Mine Automation and Data Analytics

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Week-3

Lecture-14

Remote operation and control center

Welcome back to my course on mine, automation, and data analytics. Today we'll discuss the second part of the remote operation and control center. So, this lecture will focus more on connected mining. What the concept is all about. So now we can utilize the IoT to realize the concept of connected mining. So, in this lesson, we'll cover the following: The role of communication systems for remote operations, the concept of parallel mines, the framework of the IoT base parallels mines, IoT-based parallel mining system elements. Here, we'll basically elaborate more on connected mining. Parallel management and control center, Autonomous transportation platform under the ambit of connected mining and IoT-based mining, Semi-autonomous mining or surveillance platform, Remote takeover platform.

The key technologies of IoT-based parallel mines. So let us discuss the role of communication systems for remote operations in mines. The communication system is a very essential component for this kind of coordinated mining. Particularly for coordination of different work and monitoring different activities in the mines. We need very good communication at the base stations, at the control station, as well as in the different parts of the mines.

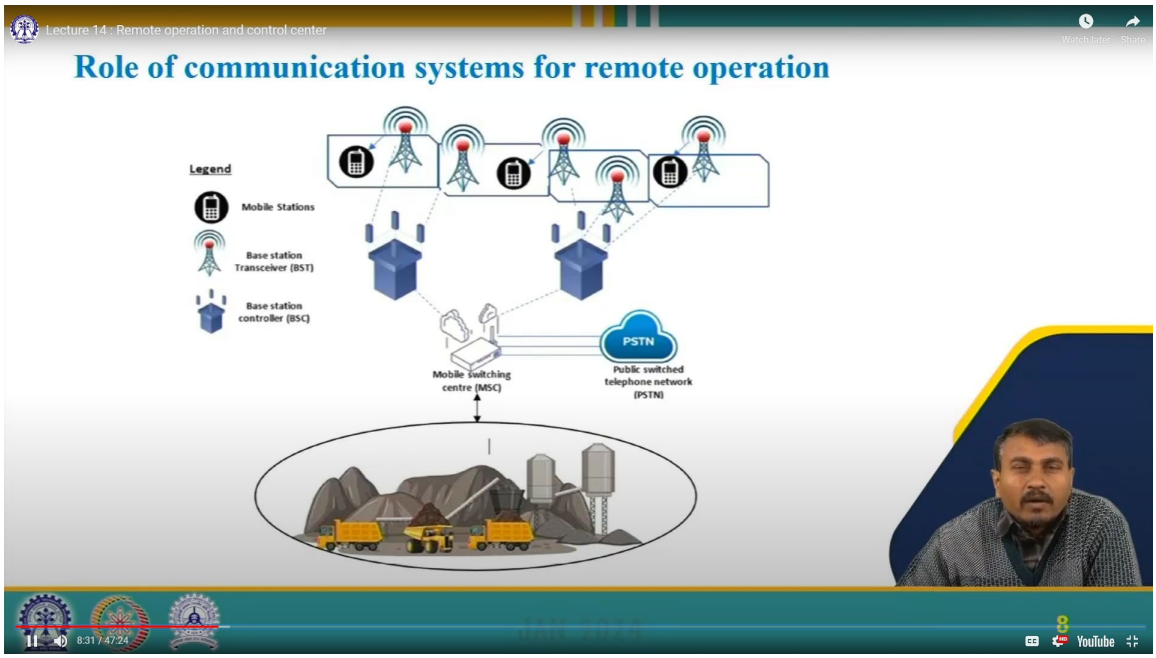
So that every part of the mines can be understood clearly from the control station. So, this technical development basically also helps to introduce the connected mining concept in the underground mines as well and by implementing this kind of system for the development of the communication system, we will be able to do the work in a faster way and operate the mines in a safer way and by that, in an underground mine, control over the site and control over different operations become very easy. So, this technology facilitates short- and long-term communication at high rates to minimize delays

So based on the infrastructure installed at the mine site as well as the plans, this communication network and its rate are basically dependent. Wireless communication systems are areas where technology is gradually improving in the mining sector and also in the underground mines as well. we are utilizing the algorithms of multi-hop protocol technology that provide wireless communication in the underground mines. That

basically has the portable relay nodes at different points. So modern mining involves the use of high technology in communication, and wireless communication networks help in the transportation of data, video, voice, and other applications that facilitate the efficiency of mining operations. As well, this also facilitates monitoring the operations seamlessly from the control station to the control center by the supervisors. Also, this will help to gather a large amount of data at the control center, which makes it possible for the application of data analytics to understand the pattern and meaning of the data so that we can optimize the operation to the next level. So broadband speed is an essential factor in mining wireless communication networks and the communication network should also support other applications to ensure cost-effectiveness. One of the newest communication technologies is Zigbee, which provides wide-ranging control applications and is also very economical.

A mining communication network supports real-time video feeds for activities, fleet management, mobile field communication, video surveillance, accessing drill and blast data, safety system monitoring, and real-time monitoring of mobile equipment. So these are basically the ways different parts of the mining operations can be monitored very easily using this good communication technology. The essential communication component is the transfer of data from sender to receiver, who may be in a group or from one worker to another. The amount and space of data traveling across the transmitting medium are the subjects of transmission and here we also have to keep in mind the security of the data.

So in addition to 4G technology above the ground, the improvement in wired and wireless communication networks such as Zigbee and radio frequency identification RFID appears to be relatively straightforward because a massive amount of data can be transferred at extremely high data rates through base stations and sufficient switching centers, as illustrated in the next slide. So, this is basically a schematic diagram of the role played by the communication system and how different layers of communication systems will be established at the mine site. So, let's see. This is basically the mobile station. Different mobile stations are installed at the mine site.



These are the base stations that basically transfer receiver BST to the different sites that are being installed, and all these stations are continuously connected to the mobile stations and also, we have a base station controller (BSC), that also tries to establish a connection with the base station transceiver. And we may require a number of base station controllers, depending on the size of the mines. And after that, it is basically in continuous communication with the mobile switching center (MSC). These switches played a very important role in ensuring data security as well as continuous connectivity and release.

And these mobile switching centers are supported by the PSTN, or Public Switch Telephone Network. So, these are basically provided by different agencies at the mine site. And these are basically here; this particular protocol or algorithm can be implemented here, like in these mines. So, these machines, mobile machines, and equipment are moving around, and different parts of the mine are keeping a continuous connection to the wireless connection, and from time to time, from the control station, some information is being sent. So, this is how the overall network might be.

So, this communication system occurs over easily placed cables or optical fibers where noise can be reduced without requiring unique processes. Giant communication companies can be encouraged to build public switch telephone networks and mobile base stations closer to mines and mineral resource sites to provide solid signals and expand digital technology facilities in the mines with robust wireless communication systems. So, this is basically the requirement of the day nowadays. And we are now talking about 5G. So right now, 5G is not being implemented in the mines. 4G, somewhere in some

mines, is utilized. So, in the in the future, when good communication will come into play, that will also facilitate further enhancement of the operation and efficiency.

Concept of parallel mines. So the parallel mines are inspired by a theory. The theory is basically the SCP.

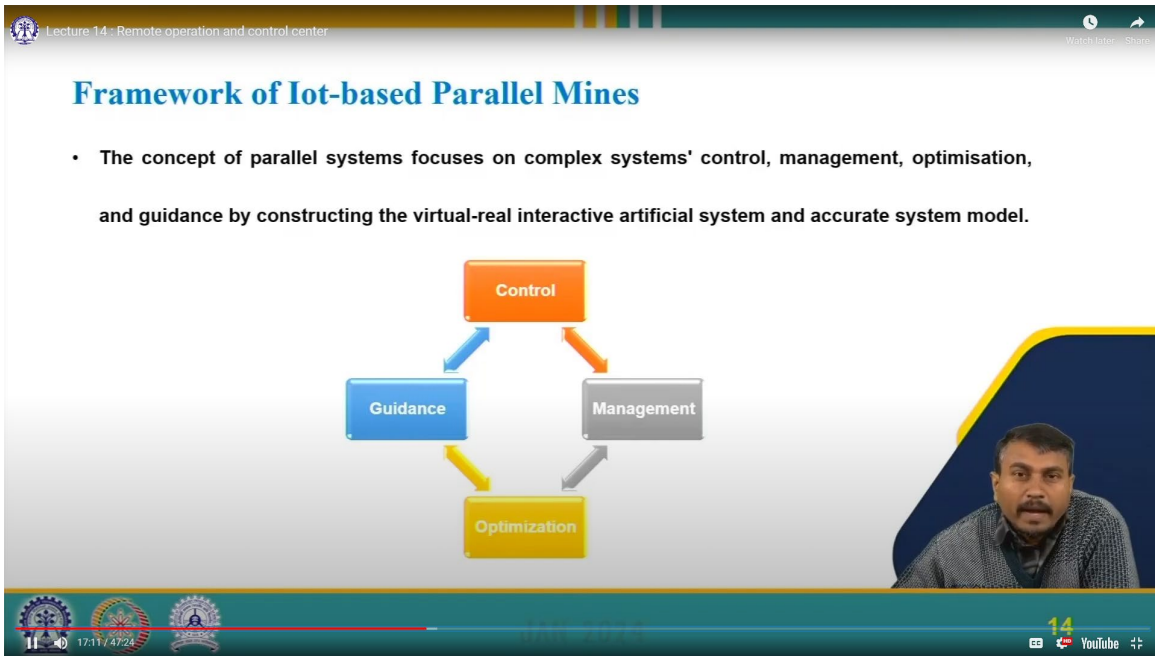
A stands for artificial society. C stands for computational experiments. And P refers to parallel execution. So together, the SCP approach is basically a highly networked and intelligent system in the scope of IoT. And this was made possible because of the development of IoT. This IoT-based similar mining also relates to human excavators, off-road dump trucks, high-speed heavy trucks, and other devices connected to the mining environment. So this is, in totality, the concept of connected mining as well. So everything is connected. All unit operations that are executed at the mine site are connected through the network, through the sensors. So that enables good, thorough information and communication between all these unit operations to the control tower or control station, from where all these operations are supervised, observed, and monitored.

So that is basically the concept here: that we are more and more going for this kind of concept for achieving higher efficiency in the mining operation. So by using IoT technology, the real-time data of critical systems in mining is collected and transmitted to the management center, where a dynamic artificial system corresponding to the natural system is constructed. And here, this system has the ability to analyze the data and come up with a very good, optimum solution. So, this artificial system is proposed to simulate a natural complex system dynamically online and in real-time. By studying the evolution and prediction of artificial systems, the prediction and management of natural mining systems are realized.

So here the data, the signal that we have received, has to be analyzed, has to be modeled, and that model should be in real-time so that we can keep track of the operation and effectively manage the operation in real-time and effectively control the operation and optimize the process so that efficiency is enhanced. Overall, it has been possible to realize autonomous driving on single mining equipment, whether on the surface or underground. To realize end-to-end autonomous mining operations, Komatsu launched the independent haulage system to operate and manage fleets of self-driving mining trucks with capabilities ranging from 200 to 400 tons. Caterpillar released the CATminestar system to optimize productivity, enhance security, and improve machine utilization. Sandvik has developed autonomous loaders and trucks that operate underground. Volvo tested its self-driving tipper inside the earth at a depth of 1320 meters, even with artificial lighting.

Framework of IoT-based parallel mines:

The concept of a parallel system focuses on complex system control, management, optimization, and guidance by constructing a virtual, interactive, and accurate system model. So here, control, management, optimization, and guidance have to work hand in hand and in close connectivity, just like this, Control, management, guidance, and optimizations.

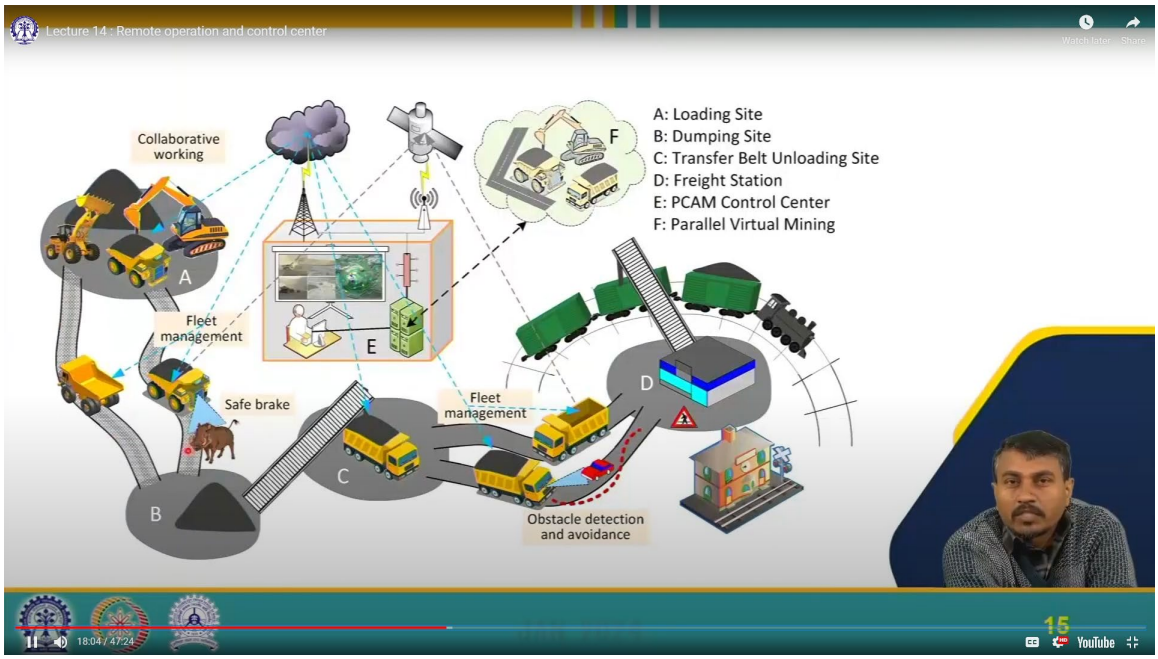


So these are the building blocks for the framework of the parallel mines. So every time our objective is to get better control, a better managed system, a systemized system, a very optimum system, and from time to time, whenever guidance or supervision is required, that will also be established based on the requirements. So that things and the system will run seamlessly. So this is basically the concept. Here are a few sites we have subdivided.

A is basically the loading site. Here, different loading operations are done. Sovel is loading the dumpers. And these are the roads through which the dumpers are moving. And there might be the possibility of some kind of obstruction or some kind of disturbance on the road. Some animals may come onto the road. So sometimes these dumpers need to apply the brake from a safe distance so that both the vehicle and these animals are saved, No accidents occur. That plan should be in place with the management. And that kind of sensing system should also be within the system.

This is site B. This site is for the dumping of the material. For example, here we are dumping the coal. Here, this site is C. This is a site for transfer belt unloading site. So this is basically from the belt, and we are basically unloading it.

Here is site D. That is basically the freight station. Different vehicles from here are basically loading. The rail car we are loading through the belt conveyor system. This is basically site E for the PCAM control center.



And F is the parallel virtual mining. In between that, we also have good communication towers in the vicinity of the mines. And also, we have the fleet management system working throughout the different sites of the mines. We also have in the vehicles the obstacle detection and avoidance system and its control system. And we also have emergency routes and an escape system as well. So here, if we focus on this particular system, through this particular figure, we are trying to illustrate how different unit operations are continuously being done.

And those informations are rightly being relayed and being visible at the control station and control center at E. And here also, we are dynamically developing a model of virtual parallel mining for the possible consequences of operating all these machines together. So beforehand, we are anticipating what kind of problems will arise in this kind of parallel virtual mining model. And we are getting the data here at E station. So the E station is fed with data, supervised data, and experienced data based on this experience of the F.

And we are getting the real data so that effective control over these activities of A, B, C, and D is done. And the efficiency level becomes very high. We are avoiding any kind of accident. We are ensuring that no accident will occur. We are ensuring higher efficiency in all these operations.

We are ensuring the optimization of all these operations. So that is the beauty of this parallel mining concept. So the framework of IoT-based parallel mining is already shown in the last slide. It is a true embodiment of a similar system in the field of mining. So as I already said, A was the loading side, B was the dumping side, C was the transfer-built unloading side, the freight station was D, and the parallel management and control center was E.

A, B, C, and D are the natural systems, while E and F can be considered virtual systems. So here in the IoT-based parallel mining system elements, we require parallel management and control centers. We require an autonomous transportation platform. We require a semi-autonomous or mining surveillance platform. we should also have a remote takeover platform as well.

So in an IoT-based parallel mining system, all these are together, and the system should have the facilities and the control so that all these operations can be done, and all these features should be there so that it can be accommodated in new situations.

Let us discuss a few questions.

What does the concept of a parallel system primarily involve?

A. simulating only the virtual, real interactive artificial system,

B. focusing solely on the optimization of complex systems,

C. managing real system models without virtual components.

D. constructing both virtual real interactive artificial systems and real system models,

E. ignoring the guidance aspect of the control system.

The right answer is D, constructing both virtual and real interactive artificial systems and real system models.

So let us come to the concept of parallel mining, illustrated in this figure. So here we have subdivided the mines into different sections.

For example, A is the collaborative working site for loading the materials. Here, the shovel loads the material for the dumpers. There is site B; this side is the dumping site; the coal is dumped here. Another site is C, which is basically the transfer belt unloading site.

And at site D, it is basically the freight station. So these are all real mining sites. So these sites are connected through the roads. here in all these systems, the fleet management system is working. This system also has facilities for emergency controls. For example,

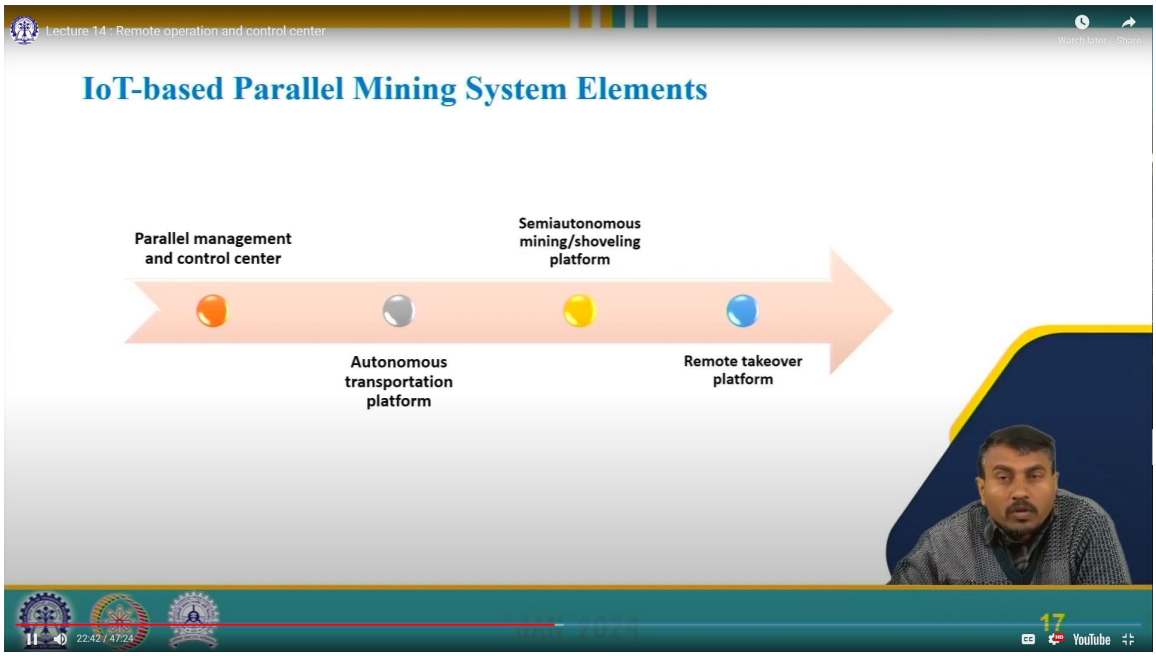
by applying the brake from a safe distance, whenever some man, animal, or something comes into the road so that both the animal, the man, or the vehicle are safe, no accident occurs.

This can be perceived through the laser and lidar systems installed in the dumpers. Also, you should have an obstacle detection and avoidance system so that these vehicles can be remotely operated safely. And we also see from this figure that we also have two stations, E and F. This E and F is basically E stands for here the control station and site F is basically parallel virtual mining. So here, this parallel virtual mining is there to anticipate what kind of problem might arise when these machines are working together at a site. So that simulation is done virtually in a model, and that data is fitted into station E. So station E knows what kind of complexities or problems might arise when these kinds of machines are operated in mines. So basically, E is supported by F. Now here also, we can see that there are a number of towers that basically provide the network for maintaining the connectivity of all these vehicles and also enable communications between the vehicles and from the vehicles to the control station like that.

So that through this communication network system, an overall connection is established in the mines, and E is basically connected through all the components of the mine site. And here also, we have some of the emergencies that escape from this particular station whenever it is necessary. so this particular picture shows collaborative mining, parallel mining, and connected mining, and it also enables the problem or the complexity that might come in a mine so that in real time we can basically interfere and operate the mines safely. So as we have already illustrated in the figure, there are a number of sites we have subdivided, and those subdivided sites are connected together. Out of that, ABCD is the natural and real system, and E and F might be considered as a virtual system to support effective operations of ABCD.

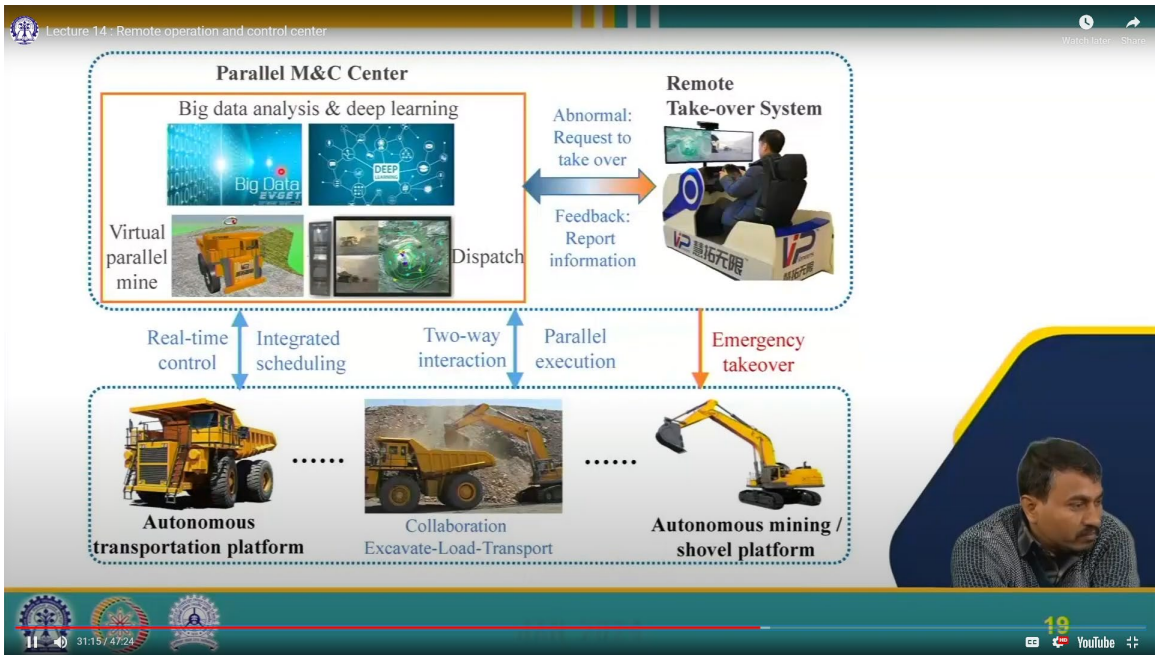
In an IoT-based parallel mining system, there are a few elements. One is the parallel management and control center. The second is the autonomous transportation platform. Here, the fleet management system might be integrated into the parallel mining system. Semi-autonomous mining or shoveling platform, remote takeover platform. So this remote takeover platform is basically whenever a control is necessary or emergency control is necessary from a distance, based on the situation and the environment, so that facilities or that kind of network and infrastructure should also be there in the parallel mining system.

So these consist of four elements: PMSC, control system, autonomous transportation platform, shoveling platform, and remote takeover platform. Let us discuss one question. What does the concept of a parallel system primarily involve? A. Simulating only the virtual real interactive artificial system. B. focusing solely on the optimization of complex systems. C. Managing real system models without virtual components. D.



Constructing both virtual and real interactive artificial systems and real system models. E. Ignoring the guidance aspect in complex systems

The right answer is D. Constructing both virtual and real interactive artificial systems and real system models.



So let us see the parallel management and control center. How it basically works in a parallel mining concept.

So here is basically the PMSC control center. Here we have the facilities and infrastructure for big data analysis and deep learning. Here, side by side, we have virtual parallel mining. That virtual parallel mining incorporates all the activities that are present in real mining conditions. All the dummy equipment is simulated, and they interact with each other. And we try to examine what kind of complexities might come, what kind of problem might come, and what issues might arise so that we have prior information about the problems that might arise in a real system.

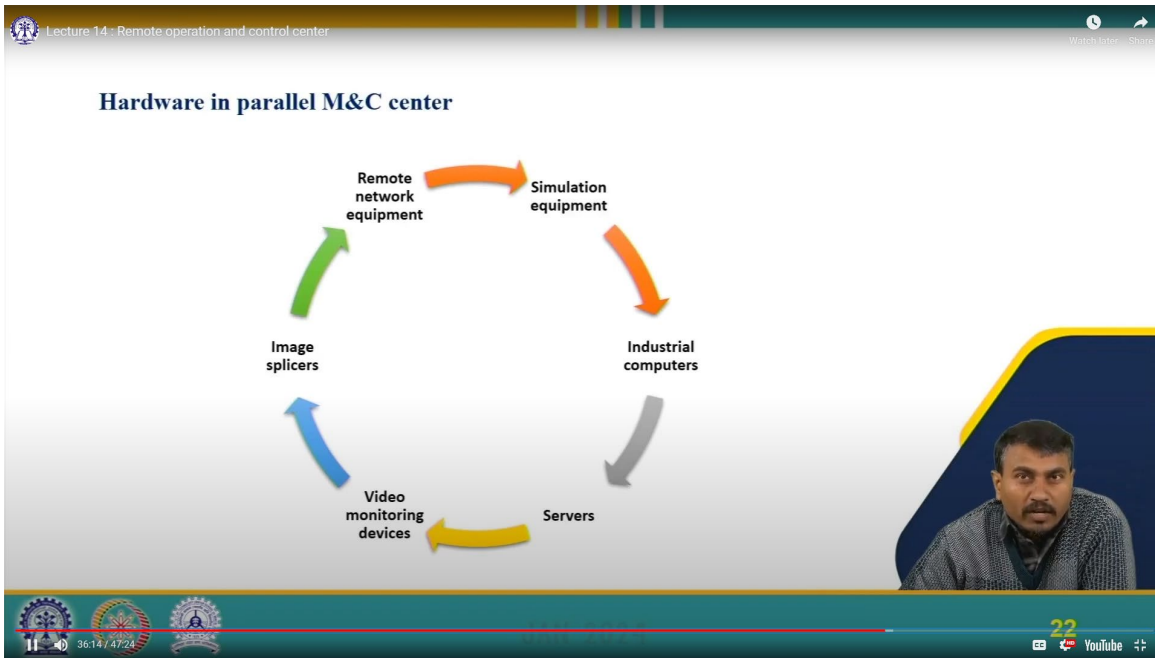
So these parallel management and control centers are connected in real time to establish control over the autonomous transportation platform. And also, from time to time, it has the facilities, and its scheduling is integrated. And also, it is working in collaboration in a two-way interaction with the excavator loader transport system. And also here we have the dispatch system, which is also attached, just like in this collaboration between the excavator and the loader.

And we also have an autonomous mining and shoveling platform. From time to time, their work is also necessary, and they are continuously working. And from time to time, or sometimes, there might be an emergency takeover from the control center. So these are the remote takeover system facilities. These facilities are taking the data from these parallel management and control centers from time to time. whenever some abnormal request, abnormal data, or abnormal characteristics are observed, it will ask for the report. Then, based on the situation or situational awareness level, it will take over control. So this is basically the overall concept of connected and parallel mining. So here we have taken a countermeasure, or we have taken consideration of the problems and issues that might arise through the virtual parallel mining model. We are doing the models, we are doing the simulations, we are analyzing the data, we are finding the patterns, and we are finding the loopholes in the data.

And we are basically informing the remote takeover system. And also, this system is always in connection with the autonomous transportation platform system, the collaborative excavator loader transportation system, and the autonomous mining and shoveling platform system. So this is basically the conceptual model of what we mean by parallel mining and connected mining.

So parallel mining is basically a concept of a description system defined by the virtual parallel mining system, a prediction system determined by extensive data analysis and the deep learning center, and a guidance system defined by the dispatch center. The various data generated during mining production and operation are transmitted to the information processing center, where each subsystem parallel to the actual mining operation is constructed through data fusion, data mining, and visualization processing. The virtual data are built using actual data to complete parallel online and real-time simulations of all aspects of mining production operations. On the other hand, natural systems prediction,

evaluation, and optimization are completed through the evolution of parallel systems and collaborative interaction with biological systems, thereby achieving the management and control of the unmanned mining system.

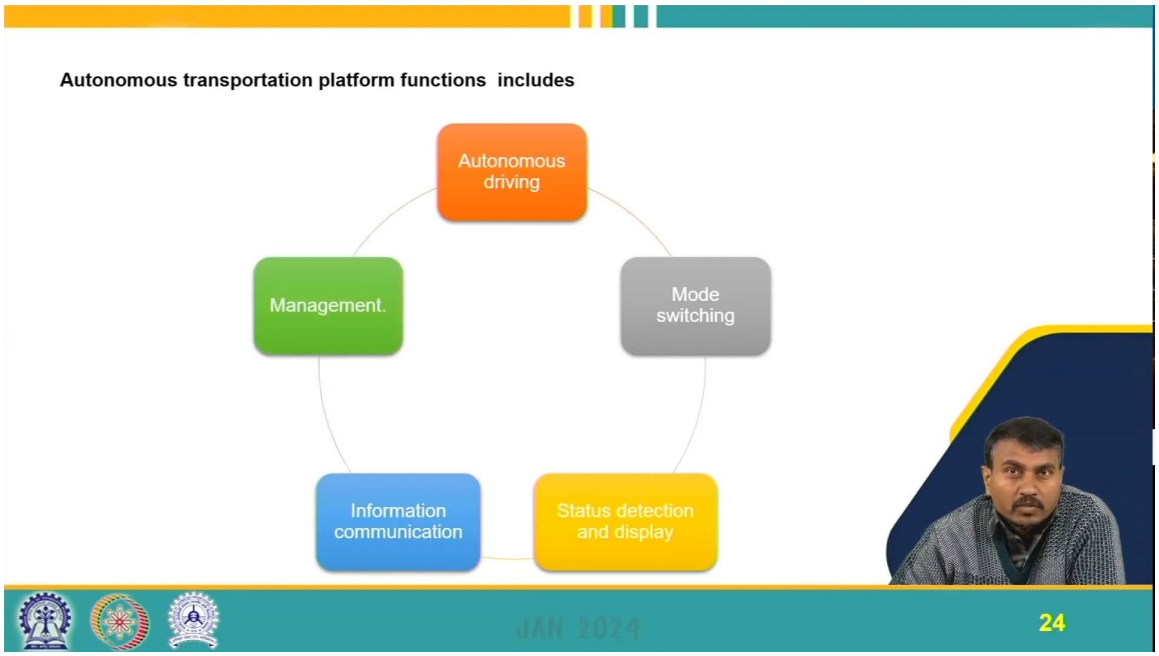


These are the hardware components in the parallel management and control center. Simulation equipment, industrial computers, servers, video monitoring devices, image splicers, and remote network equipment. So these are basically the hardware in the management and control centers in the parallel mining model.

Autonomous transportation platform:

The autonomous transportation platform mainly includes off-road dump trucks and high-speed heavy trucks used for short- and long-distance transportation, respectively. The parallel management and control center assigns the transportation route for autonomous trucks. The car runs automatically at a suitable speed in the loading, transportation, and unloading cycles according to the target route, its position, and the surrounding environment. Autonomous transportation platform functions include autonomous driving, mode switching, status detection and display systems, information communication, and management. So these are basically the five components of the autonomous transportation platform system.

The mining environment information perceived through the lidar, radar, and camera, as well as the positioning information provided by the inertial navigation systems, is provided to the decision-making and control subsystem for decision planning and control. The communication subsystem is responsible for the wireless communication between the unmanned equipment, the MC center, and the remote takeover platform, thus



providing support for remote monitoring and control and cooperation between the excavator and mining trucks.

Semi-autonomous mining or shoveling platform:

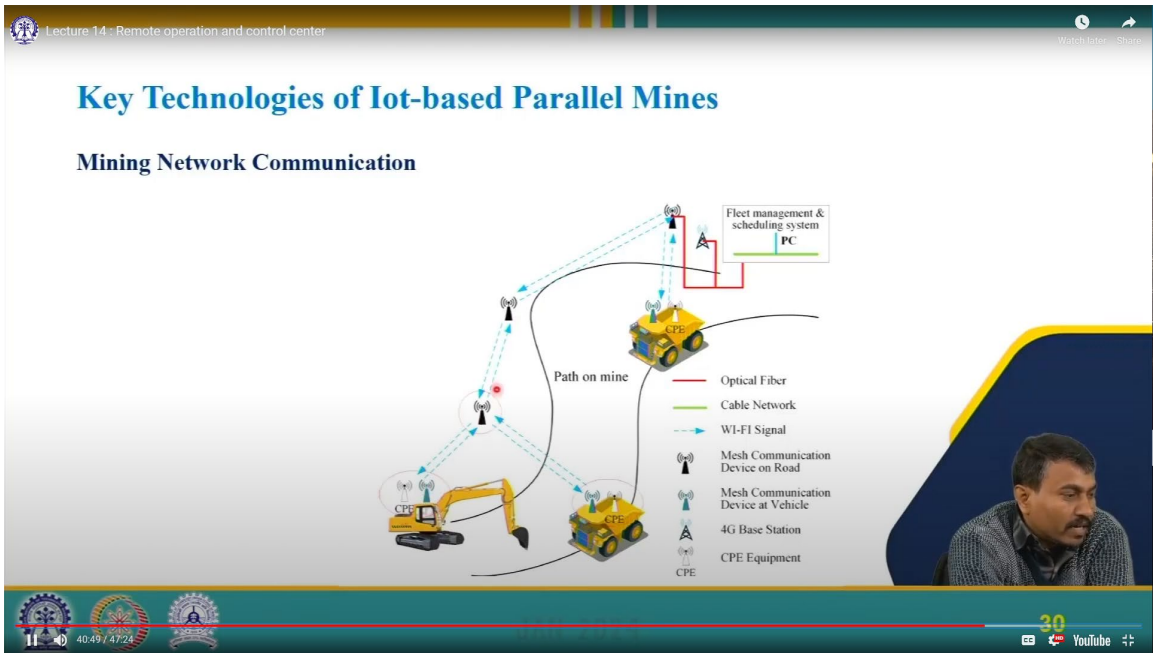
The semi-autonomous mining or shoveling platform has sensors such as a displacement sensor, a pressure sensor, a lidar sensor, an inertial navigation system, cameras, radars, etc. The excavators or loaders cooperate with the autonomous truck through semi-autonomous mining or shoveling at the mine site, depending on the necessity. In the collaboration between excavator and mining trucks, the truck's path is planned based on the excavator's positions. Using sensor data, the excavator guides the car for loading and performs automatic excavation and unloading in the truck's container. A human operator in the control center monitors the process and intervenes manually when needed, ensuring smooth operations. This cooperative approach improves efficiency and creates a better working environment for the drivers.

Remote takeover platform:

For heightened safety in unmanned mining, a remote takeover platform ensures secure manual control for autonomous trucks and excavators during emergencies. It employs diverse processing strategies and a multilevel security policy, enhancing overall operational quality and productivity while ensuring safety for human drivers and equipment.

Key technologies of IoT-based parallel mines:

Mining network communication-To ensure the reliability and stability of network communication, use a combined Wi-Fi mesh network scheme for parallel mining network communication.



The principle of network communication in parallel mining is shown in the next slide, divided into the remote communication between equipment and the terminal management communication between different equipment connected with the 4G base station to realize the V2 server communication.

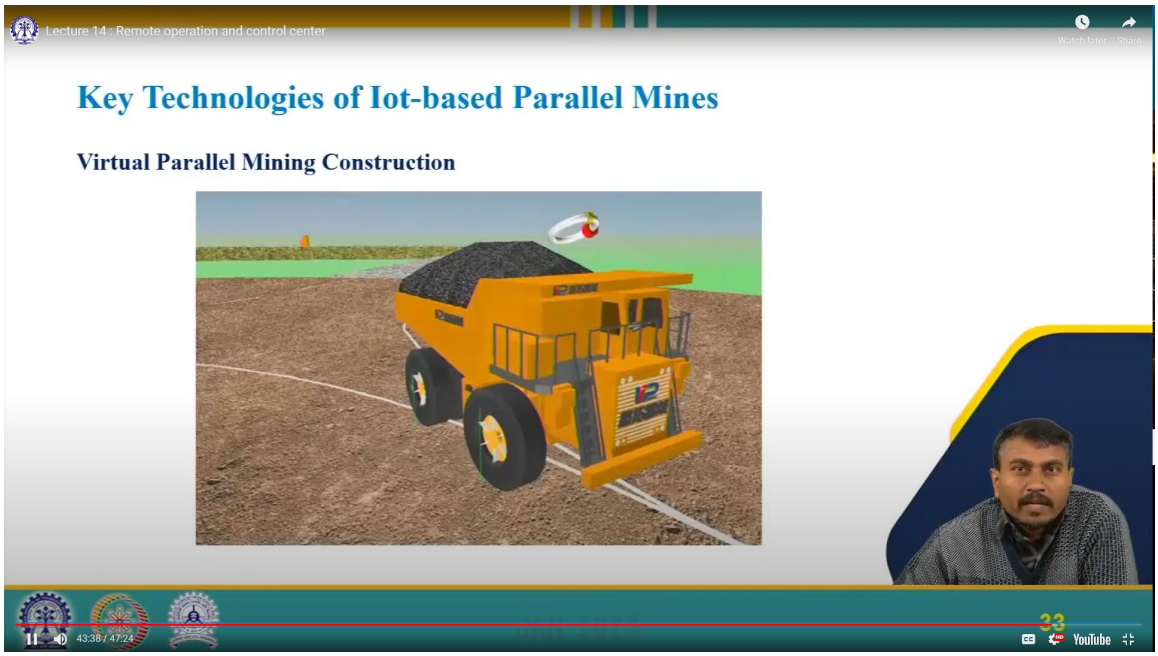
Here, the machine has network connectivity, and these networks are 2-way networks. Some data has been sent, and some data is coming.

The data mining covers the modules of vehicle dynamic model, virtual reality model, virtual sensor, environment perception, deviation calculation, planning, and decision-making and control.

In the cooperative communication between the mining truck and excavator, the WIFI-mesh communication equipment is installed on the roadside, enabling the excavator and mining truck to realize Vehicle-to-vehicle (V2V) communication. The customer premises equipment (CPE), which is communication equipment, is installed on excavators and mining trucks and connected with the 4G base station to realize the V2Server communication.

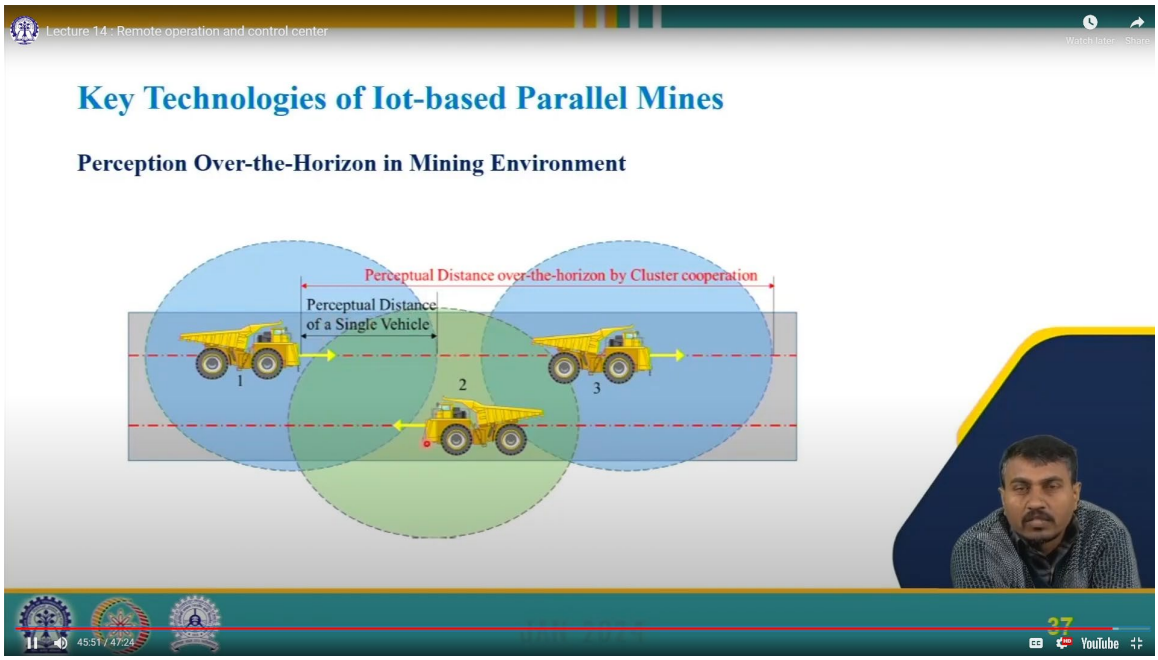
The autonomous truck simulation platform in virtual parallel mining covers the module of vehicle dynamic model, virtual reality model, virtual sensor and environment perception, deviation calculation, planning and decision making, control, etc. The output

data includes camera video from each viewpoint, radar data, 3D coordinates of vehicles, heading angle, speed, steering, wheel angle, throttle, brake, pedal position, tire force, and so on. This is a typical model of virtual mining where different equipment that operates on a real mine site is also experimentally modeled in the virtual environment so as to assess or anticipate what kind of problem, complexity, or issues might come so that, from time to time, in a real model, these kinds of precautions might be taken in advance for safer operation.



So the platform takes in relevant data from the actual truck, including current position, vehicle speed, steering commands, and pedal instructions. Collected data is imported into the artificial system in real time. The autonomous truck in virtual parallel mining is synchronized with the actual truck. The platform allows accurate simulation of truck performance and prediction of potential issues. It enables quick verification of the effectiveness of autonomous driving algorithms in planning, decision-making, and control, especially in extreme conditions. Ultimately, prediction, control, and management strategies are applied to the mining system.

Perception over the horizon in the mining environment-Each mining truck environment perception system utilizes various sensors like a lidar, radar, millimeter-level radar, camera, ultrasonic wave sensor, and infrared sensor. Multi-sensor fusion technology is employed during mining machine operation to monitor the driving area, detect and track obstacles, and identify specific targets for collision avoidance. So this is basically the perception of distance over the horizon by cluster cooperation when different vehicles are operated and for a single vehicle, we have this



perception distance of a single vehicle. So this is basically how the perception model works hand in hand with enabling different vehicles to operate safely at the mine site.

These are the references we have used. Let us discuss in a few sentences what we have covered in this lesson. We have explored the significance of communication systems in facilitating remote operations. We have introduced the concept of parallel mines and connected mining, emphasizing simultaneous and integrated mining operations. We have examined the structure and components of mining systems based on the Internet of Things. We have explored the fundamental elements of an IoT-based parallel mining system.

We have discussed the centralized centers managing and controlling parallel mining operations. We have introduced platforms utilizing autonomy for transportation within parallel mining systems. We have discussed platforms enabling remote takeover for specific mining functions. We have examined the essential technologies for the functionality of an IoT-based parallel mining system. Thank you.