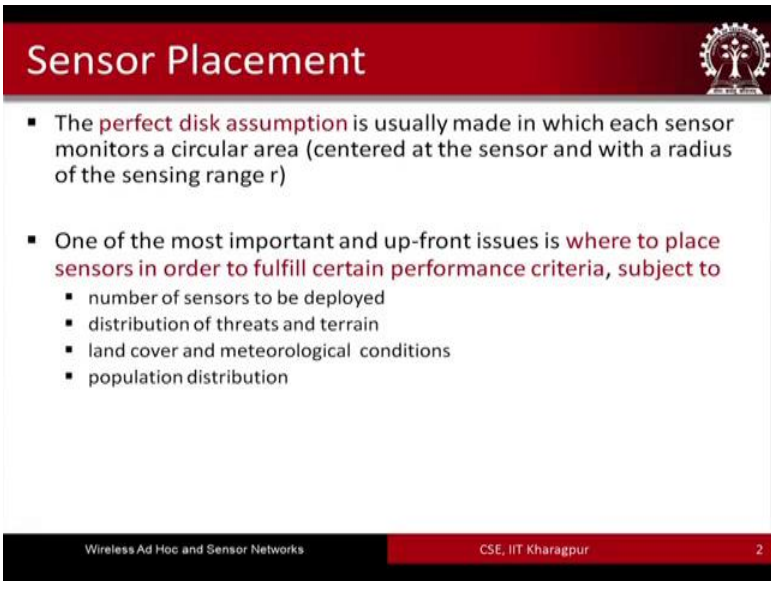
Wireless Ad Hoc and Sensor Networks
Prof. Sudip Misra
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture - 24
WSN Coverage & Placement- Part- II

We are now going to understand the placement aspect on the topic of coverage and placement of wireless sensor networks. So in the second part we are going to understand the problem of placement and the different solutions with respect to this problem.

(Refer Slide Time: 00:41)

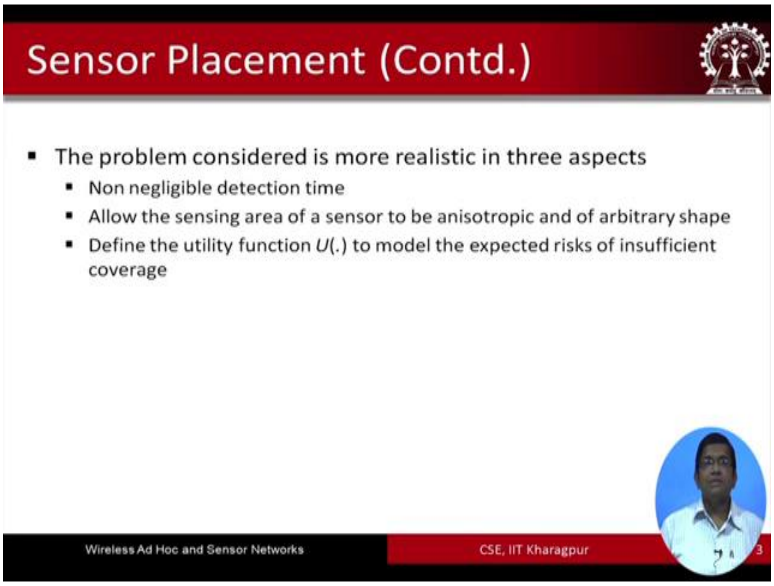


So, first of all in the sensor placement problem, it is assumed that there is a perfect disk that is used for deployment and that perfect disk assumption is usually made in which each sensor monitors a circular area that is centered at the sensor and with a radius of the sensing range r and this particular thing when we this particular concept we had covered in the previous part of this topic as well there I spoke about the not only the disks, but also the concept of unit disks.

So, when we have a sensing range which is of unit which is a value unity then what we have is the unit disk and so we are top typically you know typically in all these algorithms that are proposed in terms of coverage and so on and so forth, many of these they assume the there is a perfect there is an existence of not only a perfect disk; that means, it is completely circular in shape, but also with a particular radius r, but also that r is also unity which gives a unit disk assumption. So, typically the unit disk assumption is made in these algorithms (Refer Time: 02:16).

So, one of the most important and up front issues in this particular context is where to place the sensors in order to fulfill certain performance criteria. So, placement problem; where to place the sensors in the in the particular area of interest subject to certain constraints such as the number of sensors to be deployed the distribution of the threats in the terrain the land cover and meteorological conditions of that particular area of interest or the population distribution where you are going to place the different sensors under these different constraints the problem considered is more realistic in 3 respects.

(Refer Slide Time: 02:51)

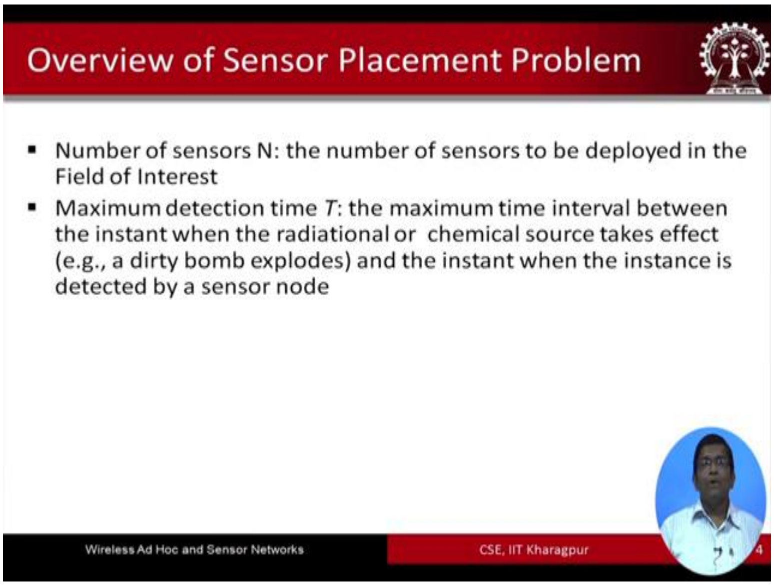


So, first of all we have to place the sensors. So, that the detection time is not negligible we have consider that the detection time is not negligible. So, we have to consider that there is a certain T duration of detection time detection time means that that time that it time that elapses from the point that the event occurs until the point that it gets detected right that is the detection time and it is not negligible second is that allowing the sensing area of a sensor to be an anisotropic and of arbitrary shape. See typically the areas of deployment or the regions of deployment they do not have a regular geometric shape a circular shape and so on.

So, you have to assume that whatever sensor placement algorithm that you propose it takes into consideration that the area of interest does not have a isotropic shape irregular shape it can have any arbitrary shape and so on and the third is defining the utility function to model the expected risks of insufficient coverage utility function concept basically has been borrowed in the optimization literature from microeconomics.

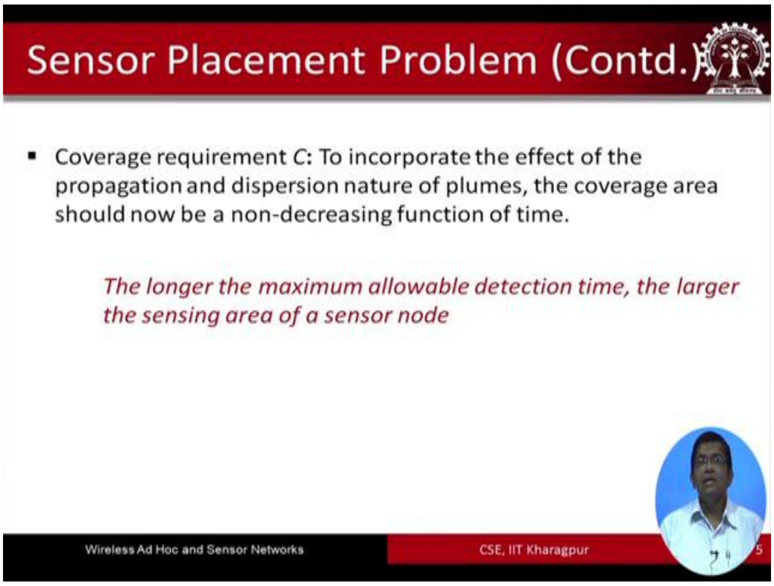
So, utility function means that by doing certain things how much is the utility right how much is the utility to the users or the legacy customers and so on in certain scenarios. So, defining the utility function to model the expected, so you have to define the utility function in such a way that the expected re disks of insufficient coverage care could be computed.

(Refer Slide Time: 04:46)



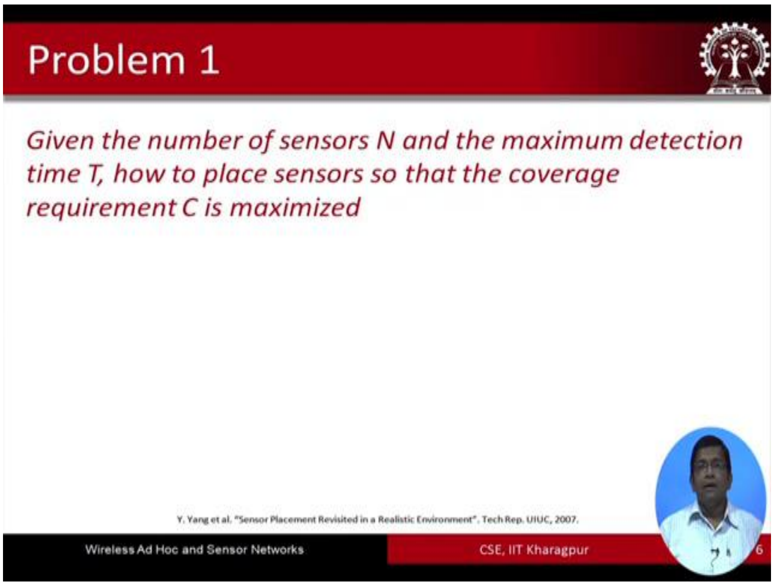
So, when we are talking about the sensor placement problem there are 3 different variables. Number one is the number of sensors to be deployed in the field of interest number 2 is the maximum detection time and detection time is something that I already told you that the time that elapses from the instant a particular event occurs to the instant in the instant when that particular event is detected by at least a sensor node. So, that is the maximum detection time. So, N T and the third is the coverage requirement. So, what is the desirable coverage C R E Q suffix? So, that one C R E Q is the coverage requirement how much is the desired coverage.

(Refer Slide Time: 05:22)



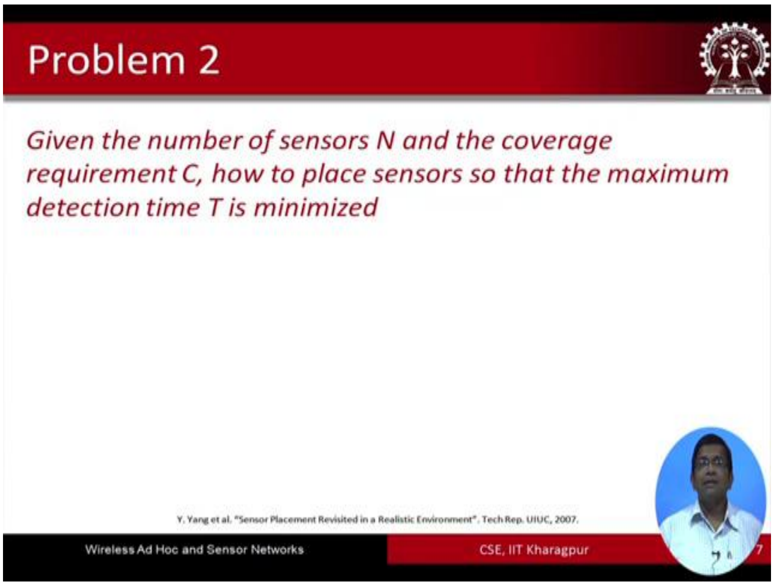
So, to incorporate the effect of propagation and dispersion nature of plumes or any other events and so on the coverage area should now be a non decreasing function of. So, coverage is a non decreasing coverage area; that means, that with time the area that is covered should not be a decreasing function at all so; that means, that either it is 0 or it increases. So, the longer the maximum allowable detection time the larger the sensing area of a sensor node.

(Refer Slide Time: 06:14)



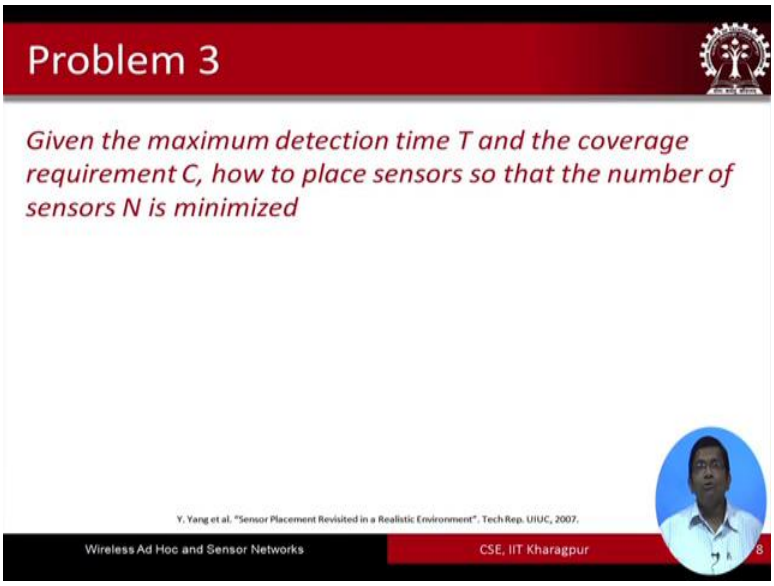
So, there are 3 problems analogous problems that have to be considered when we are considering 3 variables in capital T capital N capital T and C. So, the first variant of the problem is that given the number of sensors N and the maximum detection time T, how to place the sensor? So, that the coverage requirement C R E Q for instance. So, in this particular you know slide we have C denoted, but you know to understand better we can think of it as C sub suffixed you know R E Q. So, C R E Q is maximized.

(Refer Slide Time: 07:01)



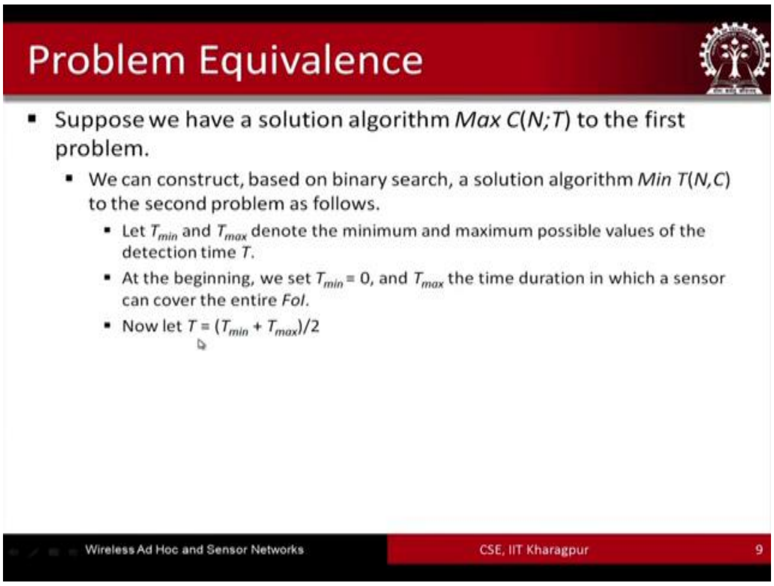
The second variant of the problem talks about that given the number of sensors N and the coverage requirement C; how to place the sensor?

(Refer Slide Time: 07:12)



So, that the maximum detection time is minimized and given the maximum detection, time T and the coverage requirement C, how to place the sensor. So, that the number of sensors capital N is minimized. So, 3 variants of the problem, by keeping 2 of these variables constant and varying the other one or maximizing or minimizing the other one.

(Refer Slide Time: 07:23)



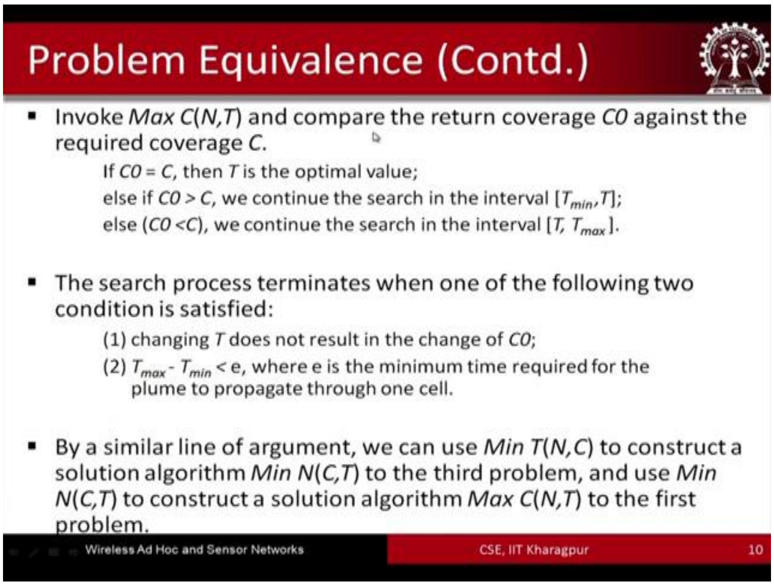
So, the problem equivalence is like this that suppose we have a solution algorithm which maximizes the coverage given N and T to the first problem then we can construct using a binary search kind of approach we can construct a solution algorithm minimize T given

N and C to the second problem as follows. So, what it is saying is that given this we can propose a solution algorithm which minimizes T even N C to the second problem in this way.

So, a binary search kind of approach can be followed like this that capital T is the entire duration of the texture. So, in one and nth we have T min the other end we have T max. So, this entire period T min to T max can be partitioned and you get the midpoint let us say. So, you reduce the subspace from T min to the middle of that search space you reduce the search space to fifty percent half of it and then continue your search operation recursively as you do in the case of binary search and I am sure that all of you who are listening to this lecture you are familiar with the binary search algorithm which is a very fundamental algorithm in computer science algorithms and so on, binary search algorithm. So, I am assuming that you know the binary search algorithm if you do not you will have to know a little bit of basics of it or even if you do not know also probably from these statements you can understand that what binary search attempts to do so?

So, let T min and T max denote the minimum and maximum possible values of the detection time T at the beginning we set T mean equal to 0 and T max the time duration in which a sensor can cover the entire field of interest. So, we have the median to be denoted at as capital T. Now T becomes T equal to T min plus T max by 2 so; that means, that as search space you have truncated to half of the previous one.

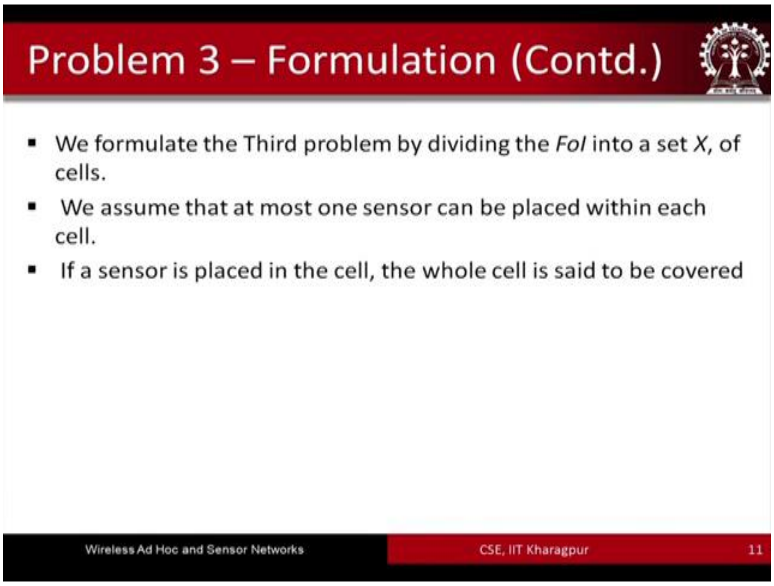
(Refer Slide Time: 10:06)



Invoke the max C N T problem and compare the return coverage C 0 against the required coverage C. So, how much coverage you are getting, you have to compare against what is the desirable coverage, now that now this part is quite obvious as it happens in the case of binary search, you follow a similar kind of approach. So, if C 0 is equal to the required cover is C then T is the optimal value, otherwise if C 0 is greater than C, we continue the search in the time interval T min T otherwise if C 0 is less than C. We continue the search in the interval T max, the search process terminates when one of the following 2 conditions is satisfied; that means, changing T does not result in change of C 0 and T min minus T max sorry, T max minus T min is less than a certain value which is the minimum time that is required for the event to propagate through at least one cell.

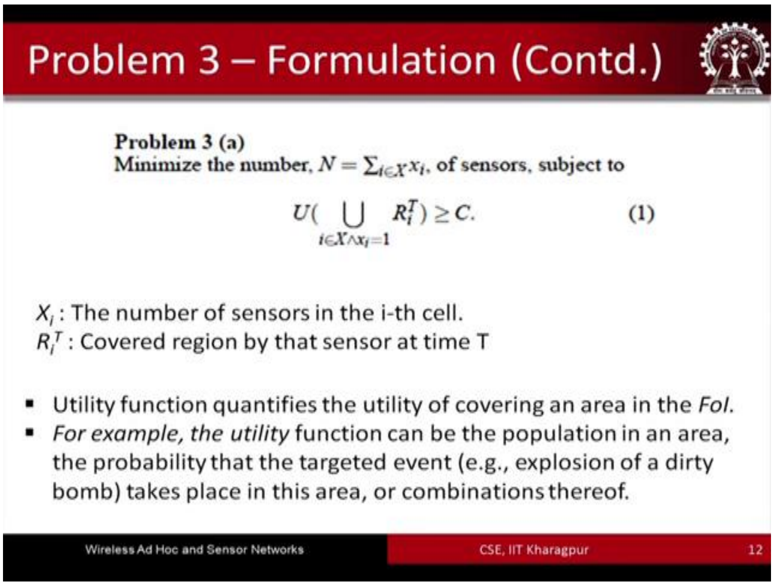
So, by a similar line of argument like what we have gone so far we have covered. So, far we can use we can use that to minimize T N C to construct and the solution to the algorithm minimize in even C T to the third problem and use the minimum minimize in given C T to construct a solution algorithm for max C and T to the first problem.

(Refer Slide Time: 11:53)



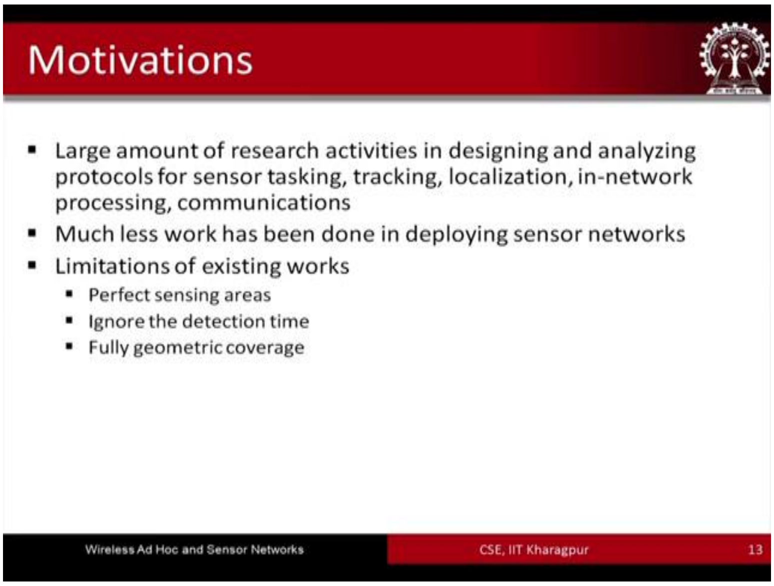
So, basically you know what it is saying is that by following the similar kind of approach we can look at the we can look at a solution for max C N T problem the third problem is bit different and this formulation is bit different and its analysis is bit different. So, we formulate the third problem by dividing the field of interest into a set X offsets. So, it is saying that you know this entire you know area is divided into a set of cells X we assume that at least that at most one sensor can be placed within each cell. So, at most one sensor, the entire region of interest use segment in 2 different cells and within each of these you know rectangular cells you place at most one sensor node at most one sensor node you place in each cell and if the cells, if all the cells have at least a sensor node place the whole cell and the whole region is said to be covered.

(Refer Slide Time: 12:54)



Now, let us look at this particular problem formulation for the third problem. So, now, what we have is to minimize the number N which is summation of X I of sensors subject to this particular condition given in equation one where u stands for the utility and or is basically the region that is covered by a sensor at particular time T or I, T stands for the covered region by a sensor at a particular time. T and X I is the number of sensors in the I X l the utility function quantifies the utility of covering an area in the field of interest for example, the utility function can be population in of an area the probability that the targeted event in that takes place in the area or combinations thereof.

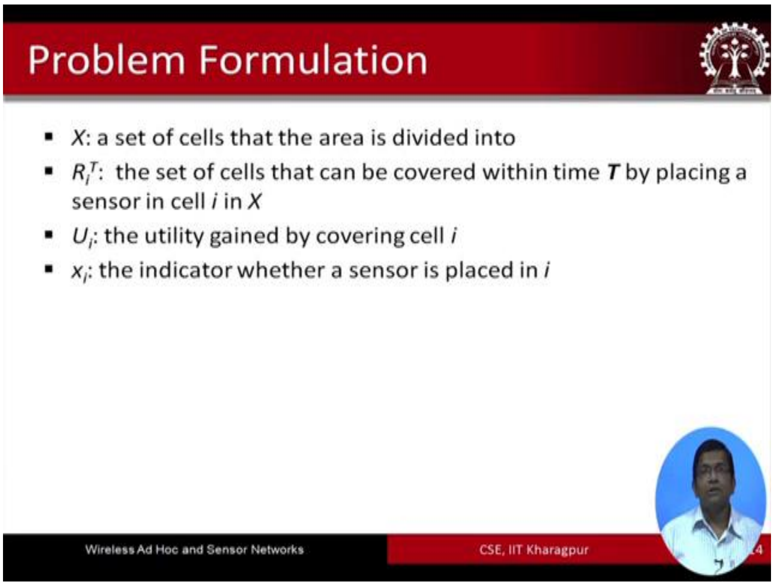
(Refer Slide Time: 13:56)



So, now the motivations are that there are large amount of research activities have been undertaken in designing and analyzing protocols for sensor tasking that mean scheduling the activities of these different sensors tracking sensor tracking means that you know even the sensors which are deployed, how to track the trajectories of the targets that are moving in that sensor field localization. Means finding out the locations of the different targets or even the locations of the different nodes in the network and in network processing and communication and there has been much less work that has been done in deploying sensor nodes sensor networks.

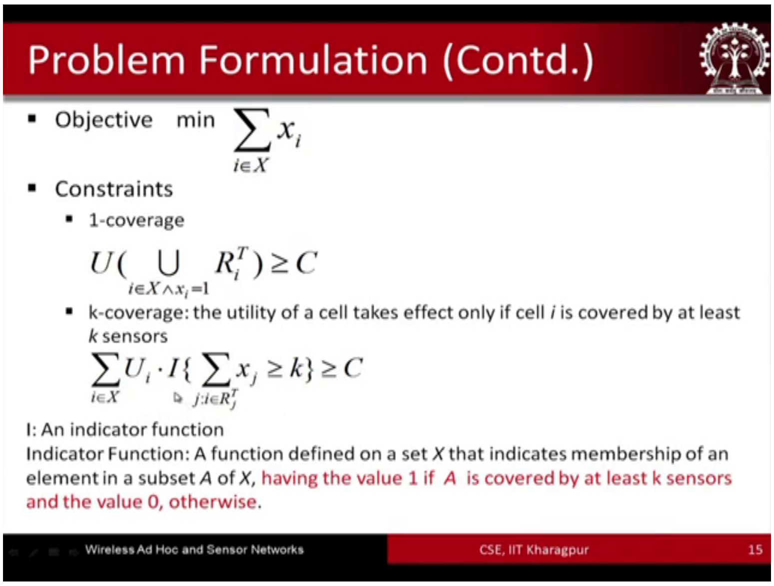
The limitations of the existing works are like this that they assume that there is a perfect sensing area; that means, it is a some sort of a perfect sensing area means a completely circular area or some regular shape and some kind of isotropic shape of the area ignoring the detection time and assuming that fully there is fully geometric coverage. These are the some of the limitations of these existing areas existing works and these limitations basically motivate motivated the authors to come up with to do this perform this particular study this analytical study.

(Refer Slide Time: 15:13)



So, let us look at the problem formulation for the last part once again. So, let us assume that X is a set of cells X is a set of what set of cells that the area is divided in 2 and it is divided. So, we have a rectangular shaped area let us say you have divided into different cells. So, you have small small rectangles and within each of these you have to place these X is X on you know subscript I is basically the i th sensor to be placed particular cell X i th sensor R I is the set of cells that can be covered in a particular duration of time by placing the sensor in the cell and U i is the utility that is gained by covering the particular cell.

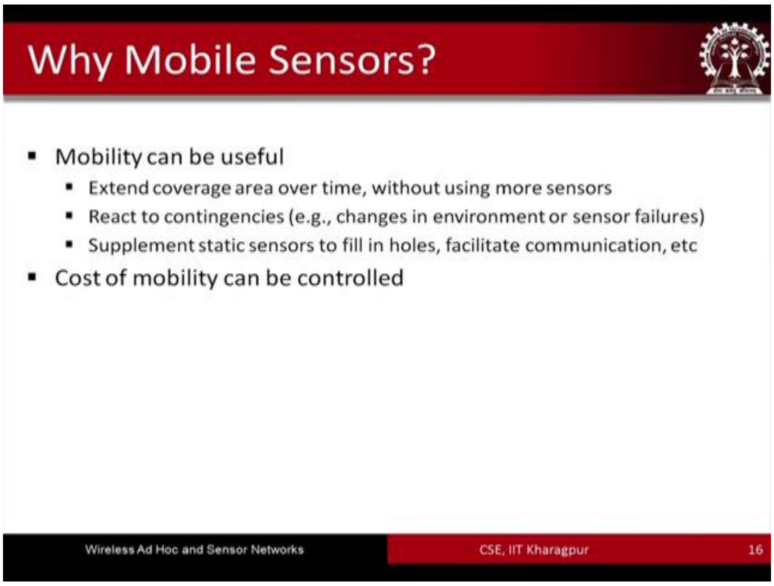
(Refer Slide Time: 16:10)



The objective function is to minimize the summation of all these X is and there are 2 constants if it if we are talking about the one coverage problem the constraint is like this that utility of the union of all these arise that should be greater than or equal to C which is the coverage requirement and if it is a K coverage problem the corresponding constraint equation is as shown.

So, this is the corresponding coverage equation and over here I is an indicator function and what is an indicator function; this is a function that is defined on a set X that indicates the membership of an element in a subset a of X having the value of 1. So, this indicator functions; so, this part is important. So, this indicator function has a value of one if a is covered by at least K sensors and the value of N it has a value of 0 if it is not; that means, otherwise it has a value of 0.

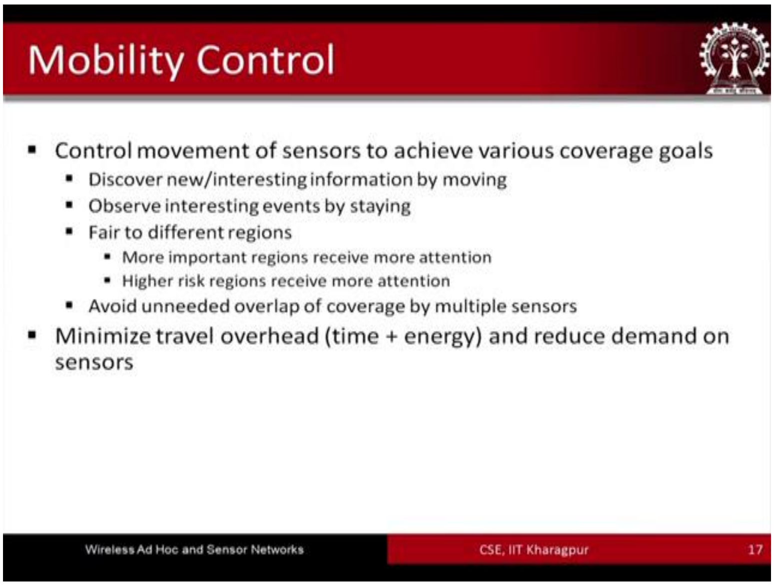
(Refer Slide Time: 17:20)



So, those discussions were to do with you know stationary sensors, but mobile sensors are also very useful because spatiotemporally you can have better coverage by having lesser number of sensors if we are considering mobility of the different sensors right. So, mobility can be useful to extend the coverage area over time without using more sensors and reacting to contingencies example changes in the environment or sensor failures and supplementing static sensors to fill in holes coverage holes that might be existing or facilitating communication between the different parts of the area.

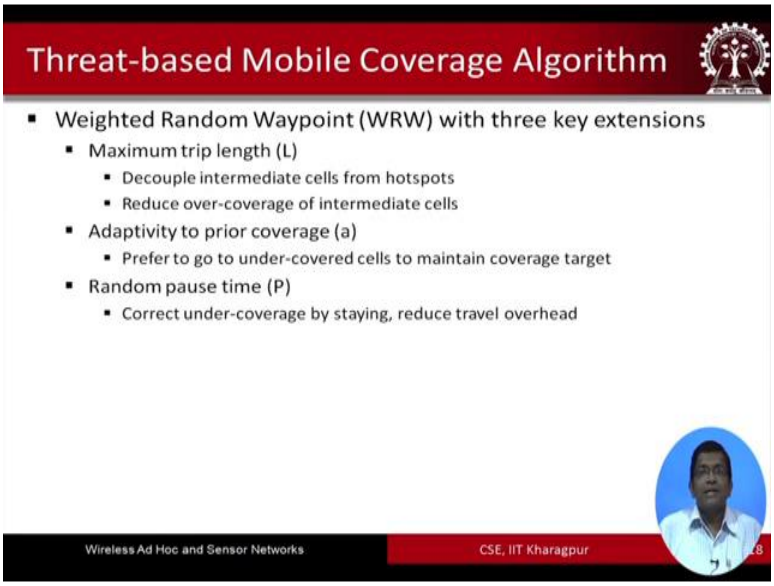
So, cost of mobility can be controlled in different ways. So, the control movement of the sensors it is required to control the movement of the sensors to achieve various coverage goals and this coverage goals might be to discover new or interesting information through mobility observing interesting events by staying in the network or to be fair to different regions with different degrees.

(Refer Slide Time: 18:04)



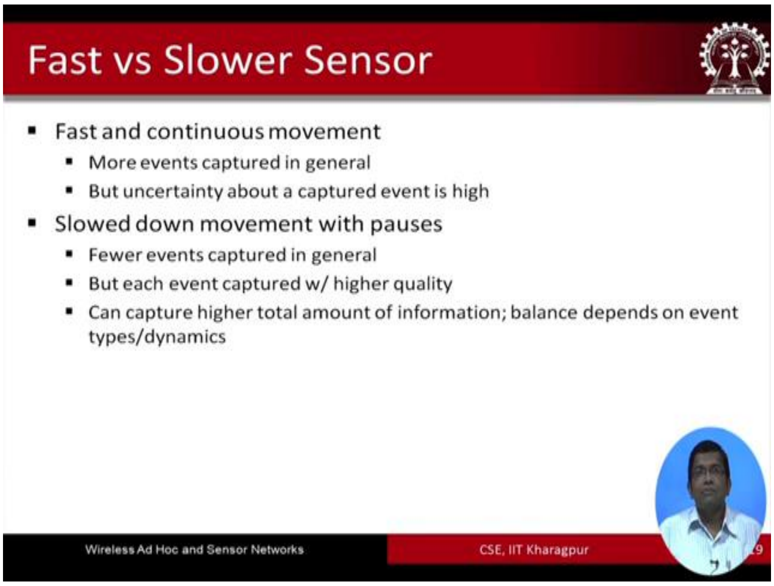
So, maybe you know being more giving you know more important regions more attention and higher risk regions giving more attention and so on. So, what is required is to minimize the travel overhead in terms of time and energy and reduce the demand on the sensors.

(Refer Slide Time: 18:54)



So, there is a an algorithm the WRP algorithm which is which is a thread based mobile coverage algorithm that is proposed and I am not going to go through it in detail, but just to give you a little bit of feeling of what it does. So, 3 different parameters are considered one is the maximum trip length the second one is the adaptivity to prior coverage and the third one is the random pause time. So, 3 different criteria are considered and a mobile coverage algorithm is proposed.

(Refer Slide Time: 19:26)



So, how fast the sensor nodes are moving how fast or how slow the sensor nodes are moving whether they are moving continuously or not. So, these things basically have implications on the coverage using mobile sensor nodes and you know. So, how long they are going to move and then whether they are going to pause for certain duration of time. So, these things, the pause time mobility etcetera, etcetera the rate of mobility the speed of mobility of the different nodes all these things have implications on the coverage using mobile sensor nodes in these networks.

(Refer Slide Time: 20:04)

So, these are some of the important references that one can go through in order to supplement ones understanding of the problem of placement on the topic of coverage and placement in wireless sensor networks.

Thank you.