Applied Optimization for Wireless, Machine Learning, Big Data
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Lecture – 16
Applications: Cooperative Cellular Transmission

Hello, welcome to another module in this massive open online course. So, we are looking at a wireless base station cooperation scenario, in which several base stations are cooperating to transmit to a single user or group of users.

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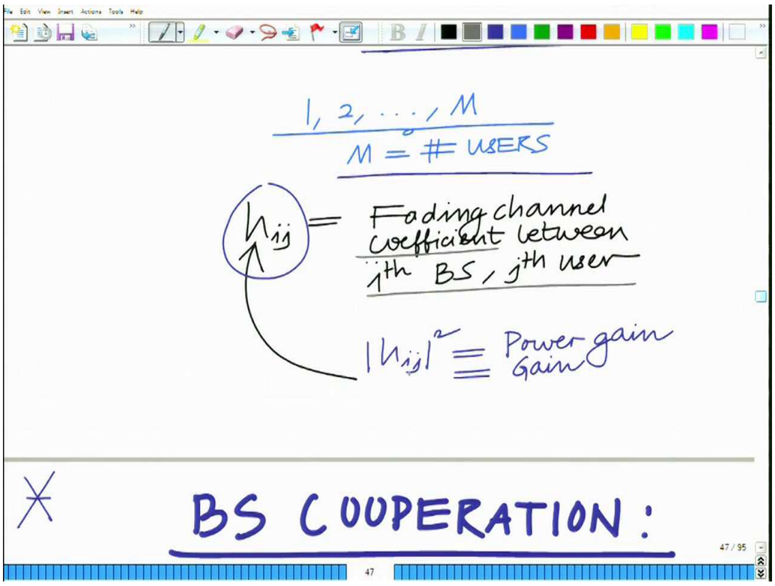

So, lets discuss the scenario in cellular network termed as base station cooperation. So there are K base stations where each mobile is cooperatively served by i number of base stations such that $1 \le i \le K$.

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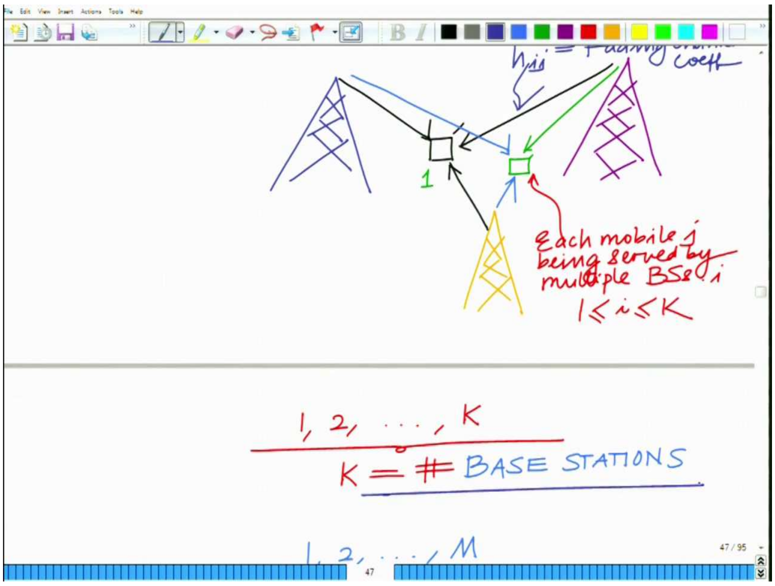

There are total M number of users. These users are typically located in a region at the intersection of these various cells where they can receive the signals from the multiple users. So, the base stations can cooperate with other to enhance the signal to noise modulation at each user. The channels between base stations and users are characterized by fading channel coefficient h_{ij} between ith base station and jth user and $|h_{ij}|^2$ represents the power gain.

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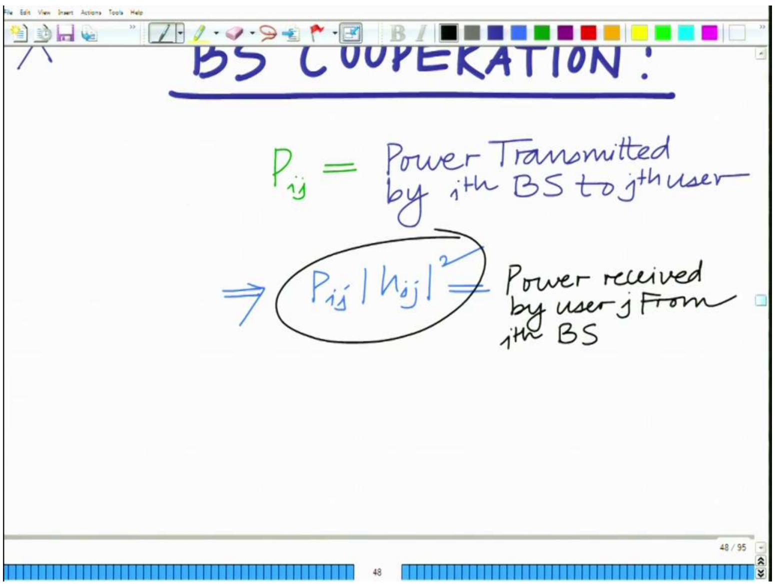

Let say P_{ij} is the power transmitted by ith base station to jth user. Therefore the power received by jth user from ith base station will be $P_{ij}\left|h_{ij}\right|^2$.

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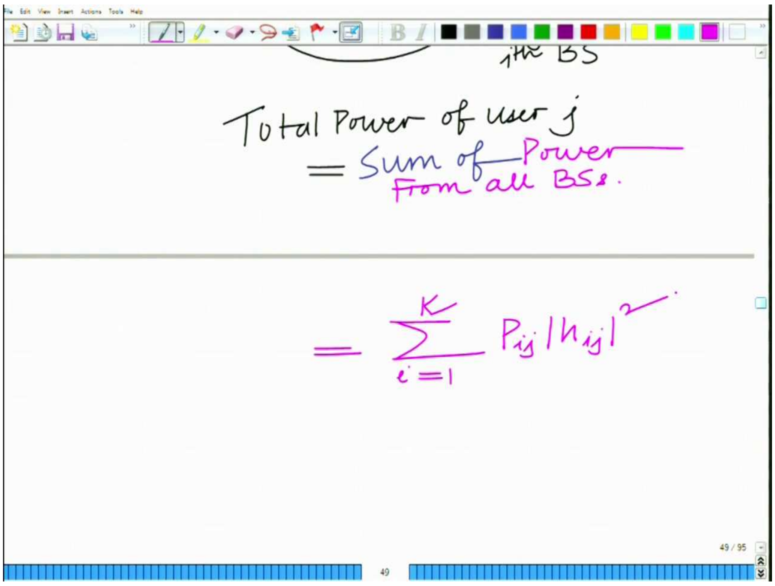

So to compute the total power received by any particular user from all the cooperating BSs will be $\sum_{i=1}^{K} P_{ij}\left|h_{ij}\right|^2$.

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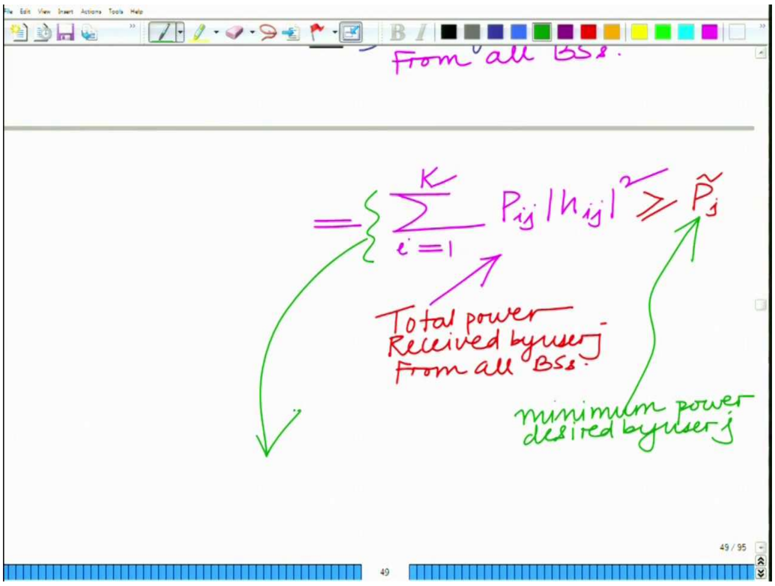

Also the minimum amount of power desired by any user j is $\tilde{P}_j$. So, the total power received at j[th] user must be greater than or equal to $\tilde{P}_j$.

$$\sum_{i=1}^{K} P_{ij} \left|h_{ij}\right|^2 \geq \tilde{P}_j$$

This is known as Quality of Service (QoS) constraint.

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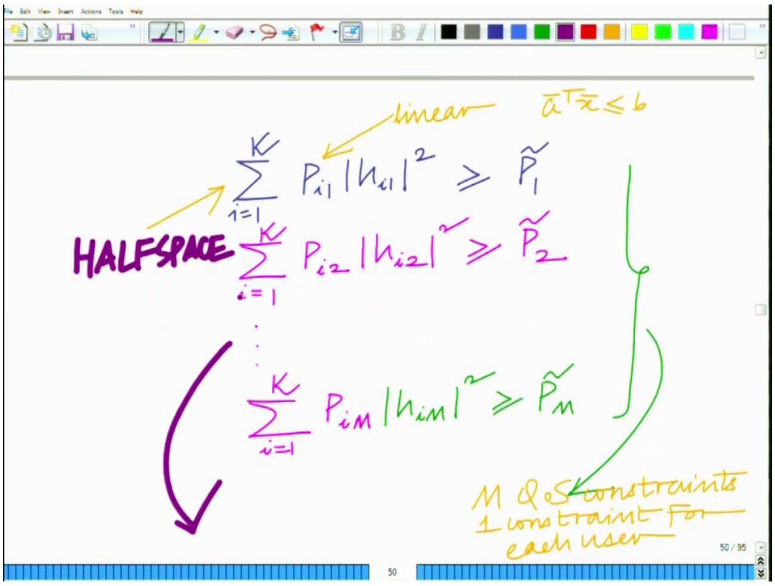

Each user has its own quality of service constraint. Thus there are M such quality of service constraints.

$$\sum_{i=1}^{K} P_{i1} \left|h_{i1}\right|^2 \geq \tilde{P}_1$$
$$\sum_{i=1}^{K} P_{i2} \left|h_{i2}\right|^2 \geq \tilde{P}_2$$
$$\vdots$$
$$\sum_{i=1}^{K} P_{iM} \left|h_{iM}\right|^2 \geq \tilde{P}_M$$

Each of these above inequality is a linear combination of the powers such that each P_{ij} is $\bar{a}^T$, the power gains $\left|h_{ij}\right|^2$ is $\bar{x}$ and $\tilde{P}_j$ is the inverse of b in the following linear combination.

$\bar{a}^T \bar{x} \le b$

Each of these QoS constraints represents a half space and intersection of these half spaces is a polyhedron.

So this is an interesting practical application of polyhedron. Therefore, the set of all possible powers which meet the QoS constraints of different users in the cooperative base station setup lie in a polyhedron. Thus to optimize these powers that are transmitted to the different users by the base station, one has to consider that the set of all possible powers lie inside a polyhedron.

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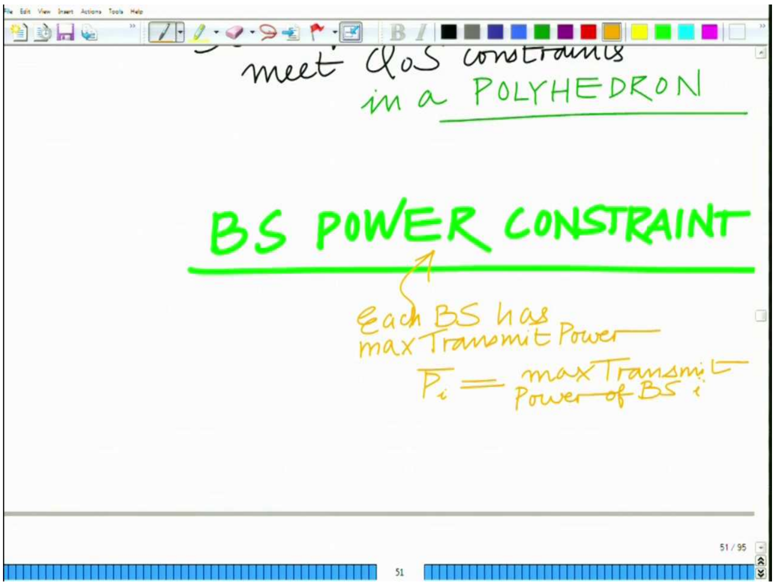

Similarly, each base station also has a total power constraint. Also, each base station has a certain maximum transmit power. Let us call it as $\bar{P}_i$ for i[th] base station.

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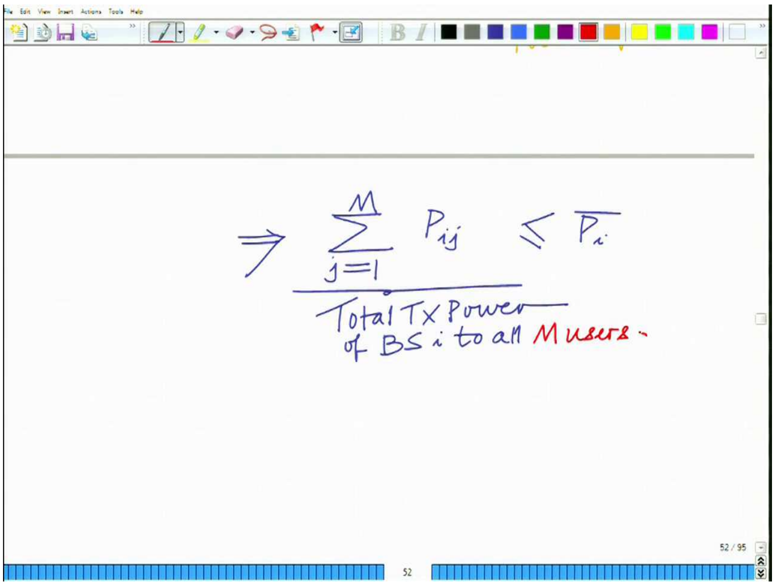

So, According to the total power constraint, the power that is transmitted to all the M users by each base station i has to be less than or equal to $\overline{P}_i$. And hence

$$\sum_{j=1}^{M} P_{ij} \leq \overline{P}_i$$

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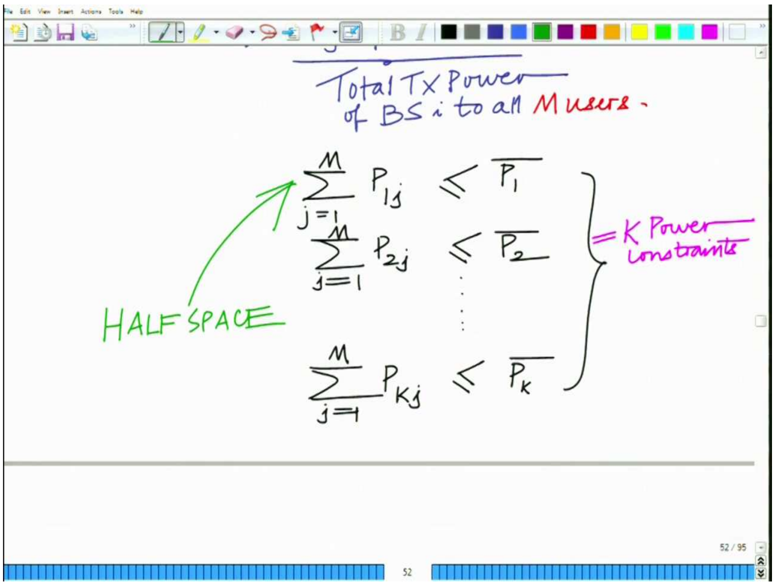

Therefore for K base stations, there are K power constraints.

$$\sum_{j=1}^{M} P_{1j} \le \bar{P}_1$$

$$\sum_{j=1}^{M} P_{2j} \le \bar{P}_2$$

$$\vdots$$

$$\sum_{j=1}^{M} P_{Kj} \le \bar{P}_K$$

Again each of the above power constraint is a half space and the intersection of the K half spaces represents a polyhedron.

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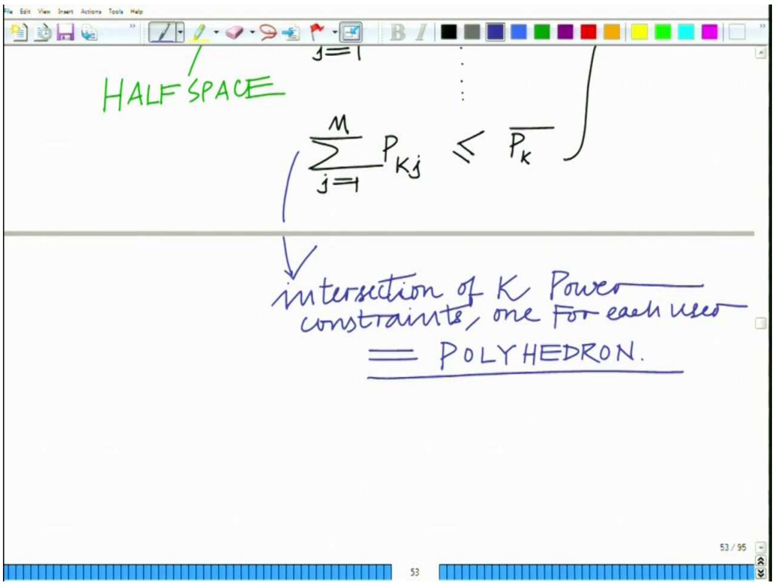

Therefore, this polyhedron, which is the convex, has a significant utility in various optimization problems especially in the context of signal processing and communication. Let us continue in the subsequent modulus.