Real-Time Systems

Prof. Dr. Rajib Mall

Department of Computer Science and Engineering

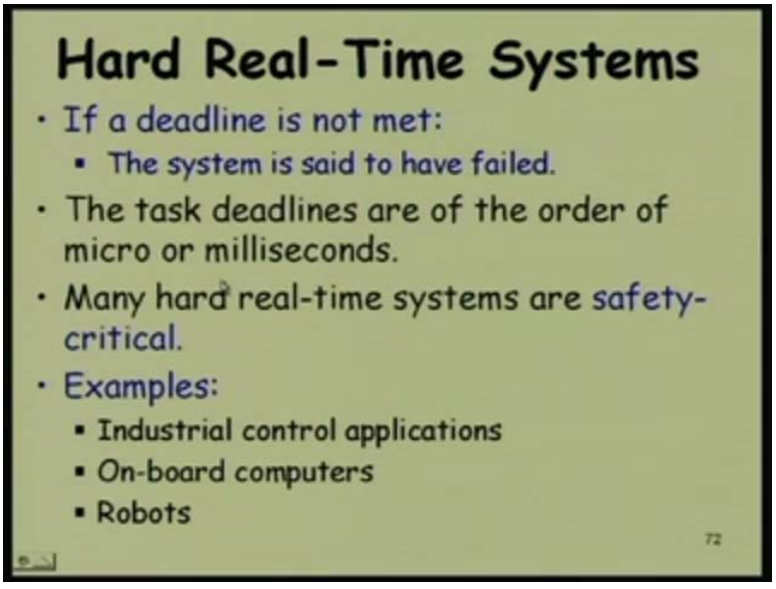
Indian Institute of Technology, Kharagpur

Lecture No. # 04

Modelling Timing Constraints

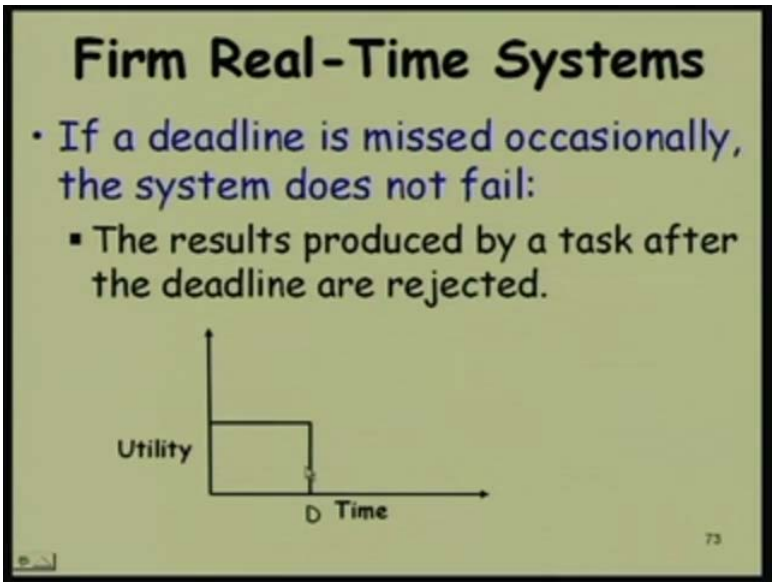
Let us continue from what we were doing last time. Last time if you remember, we just starting our discussion about the timing constraints, the different types of timing constraints associated with the tasks and so on. Now let us proceed from there.

(Refer Slide Time: 00:52)



Last time I had seen this that the different types of tasks in a real-time system can have different types of timing constraints, based on that we can classify them as either hard, soft or firm real-time systems. We also had discussed this one that in a hard real-time system, the tasks have time constraints, and even if one constraint is not met, the system is assumed to have failed. And we had taken examples from robots timing constraint violation can cross the robot, similarly on board computers, industrial control applications and so on.

(Refer Slide Time: 01:27)

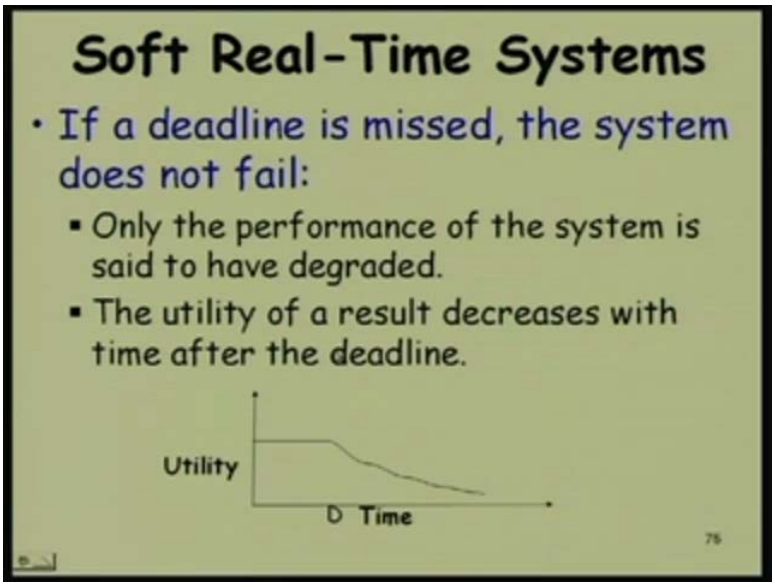


We had seen another category of tasks, the firm real-time tasks. Here, in this kind of constraints, here again we have timing constraints associated with the tasks. And if one or few timing constraints are missed, then the system does not fail. The results are simply ignored; the results which are produced after the deadline or after the time requirement just ignored.

(Refer Slide Time: 02:04)

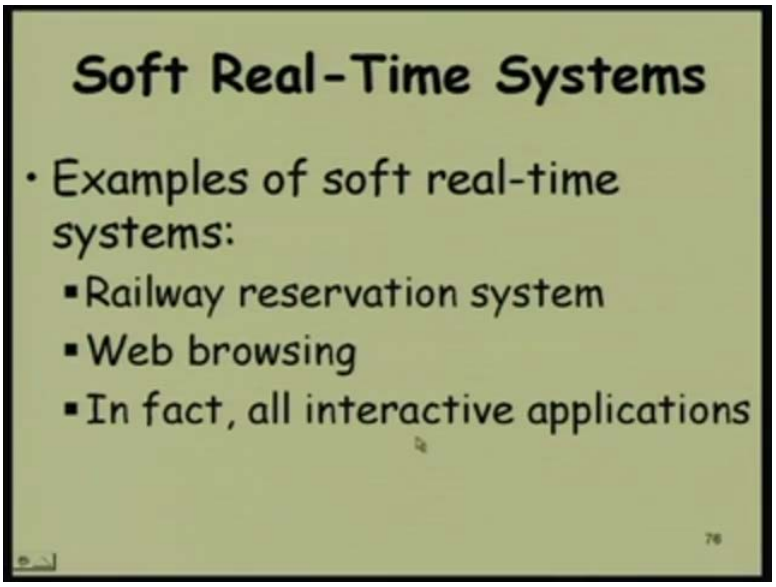
Examples: I had said that most of the multimedia applications following this category; we talked about video conferencing, telemetry and satellite surveillance applications.

(Refer Slide Time: 02:15)



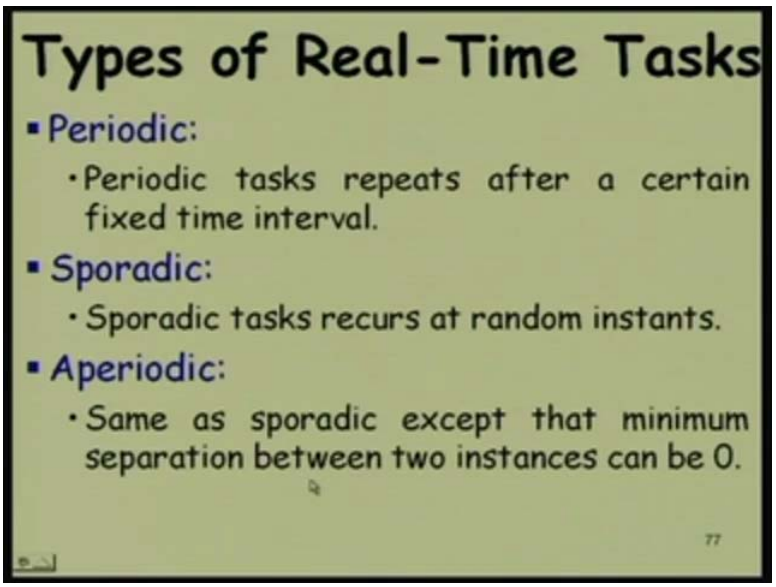
And then, we had looked at the soft real-time tasks. Where if the deadline is missed then the results are not discarded like in a firm real-time systems, but the utility of the results go on diminishing with time and after sometime it is no more useful; it is ignored. If the results appear within the deadline say that the performance is good, otherwise we say that the system is operating in degraded performance, we do not say that it is failed.

(Refer Slide Time: 02:55)



We had said that most of the tasks that are interactive in nature, that are actually soft real time tasks. We can have another type of classification of real time tasks some are periodic.

(Refer Slide Time: 03:06)



So, they repeat after fixed time interval. Of course, to make them repeat after fixed time interval must have a clock somewhere a timer it is the timer in the system, which actually gives the interrupt based on this tasks run.

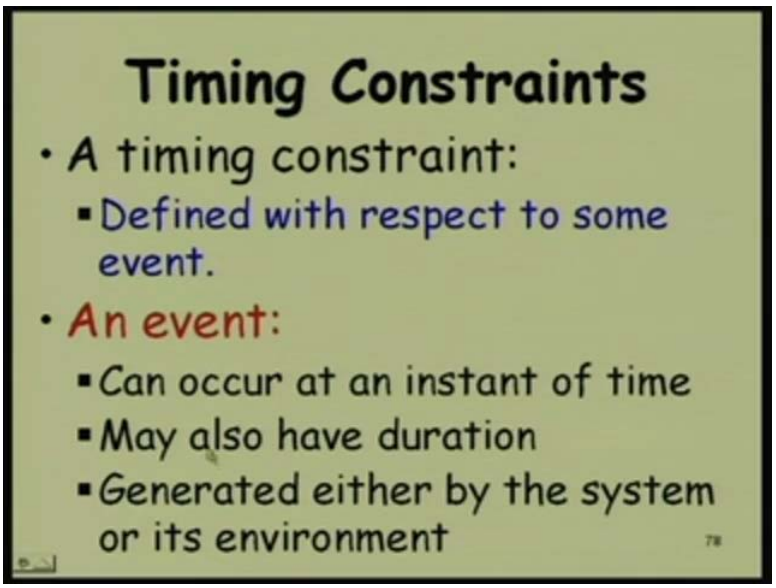
The periodic interrupts from a timer make the periodic tasks run, whereas the sporadic and a periodic they are the events caused by the environment no clock is involved.

The sporadic tasks as we are saying that this can occur at any time may be a fire condition started do not know when it will start, but when it starts the signal will be the event will be sensed by a sensor the task will be generated. So, these there is no periodic this can occur any time at random instants.

And the aperiodic tasks are somewhat similar to sporadic tasks, but with a minor difference in the sporadic task again the events that caused this tasks occur at random instants, but here the separation between two instances can be zero; that means, two aperiodic instances tasks can yes they can occur at the same time and the distance between them can be zero.

There can be several examples we will actually discuss some of these situations how they are handled in the real time operating system. One example is let us say we have a intrusion detection system. Now the intrusion may occur at different points and the intrusion can occur at the same time and we need to be able to handle that we can say that we just one intrusion will be alright.

(Refer Slide Time: 05:23)



Now, look at let us look at the timings constraints more deeply because the later part of the course we will a major discussion will revolve all around how this different types of constraints are handled satisfactorily, what does the operating system do, what does the communication protocol do, what does the database do, to meet this timing constraints.

One thing that we must remember, that the timing constraint is defined with respect to some event and the event we can conveniently think of the instant of time.

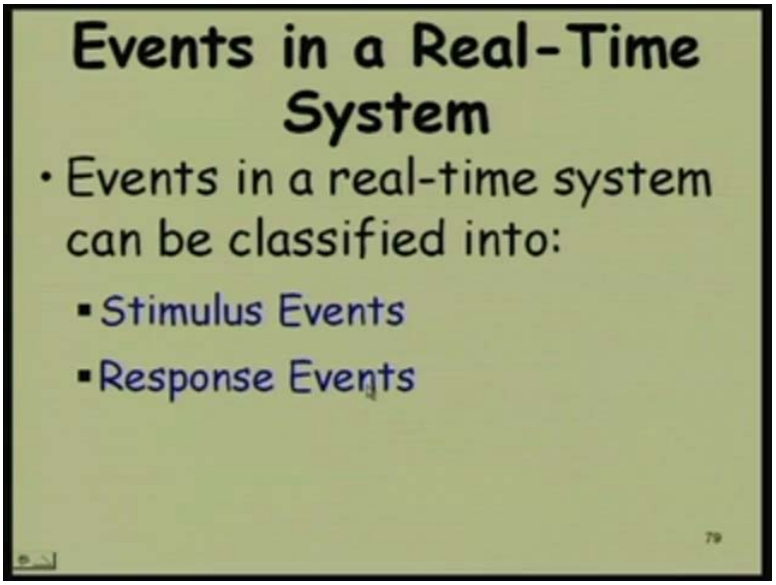
So an event is instantaneous, but again to think of it an event does not really occur at instant of time. For example, you press a telephone button is that an instant or keep the telephone button pressed for some time to make it work. So, it is not really an instant if you think many events they do not occur instantaneously see instant we assume that instantaneously because many events can be approximated to be some specific instant of time.

But it is necessary to consider that some events have duration, but again this duration events we can have instants of time associated with the start of the duration event and the end of the duration event.

Finally, we can say that every event can be associated with a unique time on the time scale whatever may be the granularity of the time it may be millisecond, nanosecond do not bother we can associate a unique time point with these events and the time constraint will be with respect to that event.

Now, who generates the event? The event is generated either by the system itself or by the environment user different activities occurring in the environment this will cause the events.

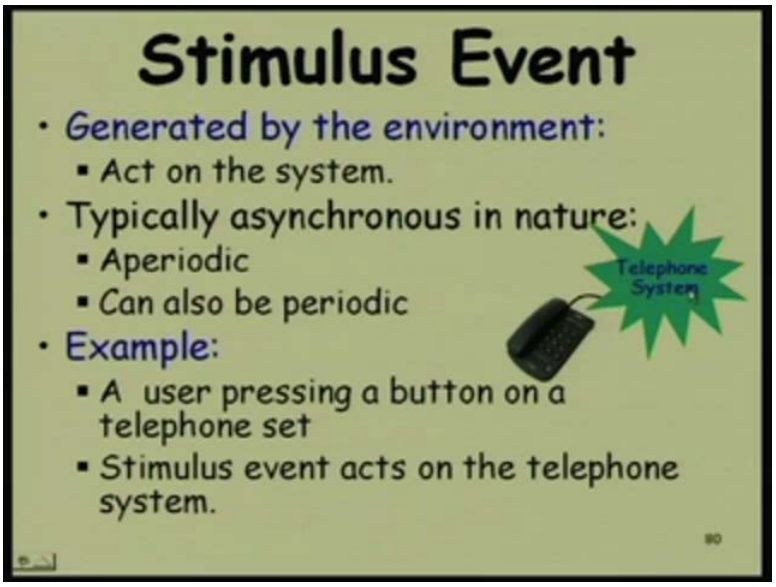
(Refer Slide Time: 07:51)



Now let us see them further, actually there are two types of events that will be concerned with one is the stimulus event. The stimulus event is generated by the environment; so this environment gives a stimulus to the system.

For example, the temperature exceeded some value action need to be taken so the temperature exceeding some value is a stimulus event to the system and the system will recognize that and it will respond to that. So, the response events are generated by the system. Stimulus is by the environment and response is by the system two distinct categories of events that we will talk off.

(Refer Slide Time: 08:45)



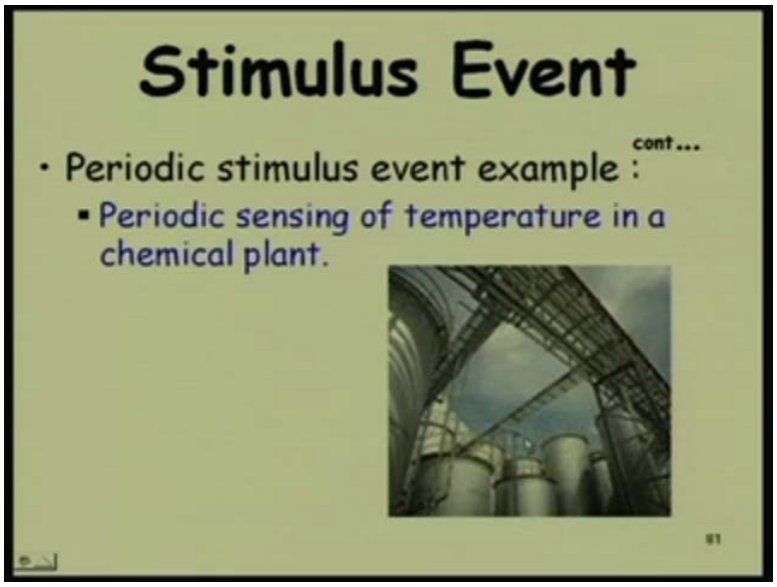
Now, let us look at the stimulus events seen that these are generated by the environment to act on the system recognized by the system and many of these events generated by the environment are asynchronous.

They do not occur according to some clock and that is the reason many of them are aperiodic or sporadic, but this can also be periodic because there might be a clock and according to that it generate some events, but a vast majority of them are aperiodic.

Just to give some examples of the stimulus event just consider a telephone connected to the telephone system and that is connects to the destination or the receiver. Now, let us say a user trying to dial a number he just lift the handset and presses a number. So, lifting the handset or dialing a digit are examples of stimulus events.

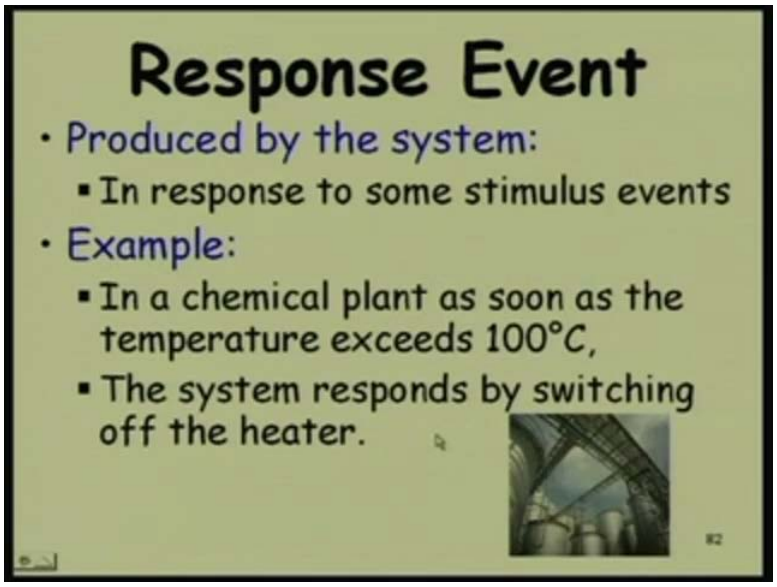
So, the stimulus event acts on the telephone system where we might have computers which respond to this event.

(Refer Slide Time: 10:19)

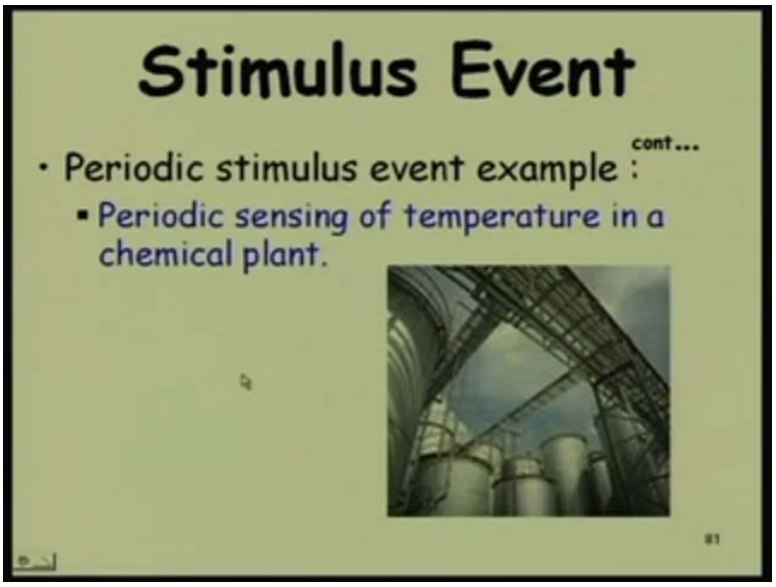


There can be also periodic stimulus events. For example, the temperature is sensed periodically according to a clock and this we can consider as periodic stimulus events is the chemical plant and large number of sensors will be placed temperature of different reaction chambers will be measured. But the sensing is done by system not by the environment.

(Refer Slide Time: 10:50)



(Refer Slide Time: 10:54)

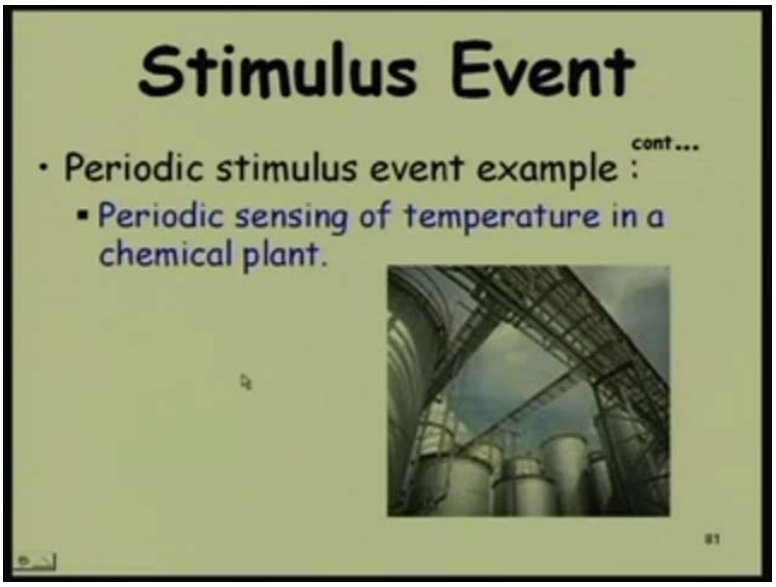


Yeah right. So, the question is that the sensing is done by the system it is not in that sense generated by the event because for this the environment to generate the event it basically like you know initiatively we say that it pressed the button or something.

But here we can think of it that these events of the system were recognized by the sorry the events of the environment were recognized by the system periodically it I mean it is not according to the intuition that the environment presses something or generates a event, but the environment is proceeding on its own way.

And then the system is sampling and this we can think of that the system has recognized these events of the environment something like that. So, this is an approximation it is not really a event in that sense generated by the system where it presses something or no it just the system samples the environmental event, but we will consider this to be stimulus events.

(Refer Slide Time: 12:11)

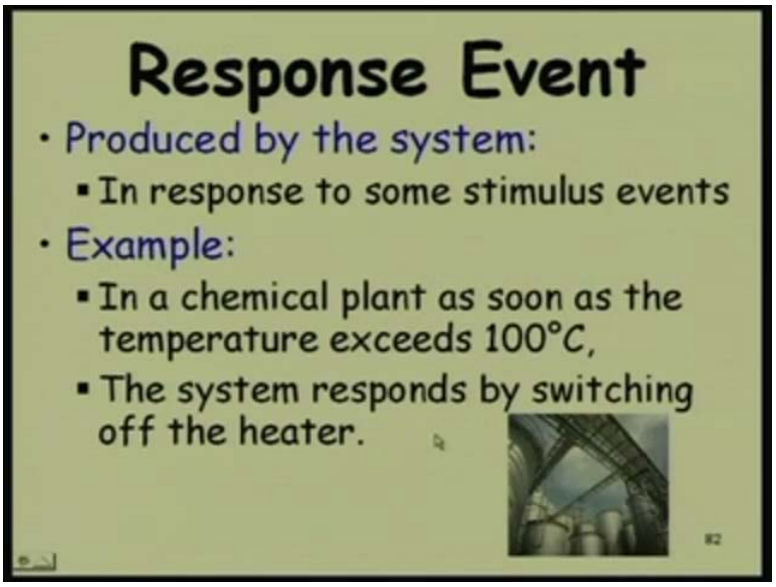


Can we say that an interface to the system is sensing this stimulus?

He said that the interface is a part of the system. So, the system is actually sensing the environment. Environment is not doing anything special to generate the event it is just proceeding on its own way and we are sampling the activities of the environment I mean the system is sampling.

This is, I mean we can think of an event of the environment recognized by the system as a event generated by the system sorry generated by the environment. So, let us proceed.

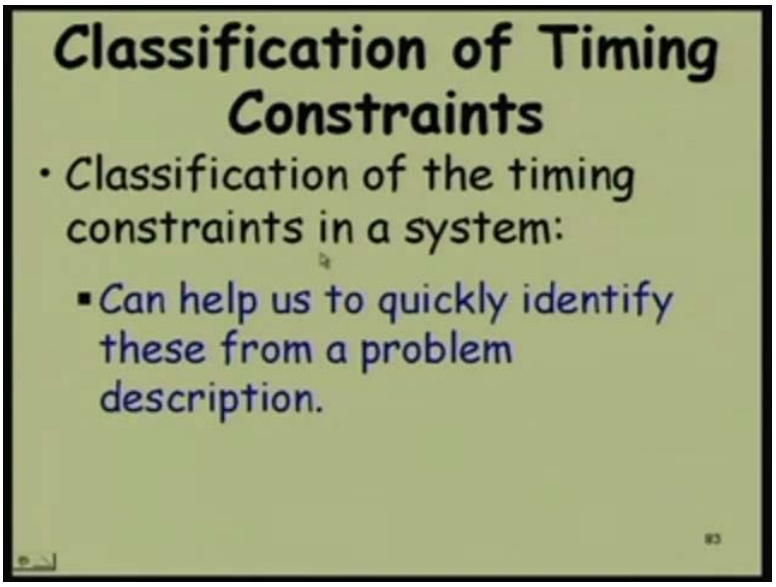
(Refer Slide Time: 12:52)



Now, the response events these are produced by the system and normally most of the cases we will see that the system does not produce response events simply by itself. It actually responds to some event which were generated by the environment or some stimulus events and based on that it processes and responds to that.

An example is that there might be a stimulus event that the temperature exceeded hundred degrees centigrade and has been sensed by the system. So, this is the stimulus event with respect to that the system generates a response event switches off the heater. As we proceed we will see more and more examples of stimulus events and response events.

(Refer Slide Time: 13:52)



Yes please.

Difference between periodic response events and periodic stimulus events:

See stimulus events can be periodic. I mean most of the stimulus events are actually aperiodic like for example somebody pressing a switch or something, but if we talk of something being sensed periodically.

That is a periodic stimulus event, but the actions they occur with response to a stimulus event so it is I mean hard to or it is not very logical or very initiative to say that a response event will also be periodic.

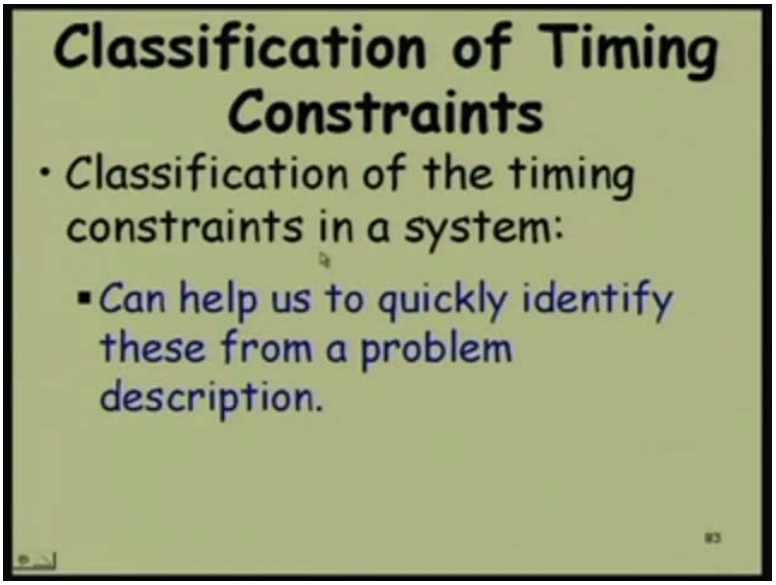
Response event with respect to a stimulus event we will always talk like that. May be we might have some cases where one say stimulus events occur periodically some actions by the system takes place, but very rare. Most of the events that we will see with respect to some stimulate event response event occur with respect to some stimulate event and does not act by its self. Is that ok.

Stimulate have one response so that stimulate response (( )).

Exactly, the question is here that the response events as you said with respect to stimulate events, so the stimulate events is periodic and we say that the response events

is periodic need not be the response events the stimulate events is periodic the response events is may not be periodic. It may be that some time action to be taken; some time it not to be taken and depends on the system response time that may vary from with stand to with stand. The periodic stimulate events did not produce the periodic response events.

(Refer Slide Time: 15:57)



Let us try to classify the timing constraints, the idea behind this classification is that if we know that what are the kinds of timing constraints that might arise when we look at a problem description we can immediately recognize that this is a time constraint. We will take up some examples later on give a problem description and ask you to identify the timing constraints.

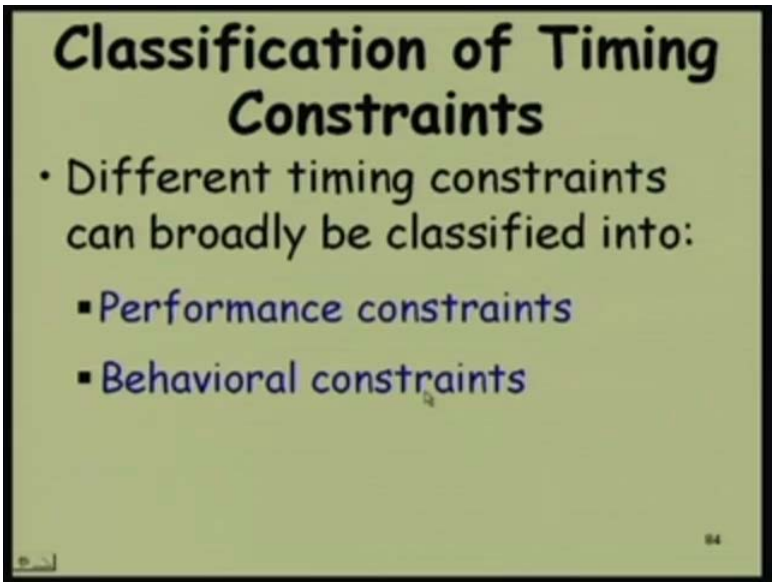
The different type's types of timing constraints exist in those problems and then we will try to model that.

(Refer Slide Time: 16:33)

So, the timing constraints as we said are defined with respect to some events and if it is there are two types of timing constraints, one is performance constraints which is a constraint imposed on the response event from the constraint is with respect to two events, actually one is the performance constraint or with respect to the stimulus event and from that how much time it takes to generate the response event by the system that is the performance of the system. And we can have the behavioral constraints where given an event generated by the system how long does the environment take to takes to respond to it.

For example, in a telephone once the dial tone appears after you lift a handset the system generates the dial tone and then how much time do you take to press the buttons or the digits to be dialed. So, that is a behavioral constraint.

(Refer Slide Time: 17:55)



If you take too long to dial the digit, then the dial tone will vanish and you have not really met the behavioral constraint.

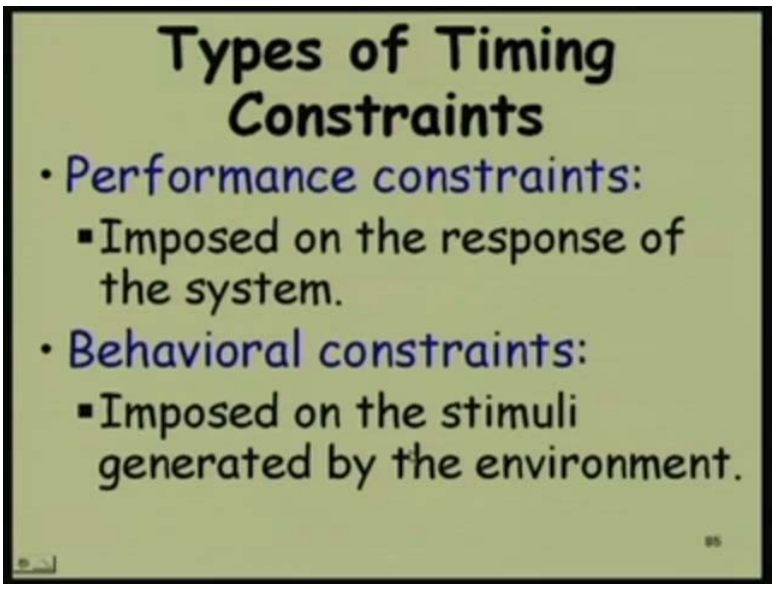
So, every system that we will discuss or that are that exist practically they have two types of constraints there. One is defined on the response events of the system and the other is on the environment itself and the environmental events. So, if the environment does not meet the constraints then some action need to be taken.

(Refer Slide Time: 18:05)

For example, in a telephone set if after the dial tone appears even after five minutes you do not dial a digit then it will produce a beeping tone, a idle tone or a beeping tone.

So, that is the action that it will take because the environment could not meet the time constraint the behavioral constraint.

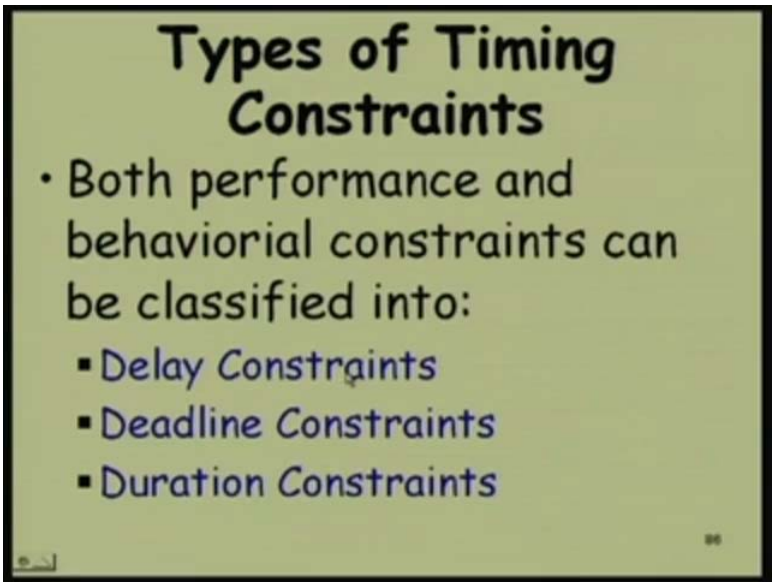
(Refer Slide Time: 18:52)



This we have already seen that the performance constraint is on the response of the system with respect to normally a stimulus event. The response event is defined but in rare cases we will have a performance constraint from one response to another response.

The behavioral constraints are imposed on the events generated by the environment.

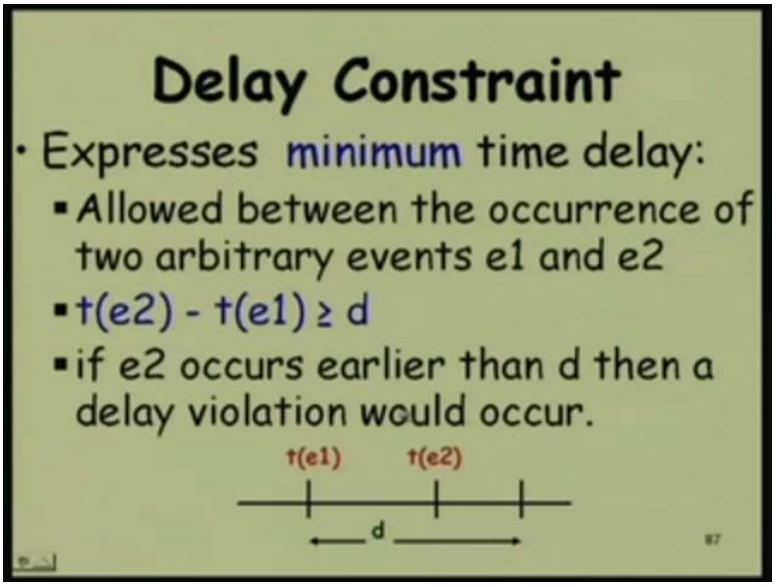
(Refer Slide Time: 19:21)



Now, again we can classify these different types of constraints both the behavioral constraint and the performance constraint into three types one is a delay constraint, another is a deadline constraint and one more is a duration constraint.

Let us look at these three types of constraints and how they become applicable to these three types of events with some examples.

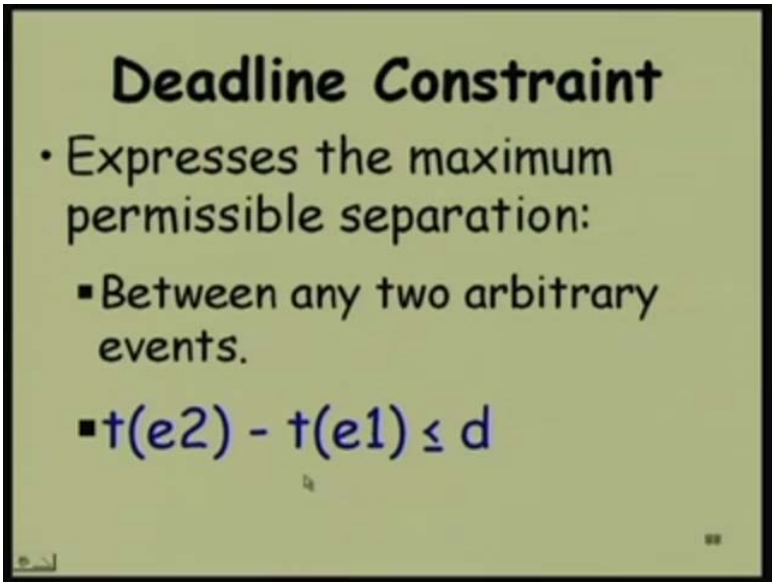
(Refer Slide Time: 19:48)



Now let us look at the delay constraint, these delay constraint expresses the minimum delay that need to elapse before an event should be produced. The delay constraint is the minimum delay that must elapse from one event before the other event is produced. Just see here e1 occurs and now for e2 for delay constraint to let us say d is the delay constraint then e2 should occur after d. te2 minus te1 must be greater than equal to d. It must occur after here.

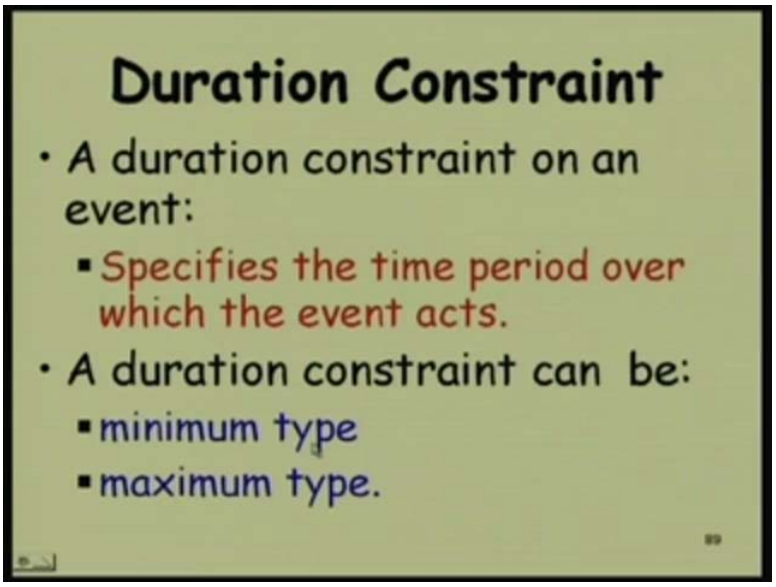
So if it occurs before d then it has violated the delay constraint is the delay violation, e2 has earlier than d and there is a delay violation.

(Refer Slide Time: 20:54)



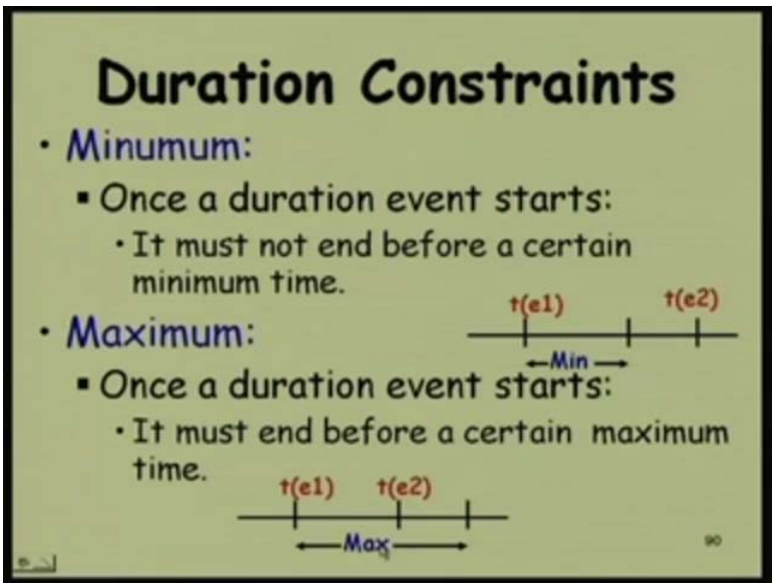
A deadline constraint expresses the maximum time that might elapse before a event is produced from another event if e1 occurred and there is after that e2 needs to be produced then the maximum time that is allowed is d it must be produce before t.

(Refer Slide Time: 21:18)



Now a duration constraint it specifies a period of time over which a event acts, similarly we can have a maximum or a minimum type of duration where the duration must be of certain minimum duration or it may be of a maximum type where the duration is can be up to some maximum.

(Refer Slide Time: 21:47)

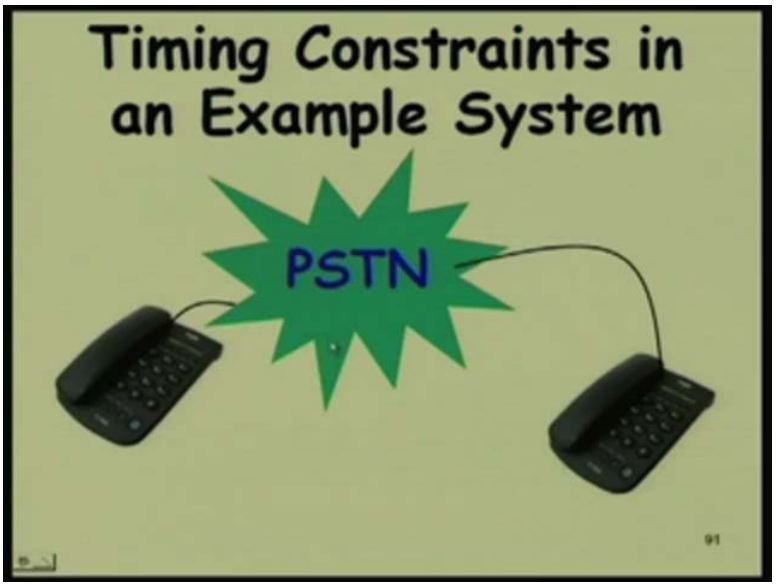


Now let us look at this minimum duration constraint, so once the duration events starts here e1 the end of the duration event must occur after the minimum time. So, this is the

delay after which e2 must be produced otherwise there will be a violation of this minimum constraint.

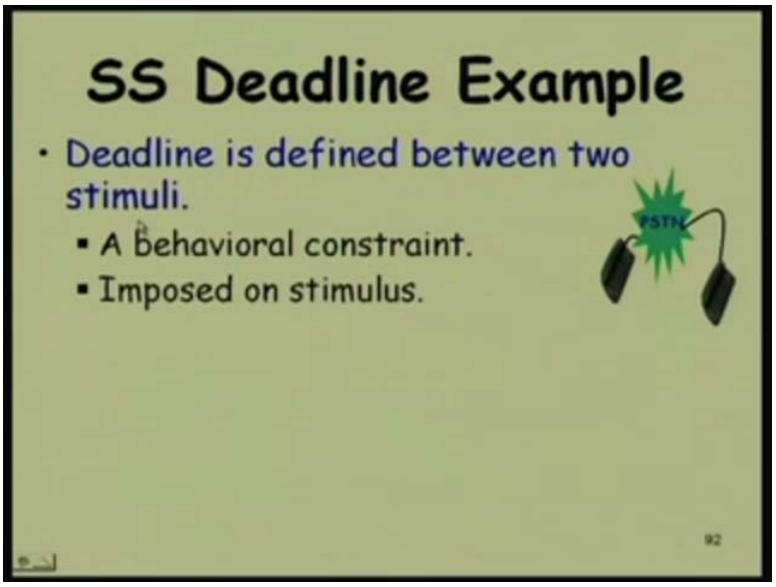
Similarly, we can have a maximum constraint once a delay constraint once a duration event starts then the end of the duration must occur before the maximum delay or the event to satisfy the duration maximum duration constraint does that appear.

(Refer Slide Time: 22:40)



Now, let us look at examples of such constraints we will look at examples with respect to a telephone system where we have a initiator call initiator who is trying to dial a number to reach out to somebody where a ringtone will be produced and this is the number the number will be dialed from here this is the example we will take.

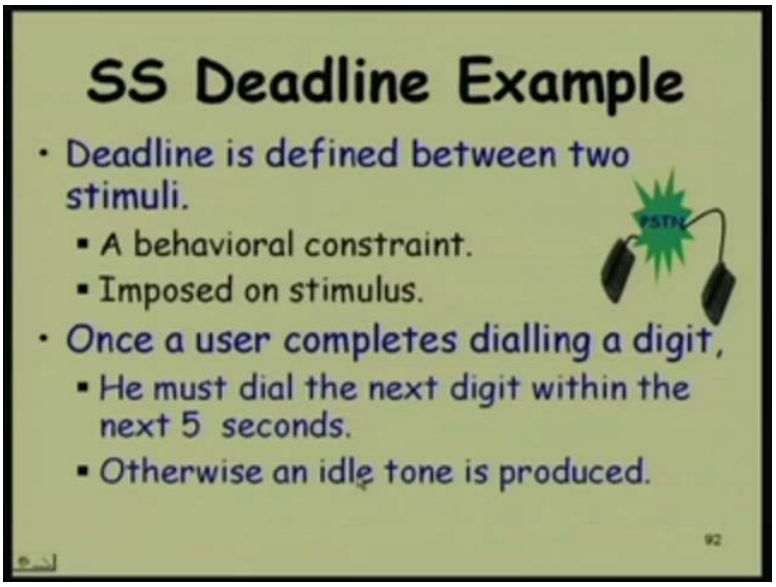
(Refer Slide Time: 23:06)



So, first let us look at the deadline example between two stimulus events. So will it be a behavioral or a performance constraint it will be a behavioral constraint why is that, because it is it applies on one stimulus whenever the constraint applies on a stimulus it will be a behavioral constraint.

So it is with respect to two stimulus events does not matter, but finally, it is applying on to the stimulus event. So that is the reason that it is imposed on the stimulus that is why you were telling it as a behavioral constraint.

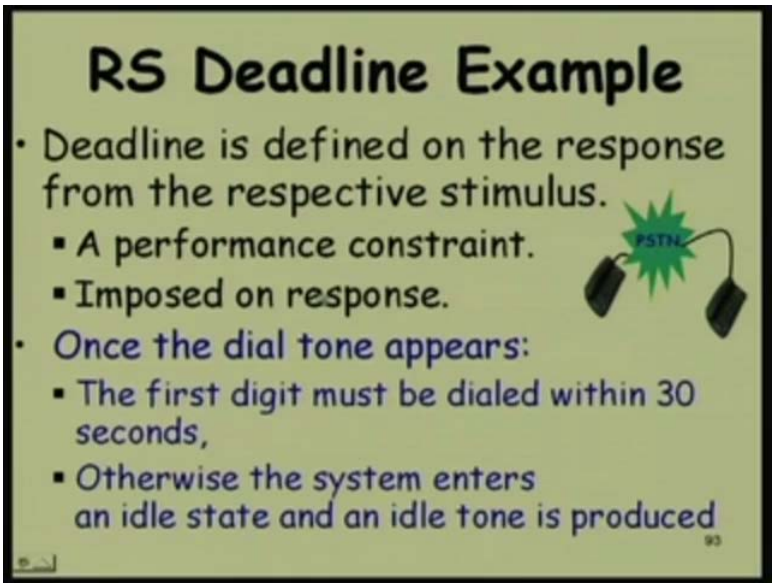
(Refer Slide Time: 23:55)



Let us look at an example that a when a user completes dialing a digit. So, this is one event that has been produced by the environment or the user he has completed the dialing the digit dialing one digit. So, he wants to dial a let us say 7 digit numbers or something he has dialed one digit let us say the 4^{th} digit. Now the 5^{th} digit must be dialed within the next 5 seconds if he delays more than 5 seconds then he has failed. The deadline constraint missed the deadline constraint violation and then an idle tone will be produced.

The event could not be produced before 5 seconds is that a deadline constraint example between two stimulus event.

(Refer Slide Time: 25:55)



Similarly we can have a deadline constraint with respect to one response and with for a stimulus event with respect to a response event. So, this is defined on the I think we have a difficulty here. So, if it is a RS deadline example it should be a stimulus event defined with respect to a response event, but what we have written here actually is that defined on the response event from the stimulus. So, it should be SR I think there is a mistake here.

It should be SR deadline example because it is a response event on which the constraint is defined with respect to a stimulus event. So, just change this one this should be SR.

Since it is defined with defined on the response event it will be a performance constraint that is because it is imposed on a response.

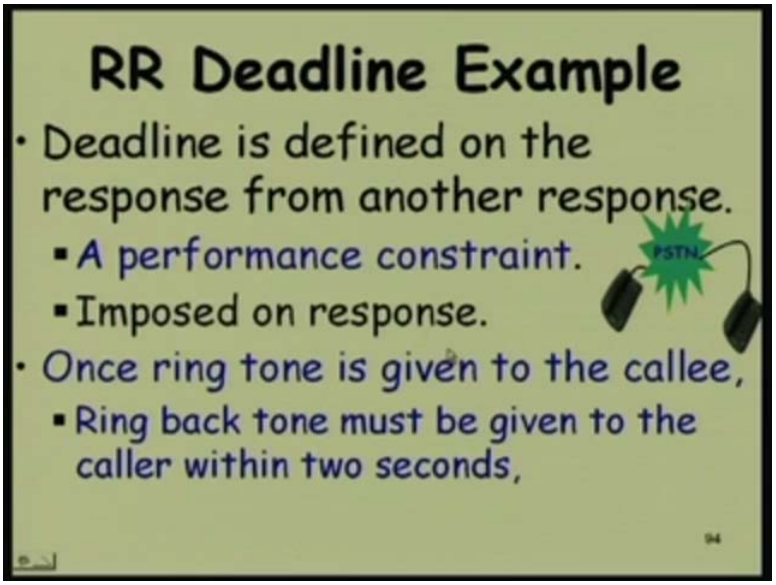
So, let us see the example once a dial tone appears this is the response I think there is a little bit of this thing an incorrect there the confusion here I mean while I prepared the slide actually RS is alright what we should have written here, is that defined on the stimulus with respect to the response and in that case it will be what kind of constraint it is a behavioral constraint just like let us look at the example then it will become clear see the dial tone is produced by the system.

So, this is the response produced I mean this is the event generated by the system and then this is the constraint on the user who must dial the first digit within 30 seconds of the dial tone appearing, otherwise there will be a constraint violation and the system will take some action, because the event the user could not meet the constraint of dialing within 30seconds the system will generate an idle tone.

So this is a RS deadline example alright, but here what we have written here is slightly incorrect it should have been a deadline defined on the stimulus event with respect to the response event.

In that case it will become a behavioral constraint because it is defined on the behavior and stimulus event.

(Refer Slide Time: 27:48)



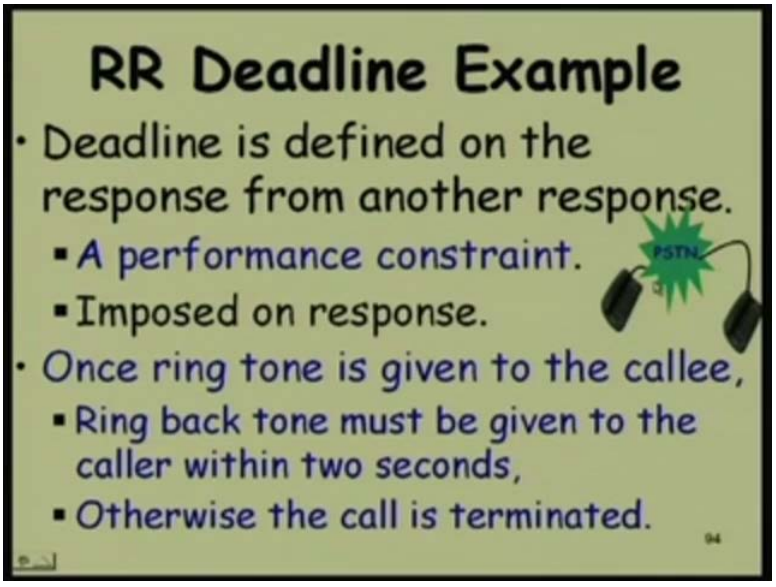
Now let us look at another example a deadline defined on two response events. So, the deadline is defined on a second response event from a first response event.

So, what kind of constraint it will be it will be a performance constraint, because it is acting on the constraint is defined on the response.

Let us take an example now the system gives a ringtone to the callee, the person whom you are calling a ringtone is given to him and within certain time a ring back tone must be given to the caller who knows that the number is getting called, ring is appearing and that must happen quickly enough. So, that it knows that ring is its already ringing otherwise what will happen know you find that suddenly he has answered even without any ringing that should not occur.

You should know immediately or within a time that is not recognizable by the human the ring back tone appears after the ring tone is produced.

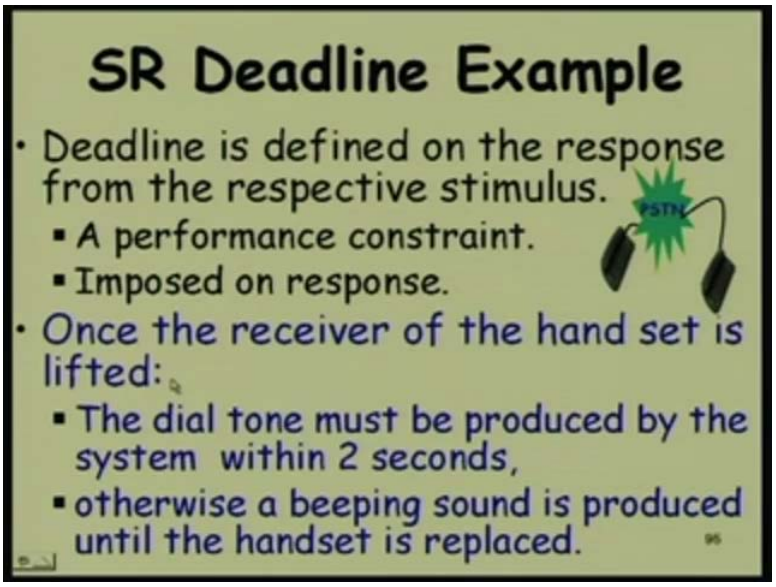
(Refer Slide Time: 28:31)



So the ring back tone must be given to the caller within two seconds, this is a typical performance constraint on most of the telephone systems that we use that the ring back tone it should be produced before the humans can actually think that why it is not getting produced. So, its within two second of the ringtone being given to the callee the ring back tone must appear to the caller within two seconds, otherwise the system has some

difficulty some error is there in the system and the call will be terminated. So, this is the example of a deadline of one response event with respect to another response event.

(Refer Slide Time: 30:00)



Let us look at the example of a I think because the other slide was I mean mixed up may be this is also mixed up. So let us see this. So, this is a deadline example of a response from the stimulus.

I think if it is on the response deadline is on the response it will be a performance constraint and will be imposed on the performance.

Now, let us look at the example. So, the receiver handset is lifted. This is a stimulus event receiver handset is lifted is by the environment or the user and this is a stimulus event and then the system must produce the dial tone within two seconds.On the system.

This is on the system or on the response event. So, looks alright.

So, it is a deadline example on the response event from a stimulus event and it is a performance constraint because it is on the response event and if the dial tone does not appear within two seconds then a beeping sound is produced until the handset is replaced. So, there is a constraint violation and the system takes an action.

(Refer Slide Time: 31:35)

Now, let us look at the different types of delay constraints. We had seen different types of deadline constraints, between two system events, between two response events, between a system event and a response event and between a response event and a system event.

Now, let us look at delay constraints examples of those so let us first look at a behavioral constraint.

The behavioral constraint will be imposed on the environmental event let us look at an example.

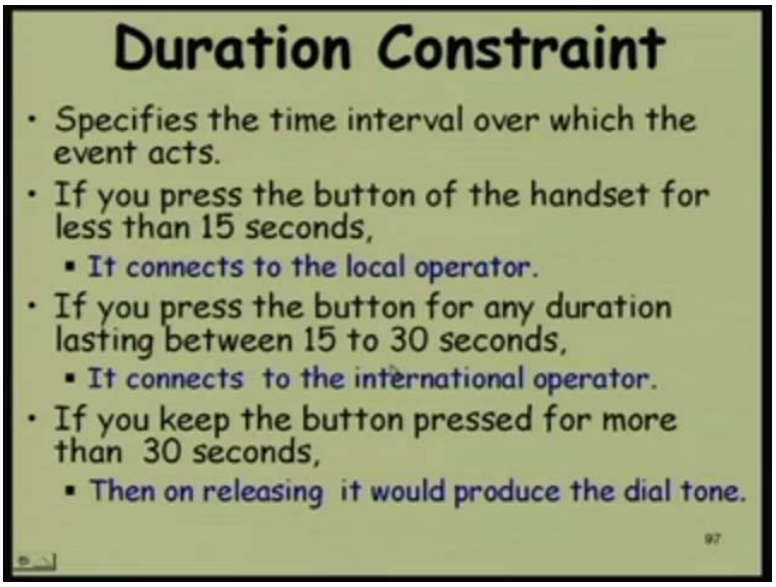
So, once the user dials a digit must dial the digit after at least one second see in the normal handsets that we have here we do not have the situation, because it does not produce a dial digit to be dialed within certain time even if you act very fast enough or let us say one thing can happen is you simultaneously press two buttons or something or one after other quickly. So, that is an error is not it.

(Refer Slide Time: 32:43)

So, there is a delay between two digits which are dialed. So, if you if the user dialed one digit the next digit dial signal must reach the system with after at least one second one second is too much because this is not the actual value actually it would have been better if I had written something like few milliseconds.

Otherwise a beeping sound is produced. So, dialed two digits too fast pressed two buttons quickly and the beeping sound will be produced by the system there is a delay constraint violation and the initiator has to terminate the call by replacing the handset and try again this is a delay constraint between two stimulus events.

(Refer Slide Time: 33:34)



We do not have examples of other delay constraint between two responses, between a stimulus and response and a response and stimulus. It is not that they do not exist they exist, but for this particular example it was hard to think of those situation between two response and stimulus etcetera. So, we just had one example of a delay constraint that is respective to stimulus events.

Now let us look at the duration constraint example in the same PSTN system that we are discussing as we had already discussed a durational event acts over certain interval of time and the duration constraint specifies the time interval over which the event should act should it be within certain time after certain time and so on.

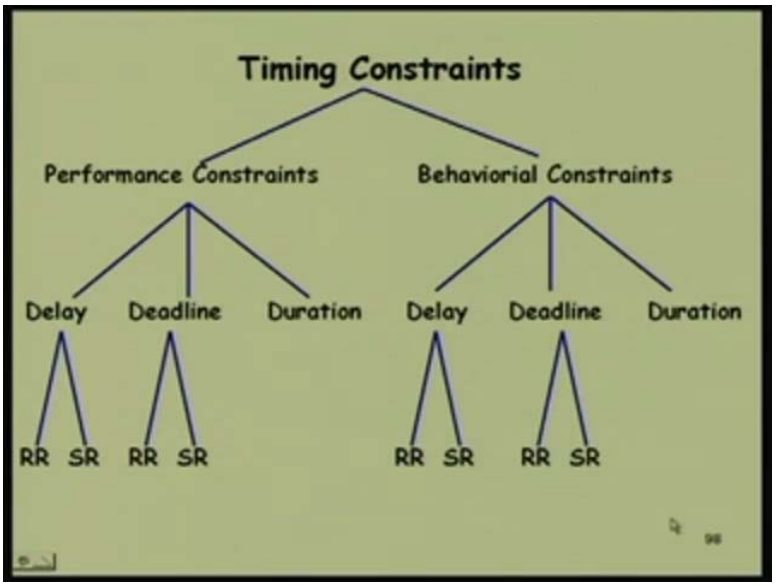
Let us say you have a telephone system in a hotel or something. Now if you press the button of the handset for less than 15 seconds you just press the button then it connects to the local operator of the hotel where you can request some call to be established or something or a fax to be sent or something.

Now, if you press the button for any duration between 15 to 30 second then it connects to an international operator. So, the operator who handles the international calls he will he will get connected if you have pressed the button between 15 to 30 seconds and possibly want to initiate a international call.

Now, if you keep the button pressed for more than 30 seconds let us say if you release after 30 seconds you'll get a dialed tone and you can dial a number.

So, this is not that such systems do not exist, but this we do not use too frequently in normal telephone system that we use does not occur, but this is an example of a telephone system which exists or which are meaningful in several situations.

(Refer Slide Time: 35:57)



Sir

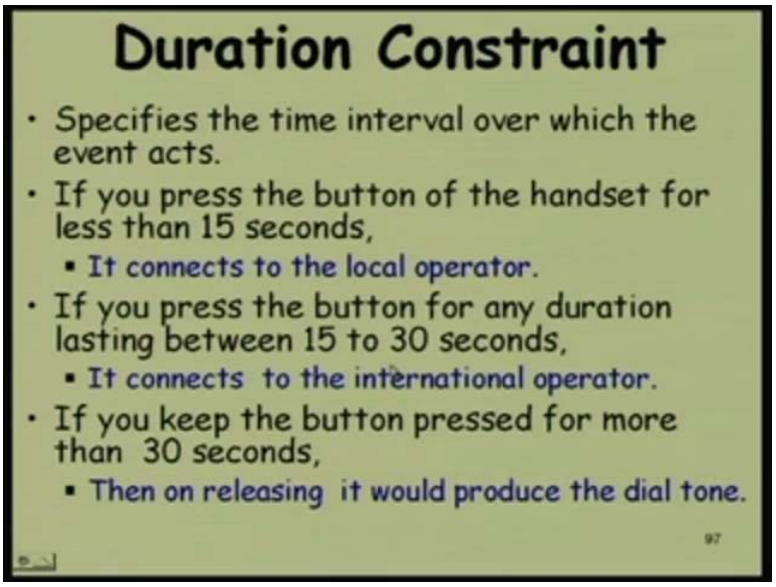
Yes please

Then can I think that the duration constraint is special case of delay.

So, the question is that whether a duration constraint is a special constraint of delay constraint. No, see if you remember we had said that a duration constraint is from a starting event for the duration to the end event of the duration and there can be various types of constraints. For example, it can be a deadline constraint that the end of the duration must occur before certain time elapses or it can be that the minimum time between the start of the duration to the end of duration must be something. So, that is a delay constraint.

So, between for a durational event we can have both delay and a deadline constraints.

(Refer Slide Time: 36:57)



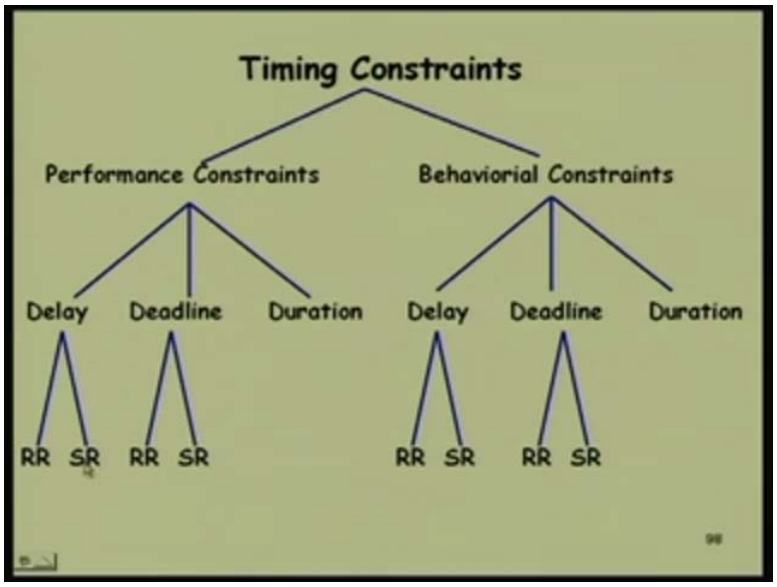
So, we will see as we model this it will become clear, that this example that we have considered here there are several types of events durational events see here one durational event is 0 to 15 and another durational event 15 to 30 and then 30 to more.

So, there are three durational events here and in one event it is a deadline in one case, but this durational event starts after a delay of 15. So, the start of the second duration is actually a delay of 15 appears on delay 15.

So, we will just see while modeling it we will decompose it into several durational events even though towards it appears like one duration that we just pressed the button and released it.

But when we actually try to model it will become clear that there are several durational events involved and that too several types of constraints on them like delay constraints and the durational event, deadline constraint and the durational event. So, this is a more complex example we will try to model it and then it will become clearer.

(Refer Slide Time: 38:15)



Let us proceed. So, we said that the timing constraints are basically two types. One is the constraint on the response of the system which we called a performance constraint and then the environmental events also there can be constraints on them we call them as behavioral constraints two main types of constraints will be dealing with any system.

And if we look closer down into the performance and behavioral constraints, we will see that the performance constraint can be either of a delay deadline or duration. And the delay constraint is with respect to a for a performance event constraint it is with respect to a response with a respect to a response from a stimulus or between two response. So, it is defined a performance constraint is defined on a response event a delay constraint.

So, always R is appearing at the second part here because it is defined on the response event either with respect to a response or with respect to stimulus.

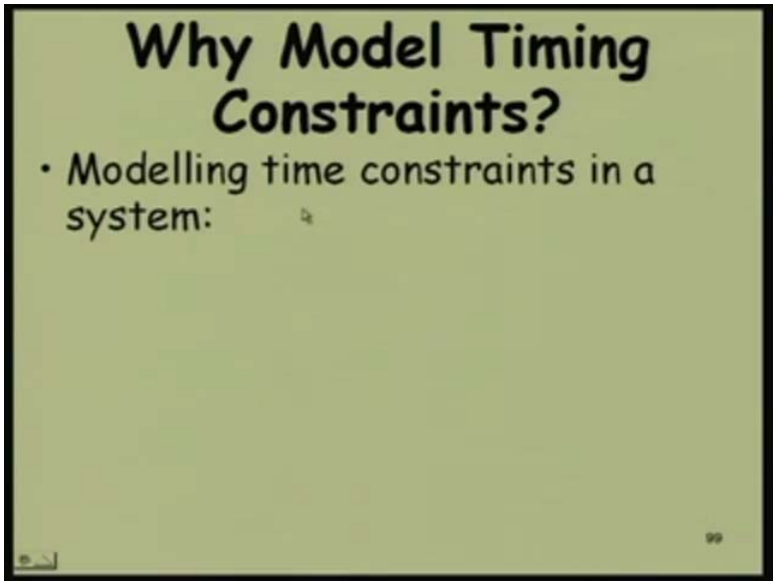
Now, on the other hand we can also have behavioral constraint as either delay a deadline or duration. I think there is a mistake here

As I want to see in ss event know.Ah there is a mistake here actually.

Because behavioral event should be always defined on a stimulus event actually what I did was I just copied this and pasted here in a hurry. I should have actually change this is incorrect.

See here the behavioral constraint should be defined on stimulus event. So, it should be RS type, SS type, RS and SS there is a mistake here. So, the behavioral constraint can be delay deadline or duration, but each time it will act on the stimulus event and the stimulus event may be with respect to a response or another stimulus.

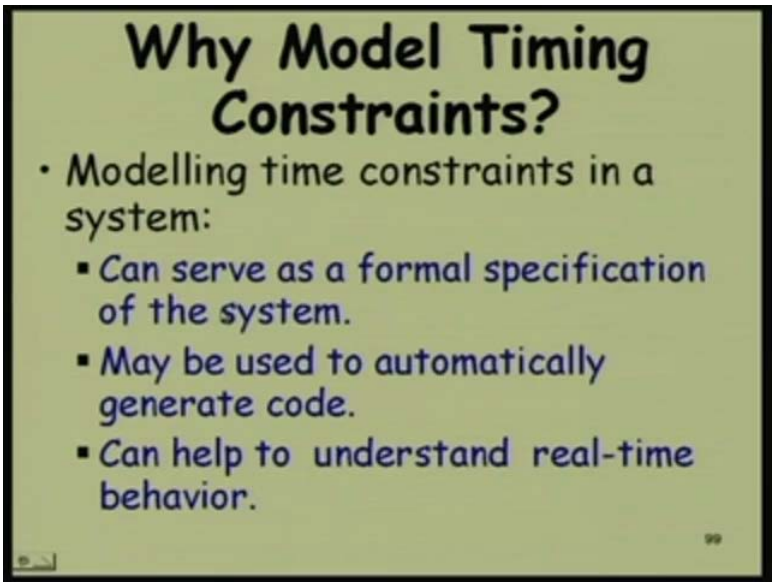
(Refer Slide Time: 40:25)



Now, let us see some very basic thing is why do we need to model this constraints is not it enough that we just recognize them and then we try to implement or take care of them and how do we model them lets answer these questions that why we need to model and how do we need to model these constraints.

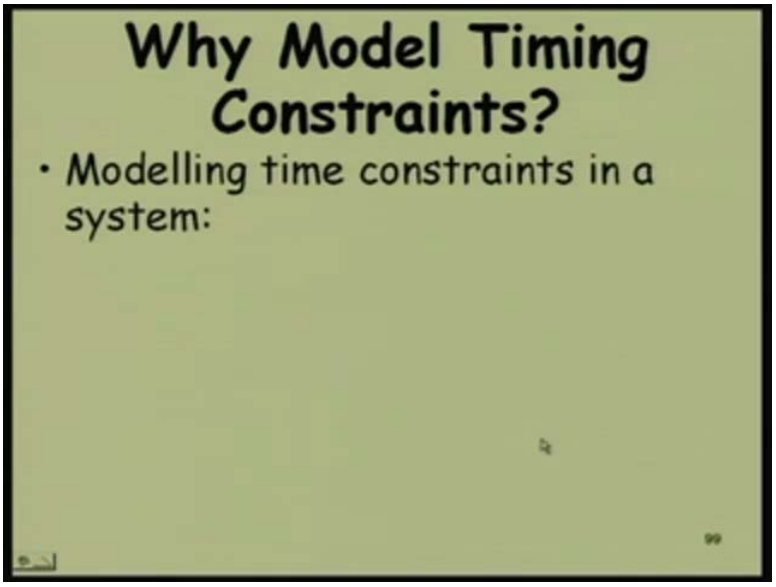
Now let us see first is why we need to model timing constraint there are many reasons why we might need to model a time constraint.

(Refer Slide Time: 40:56)



First of all when we model a time constraint, we are expressing it more formally then just a few sentences appearing as a (( )) English sentence we are constructing a model of it which is more precise.

(Refer Slide Time: 40:22)



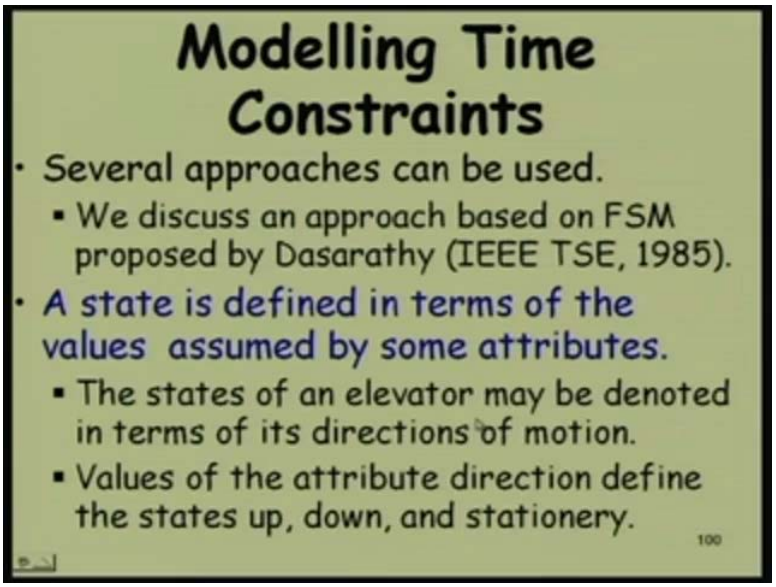
So, this can be a formal model of a constraint we can use such a formal specification to verify a system and also we can use such a model to automatically generate code.

Actually, there are several systems being used in industries where from such specifications they can generate code. We will discuss about them as we will proceed that how from a FSM model how can the code be generated or not FSM may be some other model also how code can be generated for a time constraint.

Another big advantage is that if we model it we know the inter cases in the constraint. For example, we just saw that the durational constraint we did not really realize that there are many events in that and there are different types of constraints appearing between those events. I mean we just discussed few of them when we model we will realize that there are more constraints than what we realized.

So, understanding the behavior will be more if you are able to model the timing constraints. Let us proceed.

(Refer Slide Time: 42:43)



So, there are as we were saying that there are several approaches that have been used to model time constraints. We will use a approach discussed in the IEEE transactions and software engineering 1985.

This is a model is extends the finite state machine. Finite state machine all of us are familiar and this was proposed by dasarathy B.Dasarathy and as I was saying that there are systems where if you model it with FSM then it can help you generate code and also FSM is quite initiative.

So, let us concentrate on a FSM modeling of the timing constraints. FSM we are all familiar to some extent it is used FSM is a very versatile tool used in many situations and knowingly or unknowingly over various course works we have used FSM's construct different types of model.

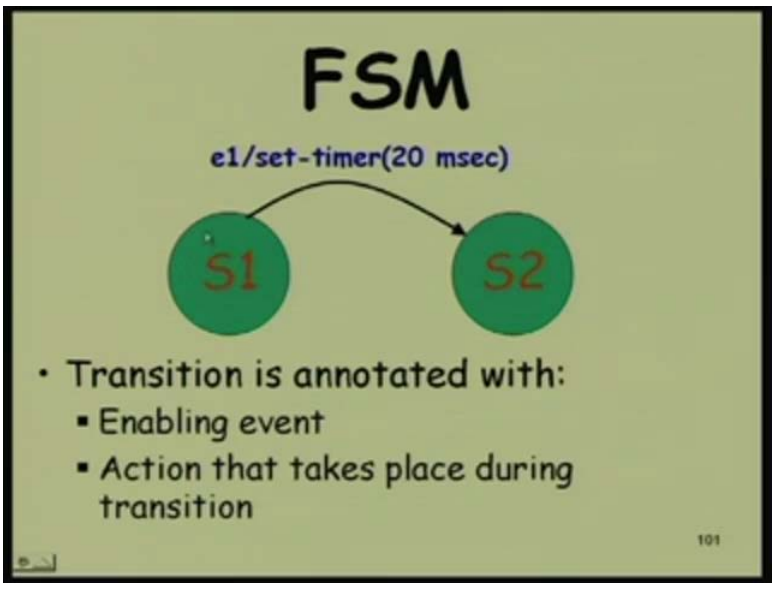
But one thing we have implicitly assumed in all that models is that a state a FSM consists of many states and transitions and the state is defined in terms of the values of some attributes in the system. For example,

Let us say we have an elevator as a system the elevator can be in different states for example the elevator is stationery standing and it is may be the elevator is in a motion up state or it is in a motion down state.

Now, this when the system is constructed the program or something will have some variables or attributes which will actually define the state in terms of this up, down and stationery.

So, if the attribute direction is zero possibilities stationery one is up, minus one is down that is a that can be a possibility. So, depending on some attributes the states on any FSM are defined think of it.

(Refer Slide Time: 45:05)



Now the convention that we will use here in our modeling is that two states are denoted s1 and s2 the transition and the transition is annotated if the event that causes this transition. And also as the transition occurs the action that takes place during the transition.

So, if you refresh your knowledge on FSM's you will see that there are two types of FSM's the milli machines and the more machines. So, those things we will not go into that we are just saying that the as the transition occurs, I mean for the transition to occur some event must occur in when the system is in state s1. For example, the system is a lift which is stationery and you pressed a lift top button e1 is the lift top button and then let us say you do some action, let us say set some motors on or something.

So, this is a separate time this is a real time constraint. So, we have just written timer. So, we will model this time constraints in terms of some timers and some actions. So, this is the state transition and transition we have a event and the notation this will give a slash and write the action that take place while the transition occurs.

So, the e1 is also called as the enabling event for this transition and we can also elaborate it little bit by adding a guard here that even if the event occurs then some condition must get satisfied we can add a guard condition here, but we will not do that here just to keep the discussion simple.

Sir,

Yes please.

Sir, in this case for one stimulus.

Yes.

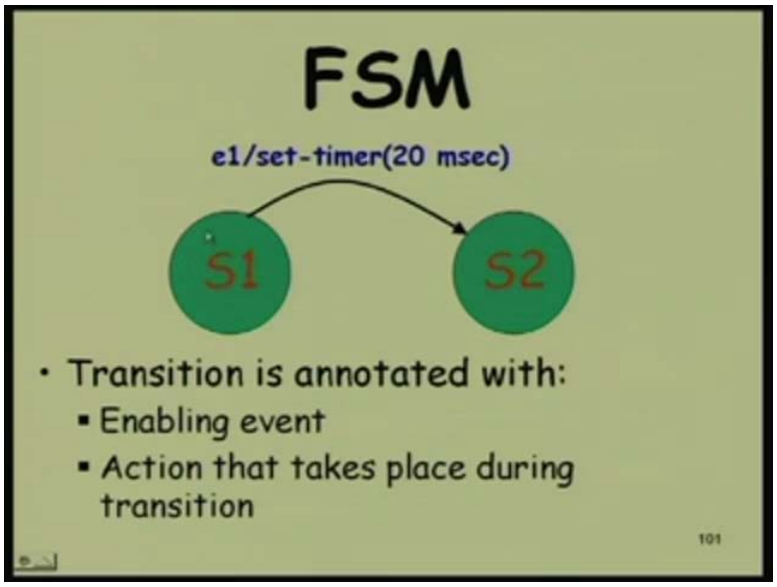
There will be two response like say suppose if there is a (( )).

Yes. Exactly

It moves up and then becomes (( )).Exactly

Then how do we? Yeah.

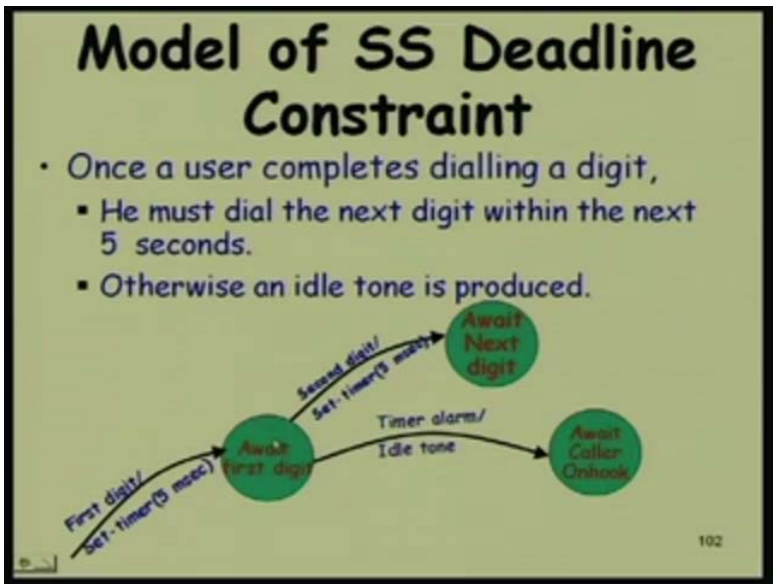
(Refer Slide Time: 47:21)



The question is that sometimes we have an event which causes a transition, but we have multiple actions occurring. So, in that case we will just the convention that we will use is that e1 slash action1 comma action2 comma action3 that is the convention that we will use.

Multiple action, multiple event, multiple responses occurring for the same event.

(Refer Slide Time: 47:43)



Now, let us try to construct a model for the SS deadline constraint. So, the example that we had discussed is that after the user completes dialing a digit. So, that is the response of the user one digit is dialed, the next digit must be dialed within 5 seconds, otherwise the constraint is violated behavioral constant is violated and then the system will produce a idle tone.

So, the system is awaiting the first digit this is the starting state for this model for this constraint and the user presses one digit and while this event occurs on this transition. We have a timer event set for 5 millisecond and if the second event comes that is I mean the event second digit dialing comes here then we await the next digit and then again set the timer to five millisecond, because from here also you have to do the same thing await the next again. We will wait for the third digit and again set the timer for five millisecond.

Sir 5 milliseconds means say deadline a constraint so within 5 milliseconds second digit should be 5 seconds.

Exactly, the idea here is that see if the second event occurs before 5 millisecond first then this will come from this state to this state.

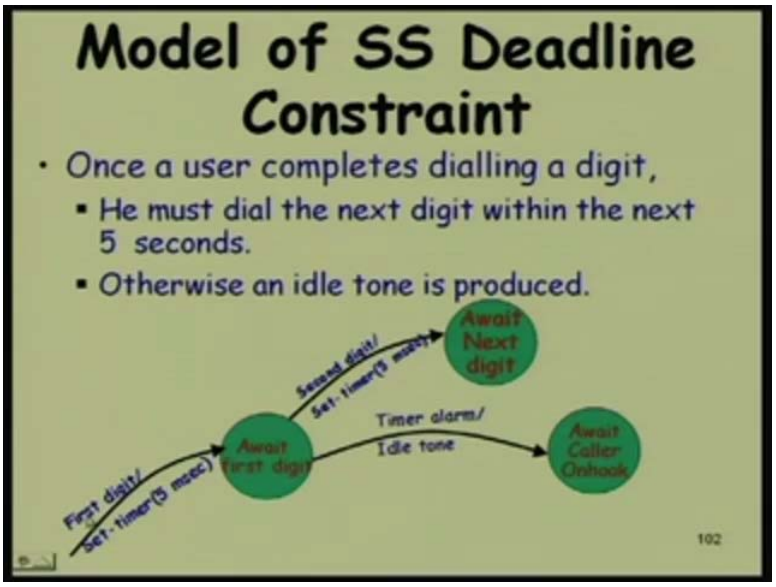
Let us say the system is waiting for the next digit and the next digit is not coming, 5 seconds are paused then the timer will fire. Once the timer fires it will come to this state await caller on hook and it will produce an idle tone whatever the caller does dials the second digit, third digit etcetera.

It does not it just produces the idle tone until the user replaces the handset.

So, if we want to represent delay constraint then what we have to.

So, we have several examples actually all the examples that we considered we will model each of them just to make the idea clear here. So, that we can take some examples and I will ask you to construct some identify the timing constraint and model those.

(Refer Slide Time: 50:23)



So, let us see all those examples that we saw the different types of deadline constraint SS, RS, SR, RR etcetera each one we will model we will also model a duration constraint.

So, the idea here is that time constraint the deadline constraint is actually handled by the timer, if the event occurs before the timer expires the timer fires then it makes the transition to a meaningful state the constraint is satisfied.

But, if the event does not occur that is indicated by the timer alarm firing and then the system takes some action to handle the violation.

Sir it is await second digit sir. Yeah.

Actually the names are I mean we could have given better name. For example, you could have written here one digit instead of writing first digit see if we want to do the complete example here of let us say 10 ten digit telephone system. So, 1st digit second digit await 2nd digit then we have another one await 3rd digit await 4th digit. You are saying that we can also do like this is it.

(( )) a more initiative one will be await 2nd digit, 3rd digit and so on and here we could have as you are right we could have written here await next 2nd digit that would have been more meaningful.

But possibly, I was in two minds whether I should write here one digit and then next digit or something. So, that is why this is has become next digit actually it should have been await 1st digit, await 2nd digit that is the correct one as rightly pointed out by you.

Sir Yes please.

Sir on what account we use (( )) that the first digit should be we are looking from the second digit phase. So, it was only when the event we have entered the 1st digit sir the event is and we are awaiting second, because the start of that.

Yes.

That is true.

Yes.

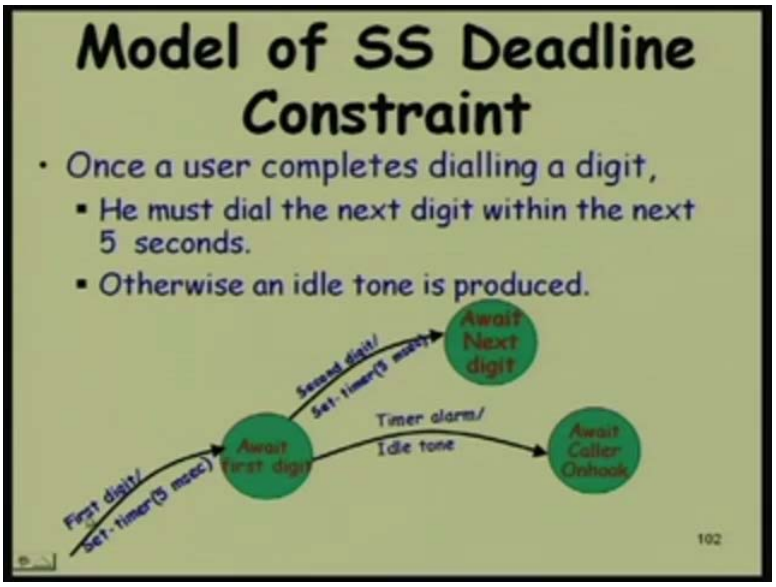
Because, the 1st digit has occurred and after that we are entering this state. So, in this state we will await the 2nd digit and once the 2nd digit occurs we should transit out.

Yes very correct.

Yes.

So, that terminology we need to or the terms we need to correct here is that here we should be await 2nd digit you are very right yes that is a mistake here.

(Refer Slide Time: 52:18)



Now, let us look at another example the deadline constraint defined on a stimulus event with respect to a response event.

So, here as we had seen this example once the dial tone appears the user must dial the 1st digit within 30 seconds, otherwise the system enters the idle state.

So, the dial tone appears and then it is the system is awaiting the 1st digit right and as the dial tone event occurs timer to 30 millisecond is 30 it should be 30 seconds.

So, as soon dial tone is set timer is set to 30 seconds and if the dial tone there is again a mistake here 1st digit right if there is a 1st digit occurring here there is a mistake here. So, I will just correct these mistakes and possibly.

First digit dial tone has appeared and it was awaiting the 1st digit and the 1st digit has occurred then it next digit.

And, if the 1st digit does not appear and the dial tone has appeared more than30 seconds earlier. Then the timer alarm set here will fire and a system will produce a beeping sound and until the caller replaces the handset on the telephone set.

So, we will look at these examples for each the modeling of each of the types of constraint examples we had discussed. And then we will just set a example problem for

you to see that whether you are able to do that from here, because as we were saying that modeling the timing constraints is important from various points of view there are many uses.

So, let us stop here we will meet in the next class.