Slide 1: This is stochastic process model 5, continuous time Markov chain and seventh… this is a seventh lecture, communication systems. In the last six lectures we have discussed the continuous-time Markov chain and in the last two lectures we have discussed the application of a continuous-time Markov chain in queuing modeling. In this lecture I am going to discuss the application of continuous time Markov chain in communication systems. So this talk is divided into three parts, the first I am going to discuss the application of CTMC in 2G cellular network system and then I am going to discuss the 3G cellular network system, 2G means the second generation and 3G means the third generation cellular network system and finally I am going to discuss the simulation of queuing systems. That is basically a discrete event simulation.

Slide 2: The cellular system or wireless system is nothing but a network system in which the calls are generated and calls are occupied for some time and leave the system. And this consists of many cells, each cell is of the hexagonal shape and our interest is to study the performance analysis of cellular networks using continuous time Markov chain. This is the center cell and all other six cells are called the neighbor cells. Either we can make the performance modeling for the whole cellular networks or we can make the model for only one cell first then we can play the hierarchical modeling for the whole cellular networks. So in this I am going to discuss the performance analysis of one cell in the cellular networks.

Slide 3: Cellular networks are wireless networks, our interest is to study the performance analysis. Suppose you think of a band width as the channels, whenever the some calls originated, it uses the one band… one cell for the or one channel for the communication. Suppose you assume that we have a finite number of bandwidth or a finite number of channels in one cell, suppose that you make it as some capital N finite quantity. So whenever the call is originated, then it will take a one channel from the cell and the call will be for random amount of time it will be keep going and once the call is completed, then the channel will be released.

Slide 4: We have designed calls with the two types of calls one is called the handoff call and the other one is called the new call. Handoff call is nothing, but a call in progress handed over to another cell due to user mobility. In that case the channel in old base station, that is in the previous cell is released and ideal Channel given to the new base station, so that is the way the handoff phenomena operates.

Slide 4: Therefore I consider the call into two types of call one is called the handoff call and the other one is a new call. Handoff call is nothing but the call originated from the neighbor cells and coming into the cell where we are studying, that means suppose the calls are originated in this neighbor cells and coming into the underlying cell, which we are considering then that calls are called the handoff calls. So either it can come from this cell to this cell or it can come from this cell to this cell and so on. So therefore the calls originated from the neighbor cells and coming into the underlying cell, that is called the handoff calls. Whereas the calls originated within the cell itself that call is called the new calls. That means the channel will be taken, channel will be given from the same base station of the cell and once the call get over then that channel will be released. Therefore the calls originated from the neighbor cell is called and of calls, the calls originated within the cells are called the new calls. These are all the two types of calls coming into the system. If there is a bandwidth or channel then the calls will be allotted and after the calls are completed the channel will be released. So there are two types of call completion also, either the call is completed within the cell itself not moving anywhere, due to mobility there is a possibility the calls can be originated within the cell or coming from the neighbor cell, it can last for whole time in the cell and it could move to the other cell also, in that case it is called the handoff to neighbor cells, the way the calls are originated from the neighbor cell, coming into the cell, the same way you can discuss the outgoing also. The calls can be completed within the cell itself or call it keep going to the neighbor cells, that is called handoff out calls.

Slide 5: Now I am going to discuss what is the concept of dropping hand the blocking probability. Since the hand of calls are having the higher priority, because the calls are already originated and keep coming into the cell and there is a possibility it can move into the other cell also, therefore we should give a higher priority to the handoff calls. There are many ways of forgiving the higher priority to the handoff calls, the one easy way is reserve few channels for the hand of calls. That means out of capital N channels, you reserve few channels for the handoff calls. Not physically few channels, whenever you have left out few channels in the system, in the pool then if that number is more than the reservation then you keep allowing the new calls as well as and of calls. If you reserve some number of channels for the end of calls and the available bandwidth or available channels at the time of arrival, it is less than that, then don't allow the new calls. So only the handoff calls will be allowed, whenever the number of available channels are going less than or equal to the prescribed number. So that is called the fixed reservation channel policy.

Slide 6: So suppose out of capital N channels, you reserved some G channels for the end of calls, that means if number of ideal channels less than or equal to G, then the new call will be blocked, whereas at the time, if the handoff calls enter into the system then it will be... channel will be allocated. If no idle channel is available, that means all the channels are busy with the calls, then handoff calls will be dropped, obviously new calls also will be dropped if no channel is available, but if the number of idle channel is less than or equal to G itself, from that point onwards the new calls will be blocked. So our interest is how to find the... our interest is to find the blocking probability and the dropping probability. So the dropping probability is nothing but the hand of calls are dropped because of no idle channel in the system, the blocking probability is nothing but the probability that the new calls are blocked because the number of ideal channels are less than or equal to G. Once we are able to find out these two performance measures, then using that one can design better cells, for a given number of channels, how we can reduce the blocking probability as well as the dropping probability. So these measures we are going to find out using continuous time Markov chain. So for that we are going to make the few assumption, so that the underlying stochastic process will be a continuous time Markov chain. And here we are making a model for only the one cell, not the whole cellular networks. So we will make the assumption, the calls are in the Poisson process for the new calls as well as the handoff calls and both are independent, we make the rate lambda 1 is the arrival rate for the new calls and the lambda 2.is the arrival rate for the end of calls, and both are independent. Therefore the call arrivals, either it is a new call or end of calls, that will be a sum of 2 Poisson, therefore that is also Poisson process with the parameter lambda 1 plus lambda 2. And also we make assumptions over the call completion. Either the call completed within the cell that is exponentially distributed the time for the call completion within the cell that is exponentially distributed with the parameter mu, as well as when the calls a handoff to other cells that is also exponentially distributed with the parameter lambda… sorry mu H, and we make the assumptions the call completion as well as the handoff to other cells, that's also independent and we have a total number of N channels as capital N out of that we reserved G channels for the end of calls and these channels are called the god channels.

Slide 7: So with this assumption, that means that we are considering only one cell and the new calls, that stream is a Poisson stream and this stream is also Poisson stream and the call duration, either call completion is exponential distribution or handoff to the neighbor cells, that is also exponential distribution, and we have total number of the N channels out of that Gs for the reserved channel. And accordingly the Markov chain, first we are going to make a stochastic process. Stochastic process is CT, that is nothing but the number of busy channels or each channel is located for one call therefore at time T how many, what is the number of calls, that is the stochastic process, that's a random variable, so over the T that is the stochastic process and since it is a number of the busy channels, therefore it is a discrete state continuous time stochastic process, with the assumptions we have discussed in this slide, the stochastic process will be a continuous time Markov chain. Only nearest neighbor transitions are allowed therefore this is not only a continuous-time Markov chain, it's a special case of continuous time Markov chain, that is the birth-death process also.

Slide 8: So it is a variation of MMcc queuing model with the rates are different. That means the birth rates are lambda N minus G, after that the birth rates are lambda 2. If you recall, this lambda is nothing, but lambda 1.is the arrival rate for the new calls and lambda 2.is arrival rate for the end of calls and lambda here it is lambda plus lambda 2, that means whenever the number of busy channels starting from 0 to N minus G minus 1, both new calls as well as end of calls are allowed into the system, therefore the arrival rate is lambda, birth rates are lambda whereas the number of busy channels from N minus G to N minus 1, the birth rates are only lambda 2, because the new calls are blocked, only handoff calls are allowed, whenever the system size is N minus G to N minus 1. Whenever the number of busy channels is 1 2 and so on till N, either the call is completed or the calls are handoff to the neighbor cell and both are exponentially distributed with the parameters mu H respectively and both are independent, therefore the rates are going to be mu 1, mu 2 and so on, where mu 1 is equal to 1 times mu H plus mu N and mu T is nothing but 2 times mu H + mu N and so on. So this is the death rates. Therefore the number of busy channels at any time, that is birth-death process, with the birth rates lambdas till N minus G minus 1, after that it is lambda 2 and the death rates are N times mu, where mu is nothing, but mu H plus... either I can use this notation or the other notation.