ones that are basically listed in the 3GPP document. So, first one is the support for support for real bound mass transit, real bound mass transit, building automation, smart healthcare, smart city, factories of the future, smart farming, centralized power generation, electric power distribution, program making, and special events, these are the different use cases, that are supported by the 3GPP released 16.

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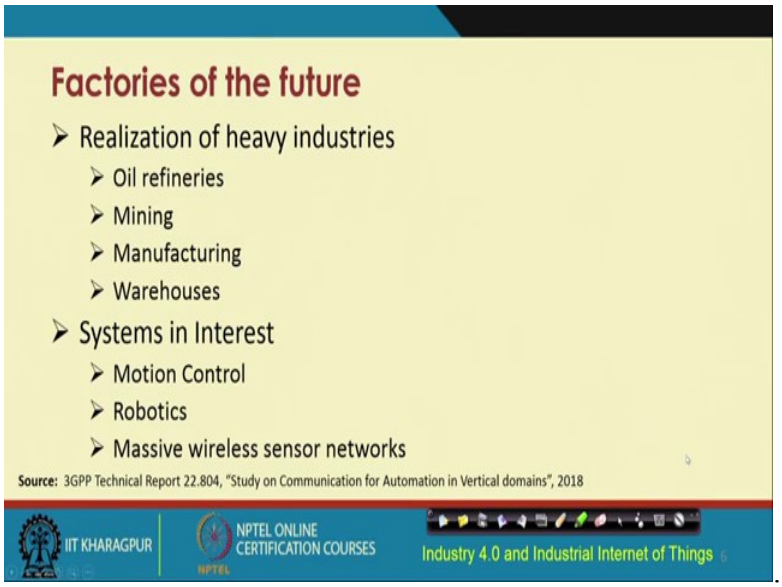

Factories of the future, here basically we are talking about catering to the heavy industries primarily such as oil refineries, mining industry, manufacturing industry, warehouses, and so on and the interests of the different systems for example, motion control this is very important, robotic machinery, sensor networks, massive wireless sensor network deployment. So, all of these are requirements specific to the smart factories of the factories of the future.

So, 5G technology could be used to build different private networks within these different industries. So, there is this 5G in our 5G new radio which has different band specifications this high band, which is basically more than this 24 Giga hertz band is this millimetre, supports millimetre wave communication, supports millimetre wave communication. Then we have this for small scale private network communication, small cell deployments are also there in the form of femtocells, picocells, integrated Wi-Fi. This device to device communication, basically, you are talking about one device supporting one type of cellular communication with another device supporting another cellular communication not another, but the same cellular communication basically device to device direct communication without involving some kind of a centralized controller is going to be performed and that is sometimes required. And this will be very much useful particularly in the industrial context, because the one machinery might want to talk directly to another machinery and you do not want to send the packets from this machinery to the central controller and then from the controller to the other machine. So, device to device communication will cut down on the overall latency of communication in the system.

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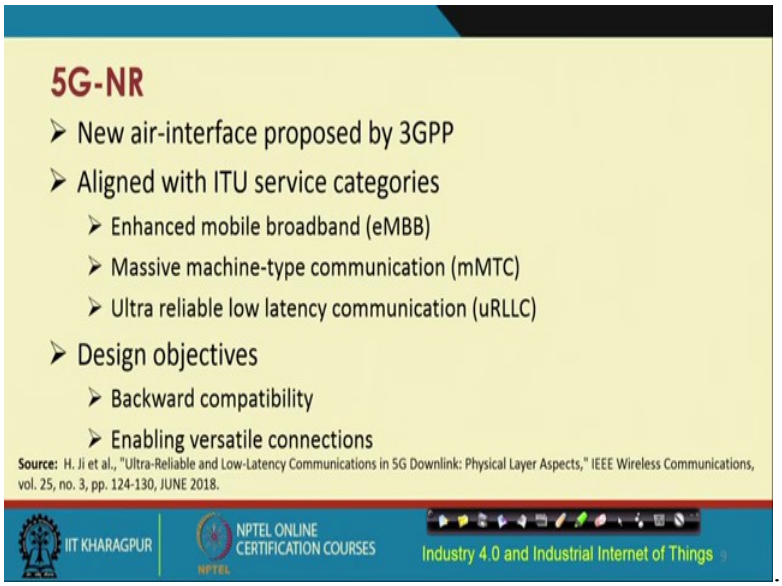

So, let us talk about this 5G- NR. So, now it provides it is a 3GPP protocol, which provides new air interface and is aligned with different ITU service categories such as the enhanced mobile broadband, eMBB, massive machine type communication, mMTC and ultra-reliable low latency communication, uRLLCC.

So, the design objectives are to offer backward compatibility; that means, connecting different devices with the help of these technologies plus the technologies that we are supported in the past backward compatibility will be supported by these different technologies and also enabling versatile connections, connections across different heterogeneous devices, produced by different vendors, supporting different standards, and small device large device devices, has supporting different speed may be PC to PLC, PLC to something different a high motion device with a small, low motion device. All these different types of heterogeneous communication could be supported with the help of this NR.

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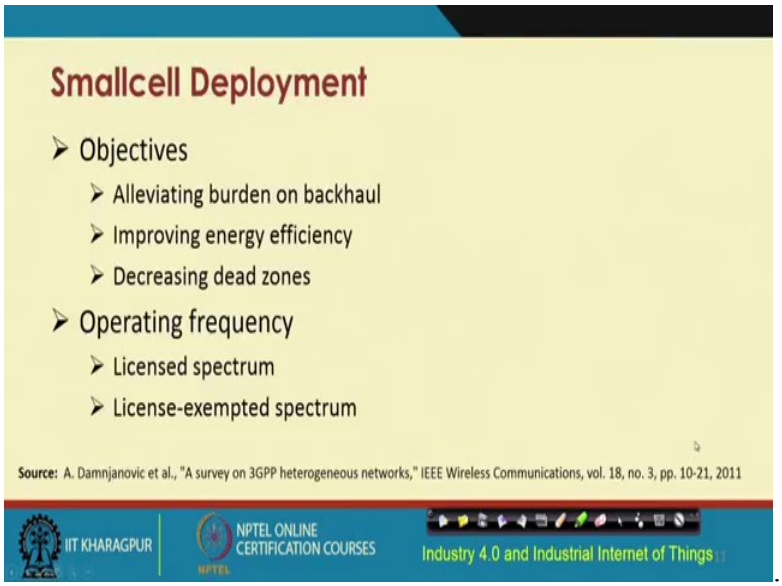

Small scale deployment here we are talking about addressing different objectives such as alleviating burden on the backhaul, improving energy efficiency and decreasing the dead zones. Dead zones are basically the ones where the network, the signals basically do not reach so, if there is if there are some dead zones, where the signals do not reach, the small cell deployment will help in this kind of offering connectivity in those dead zones, where the signals are not able to reach.

So, operating frequency these small cells support both licensed spectrum as well as licensed exempted spectrum. So, it can be supported by both of these types of spectrum.

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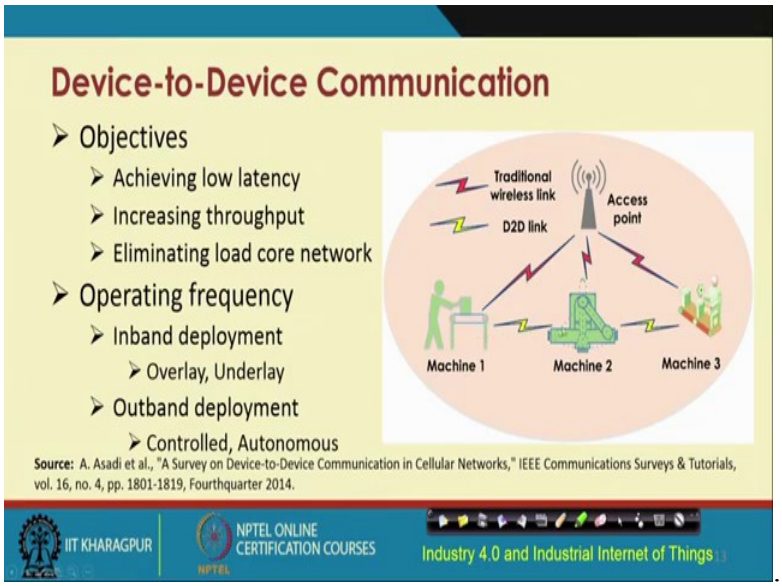

Device to device communication here we are talking about this kind of thing. So, machine 1, machine 2 they can talk to each other D2D link, again machine-to-machine 3 another D2D link device-to-device communication that basically cuts down on the time or the latency of communication and so on. So, these are the D2D links this is one, this is another and we are talking about it in contrast to the traditional links.

Traditionally what would happen is, the machine one would send the data 2 or the packets to the access point and from the access point it is going to come to the machine 2. Instead of doing around about kind of way this direct machine-to-machine communication takes place. So, the overall objective is to reduce the latency increase throughput and eliminate load onto the backbone network, the core network.

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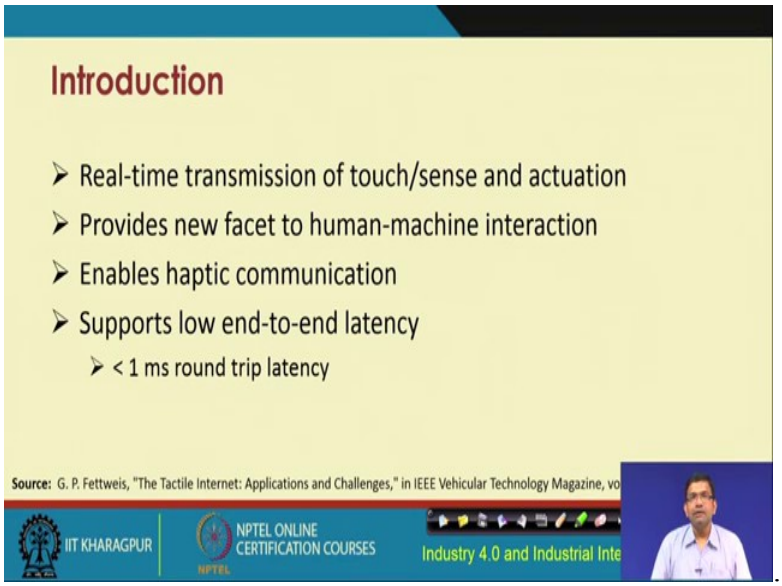

This is very important now a technology, which has become very popular is the tactile internet, which basically supports data transmission in the context of touch, offering real time transmission of touch sense devices and actuating them. So, provides a new facet to human machine interaction, particularly in the context of HCI, BCI, this a tactile internet has become very popular, haptic communication it provides haptic communication enable meant supports low end-to-end latency of less than 1 millisecond RTT.

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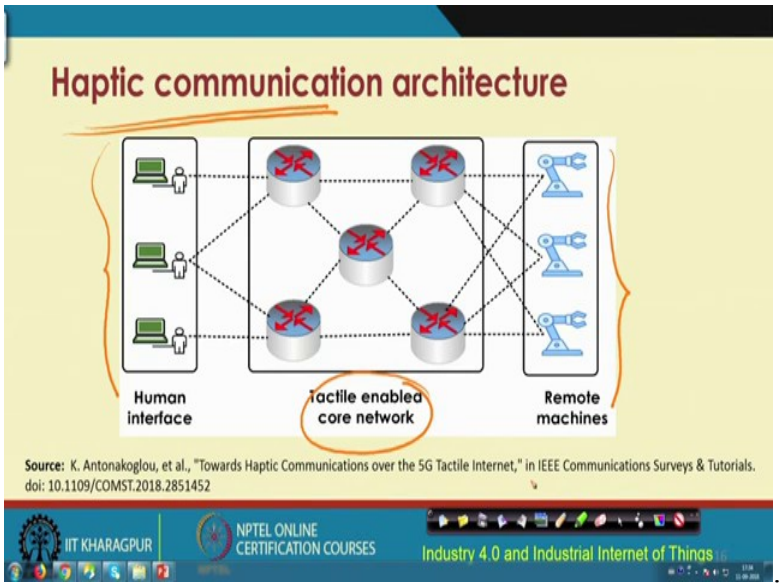

Haptic communication architecture is given over here. So, we have this human interface we have this human interface, this is this human interface we have these remote machines and in between we have this tactile enabled core network and this overall haptic communication architecture is shown over here.

So, for more details you are encouraged to look at this particular paper, which is talking about towards haptic communication over the 5G tactile internet. So, haptic communication over pair 5G tactile internet is talked about in this particular paper. So, I would encourage you to go through this particular paper to learn more details about how this these mechanisms work.

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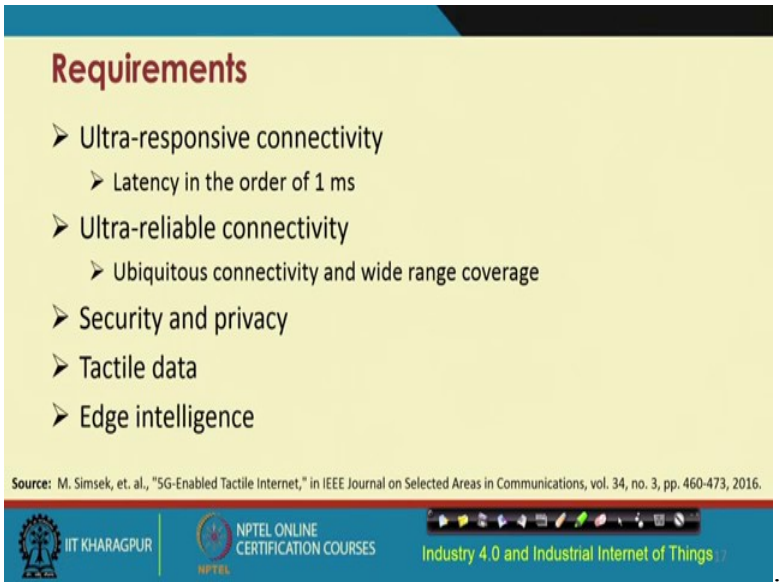

So, in terms of fulfilling requirements, requirements of ultra responsive connectivity, latency in the order of 1 millisecond, ultra reliable communication, ubiquitous connectivity, wide range of coverage, security privacy, tactile data exchange, edge intelligence; that means, close to the source of the data some of these processing is going to be done instead of sending everything to the back end to the servers and so on, for further processing.

Edge intelligence, intelligence close to the edge; that means, the source of generation of the data are going to be performed with tactile internet.

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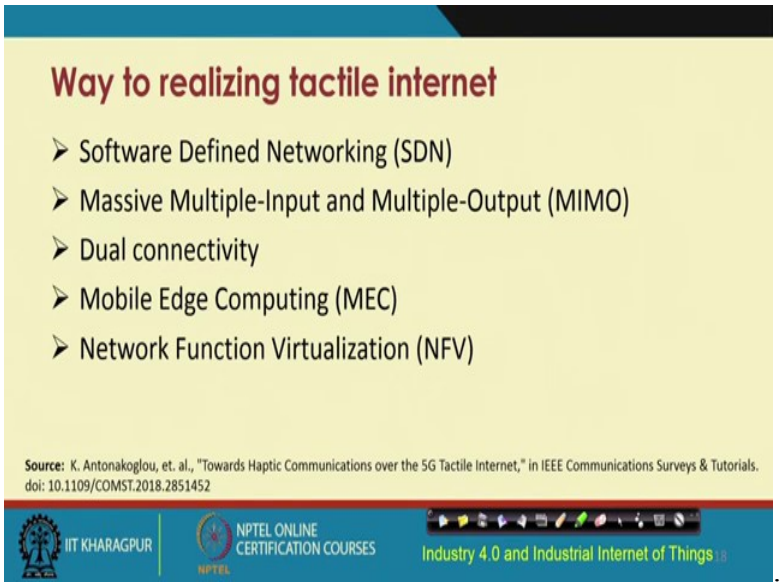

There are different ways to realize the tactile internet SDN is heavily used SDN technology, MIMO, MEC mobile aids computing, and network function virtualization.

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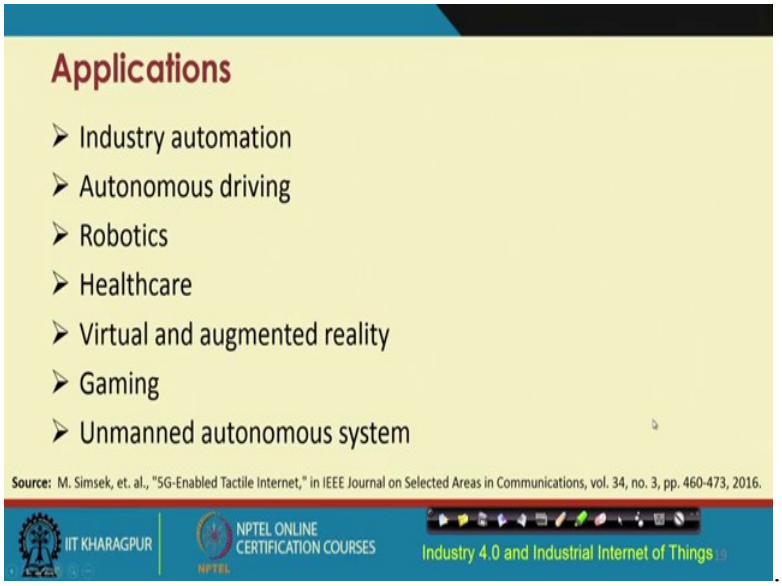

Applications for use industrial automation, autonomous driving, robotics, healthcare, virtual augmented reality, virtual reality augmented reality gaming, UAVs and so on.

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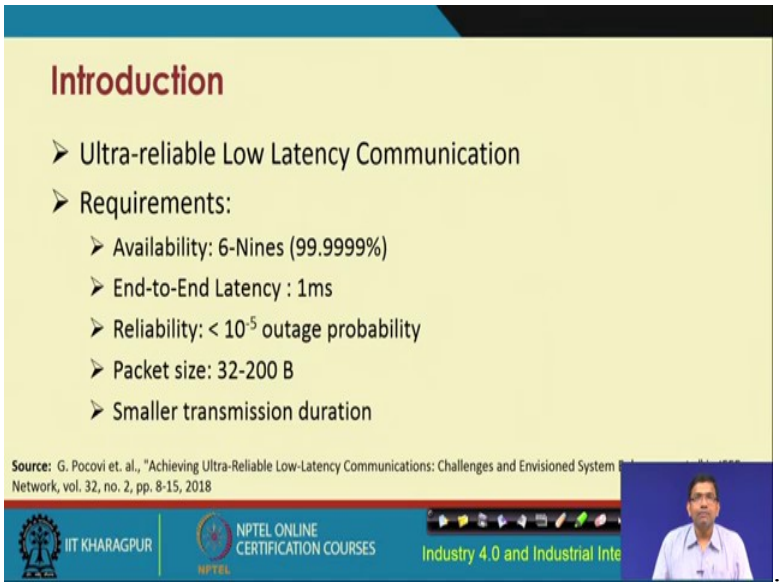

Next comes this particular protocol URLLC which is Ultra-reliable Low Latency Communication. So, as you can understand that this is quite attractive for industrial scenarios. So, here the requirements are to have availability in the order of 99.9999 percent availability. The network is made available in 6 nines 99.9999 percent of the time it is available. So, high levels of availability then into entrance e of in the order of 1 millisecond reliability in less than 10 to the power minus 5 outage, probability packet size of thirty to 200 bytes, and small smaller transmission duration.

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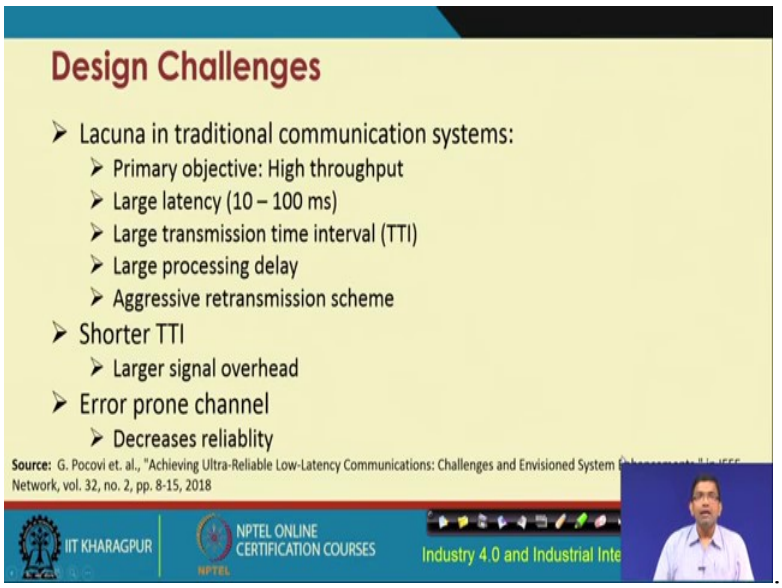

Design challenges, there are different challenges with the traditional communication systems with respect to throughput latency RTT, TTL, sorry TTL and TTL, TTI. So, TTI is basically transmission time interval, TTI then the processing delay processing delay TTI latency these are all quite high, the including the throughput is also quite high, with the traditional communication systems.

Here we need shorter TTI systems, which will provide faster communication, prompt communication, low latency communication with larger signal overhead. So, basically the signal over it is going to increase. Additionally, we have built with the challenges of errors dealing with errors we are talking about error prone challenges, which decreases the reliability.

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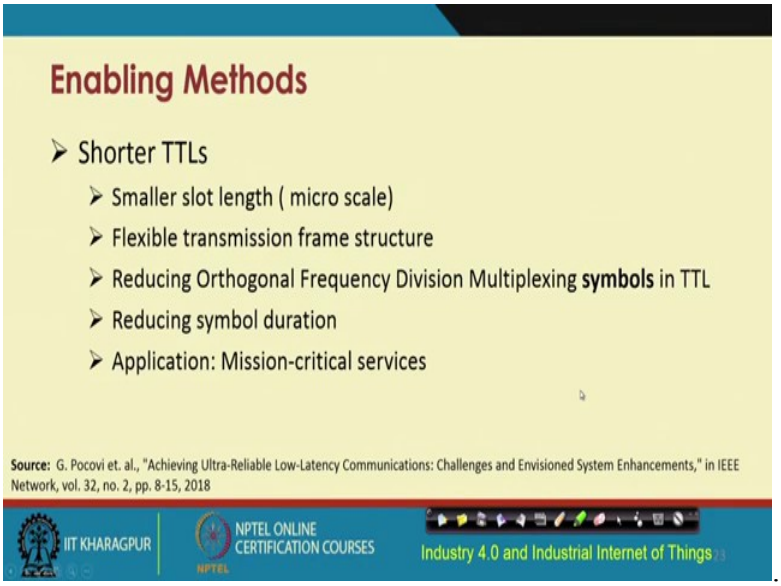

The different methods are there so, shorter TTI's or shorter TTL, whatever weight is the same thing. We are talking about shorter TTL requirements, smaller slot lengths in micro scale, flexible transmission frame structure, then reducing the orthogonal frequency division multiplexing symbols, reducing symbol duration and so on so all of these weak it attractive for use in mission critical applications.

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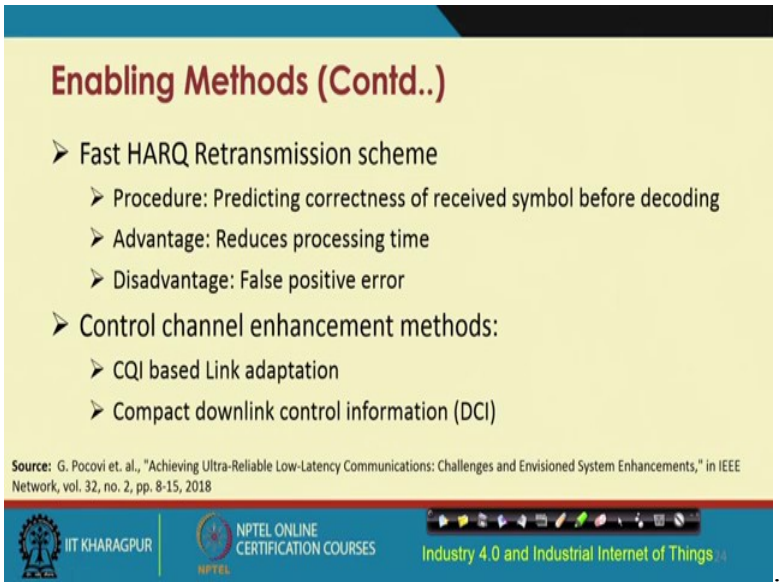

First HARQ retransmission scheme, HARQ stands for hybrid ARQ, ARQ is automatic retransmission request and basically this first HARQ is basically takes care of the retransmission through the procedure of predicting the correctness of the received symbol, before actually decode decoding it. The advantage is that it reduces the processing time and the disadvantage is that it has it leads to false positive errors.

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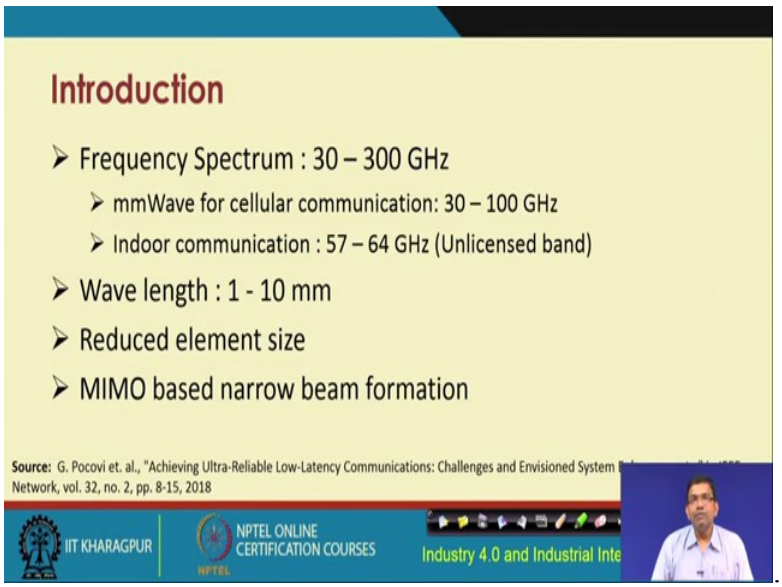

Then comes the millimetre wave communication, where the communication happens in this particular band of the spectrum 30 to 300 Giga hertz band and this basically

millimetre wave communication offer cellular connectivity in this particular band, and particularly for indoor communication, where there are dead zones and so on this is also particularly attractive.

The wavelength is typically 1 to 10 millimetre in this millimetre wave communication, and there is a reduced element size, and MIMO-based narrow beam formation in this particular millimetre wave communication.

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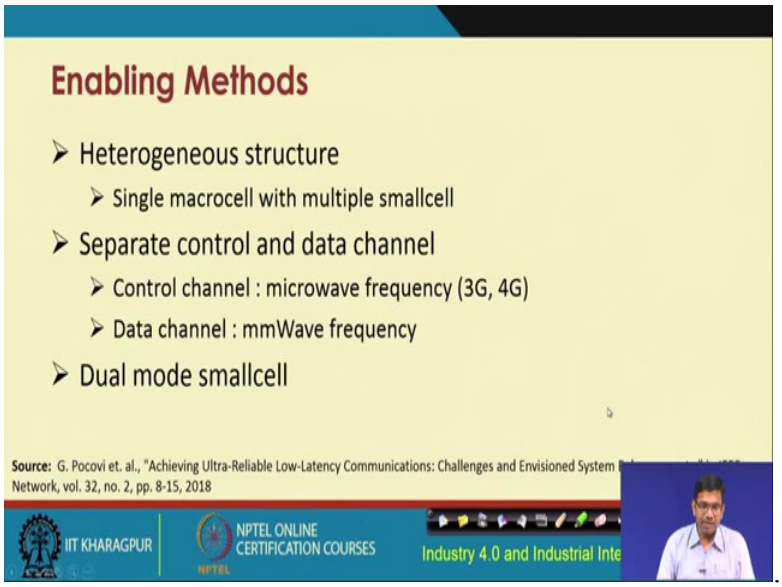

So, for details of these things I would encourage you to go through this particular paper which is the achieving ultra reliable low latency communication paper which has been published in the IEEE network magazine in 2018. So, here basically you would be able to get a lot more different types of ideas in with respect to these methods.

Enabling methods include heterogeneous structure where a single macro cell with multiple small cells would be used or separate control and data channels could be used. So, separate control channel control channel, for microwave frequency data channel, for the millimetre wave frequency, and dual mode small cell via some of these different enabling methods that could be used.

So, I am talking about these in a very high level quite fast I am mentioning these, but if you really have to go through and understand these in detail a lot more time will be required. In case you are very much interested to know about millimetre wave or any of

these technologies, in much more detail, I would encourage you to go through the corresponding material, the paper, the source, that is given at the bottom of the slide.

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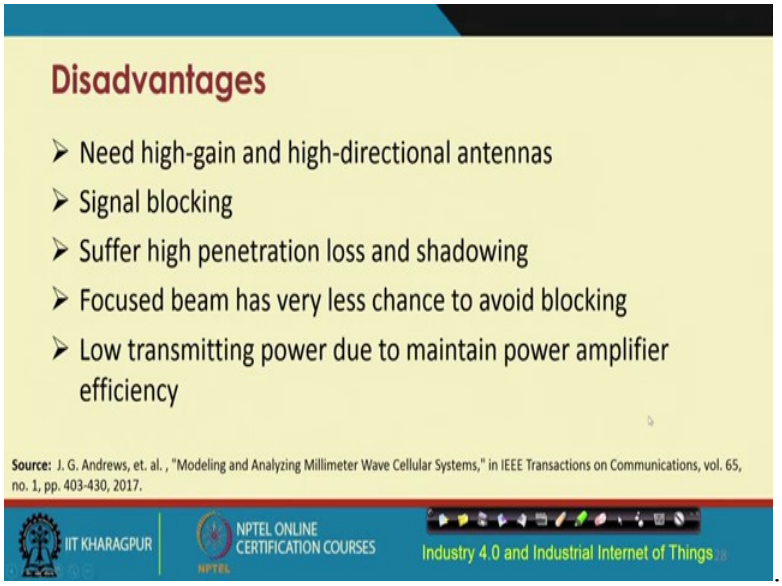

So, disadvantages of millimetre wave communication is that there is a need for high gain, and high directional antennas, and there are different other disadvantages such as have this technology suffers from high penetration loss, and shadowing, and there are many different disadvantages.

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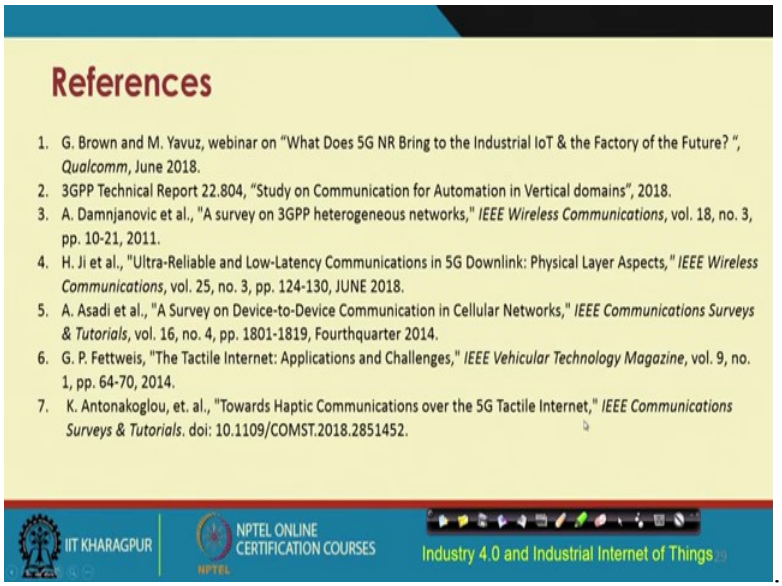

With this we come to an end of this particular lecture and we have looked at some of these different modern technologies that could be used in the context of industrial communication particularly with the help of 5G and tactile internet and so on. So, these different newer communication technologies could be used in addition to the IoT communication technology that we have discussed in the first module of this particular course, with this we come to an end.

Thank you.