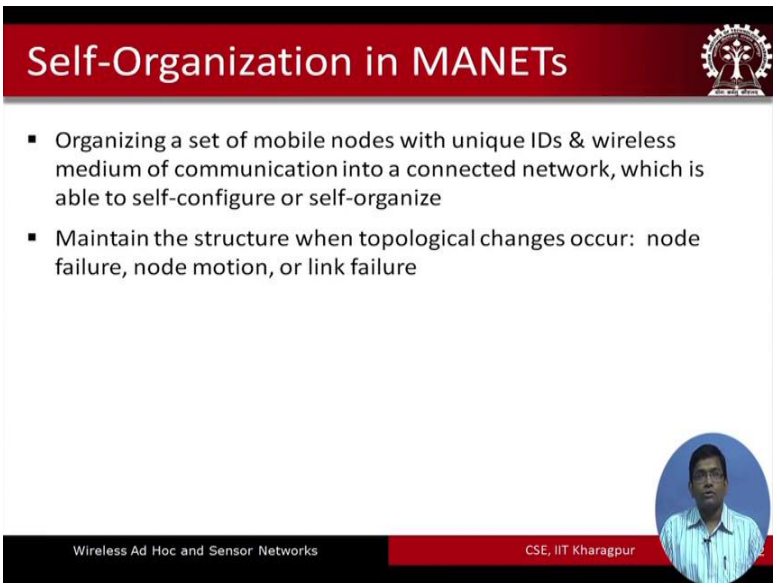
Wireless Ad Hoc and Sensor Networks
Prof. Sudip Misra
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 03
Self- organizing Behavior of Wireless Ad Hoc Networks

(Refer Slide Time: 00:26)



Our next topic is self-organizing behavior of wireless ad hoc networks. Self-organization concerns organizing a set of mobile nodes with unique identifiers, and wireless medium of communication into a connected network; which is able to do things like self-configure or self-organize. It concerns maintaining the structure when the topological changes occurred for instance with respect to node failure node motion or link failure.

(Refer Slide Time: 00:59)

Self-organization is very important in building scalable systems, particularly systems such as MANETs which are decentralized, and which is composed of typically large number of subsystems. The primary objectives of self-organization include coordination and collaboration to achieve shared goal, achieving collaboration without central entity, and improving or ensuring the reliability the scalability and availability of the system.

So, availability is all about probabilistically ensuring that as per the SLA the system will be made available to the users for a certain duration of time. Scalability concerns that how the system would scale up how the system is going to perform when the number of nodes in the MANET for in the case of MANETs when the number of nodes in the system is going to increase. And reliability is all about probabilistically ensuring that the system is overall going to behave reliably at all durations of time when it is supposed to operate. So, there are different design goals of self-organization in MANETs with respect to neighbor discovery topology configuration and topology maintenance. So, we are going to talk about each of these in more detail later on.

(Refer Slide Time: 02:38)

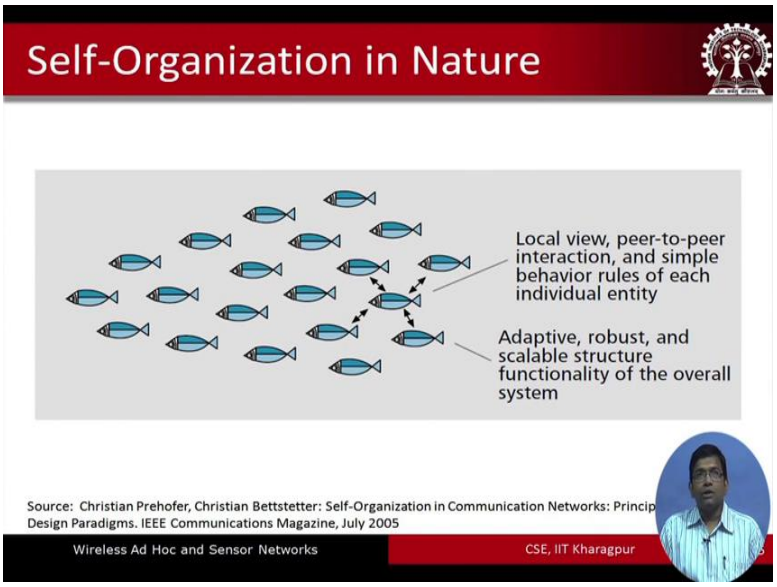
So, self-organization is a behavior that has that occurs in the nature and that has been inspired from different natural phenomena and has been adopted in network systems in in the specific case it has been adopted in mobile ad hoc network systems.

So, in self-organized behavior there are patterns which emerges at the global level using only local information generated by interaction between the low level components. So, for example, the over in the case of MANETs you know local interactions between the different nodes which are within a particular local area etcetera, and together you know they would that information would scale up to the overall network level overall system level and you know a pattern would emerge from that. Emergent behavior is another concept that comes very close when we talk about self-organization.

It basically is a behavior of a complex system that is generated by simple interaction between lower level entities in more than to ensure that it is more than the sum of their behaviors. So, the self-organization from a networking perspective includes the set of algorithms and protocols that govern global system behavior based on simple interactions between different nodes; for instance, simple message exchange between the neighbor nodes in a MANET that would lead to packet transmission from the source to the same node. So, as we have seen in the previous lectures that in MANETs we have the scenario of multi hop communication, and there are intermediate nodes that neighboring nodes which basically help in relaying the information between these 2 source and

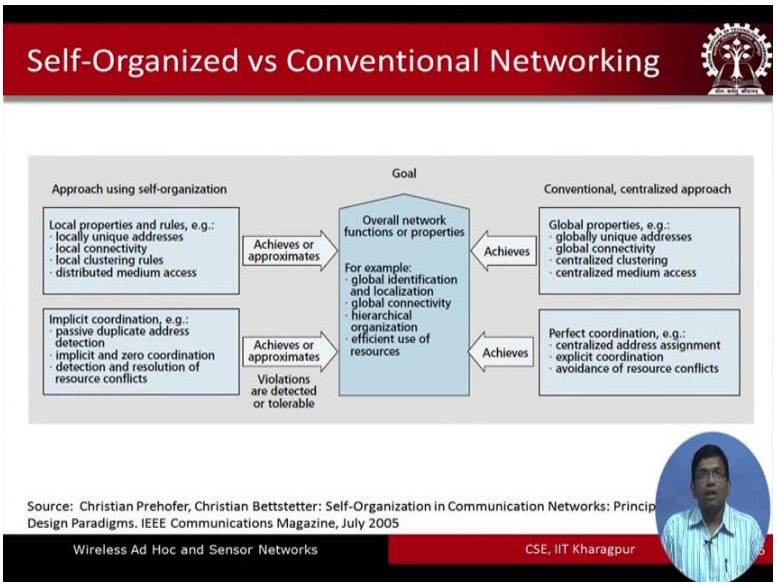
destination nodes. So, these things are powered by the self-organizing behavior and this is very important this is this example concerns message exchange, but similar kind of phenomena is observed in other aspects that other aspects that basically contribute to powering the MANETs.

(Refer Slide Time: 04:52)



It is look at the figure in front of us, to explain this phenomenon of local sorry of self-organization it is look at you know how the different nodes. So, in this particular figure as we can see that we have node which interacts with the neighboring nodes; so, these nodes they interact with the neighboring nodes. So, this particular node has local view about the behavior of the peers, and it can interact with the direct neighbors which are the peers and this behavior can be observed by this particular node, everybody does the same and together when we look at a systemic level. So, you know this particular behavior the global behavior of the overall system can be observed or it can be approximated from these local observations.

(Refer Slide Time: 06:07)

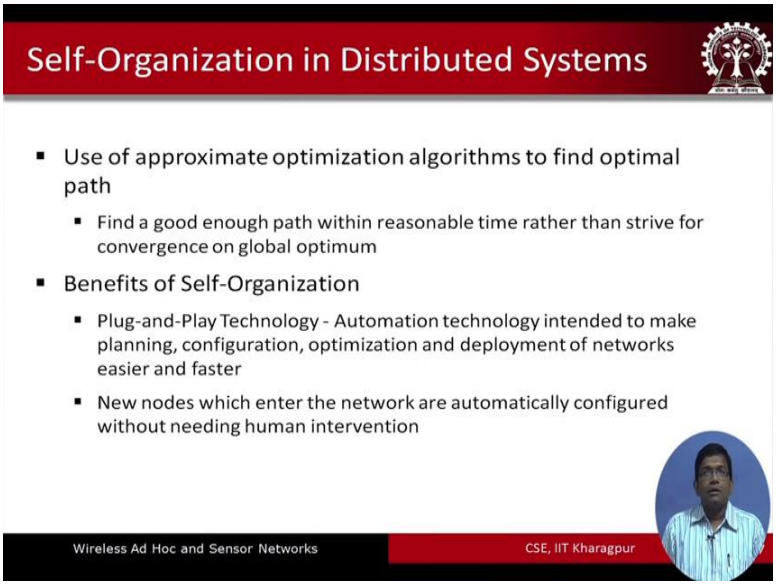


This is a very important aspect of you know enabling mobile ad hoc networks. So, in this particular figure we see a comparison a side by side comparison between self-organization and conventional networking; that means, self-organized networks and conventional networks. So, as we can see that in self-organized networks it uses local properties and rules for example, the local unique locally unique addresses local connectivity local clustering rules distributed medium axis so on and so forth. All of these local properties and rules which can achieve or which can approximate the overall network functions or properties for example, by doing all of these locally at this.

Global level at the system level one could be able to get a global identification a picture of the global you know the global context and localization; global connectivity hierarchical organization efficient use of resources and so on. So in a nutshell what we see is in self-organized networks these local properties and rules can help achieve the overall network functions and properties here you know in a very scalable manner. In contrast if we look at the conventional or the centralized approach. So, there actually we have global properties. For example, globally unique addresses global connectivity centralized clustering centralized medium access. So, everything is centralized and it is global you know the addressing scheme itself is global whereas, as we have seen in the case.

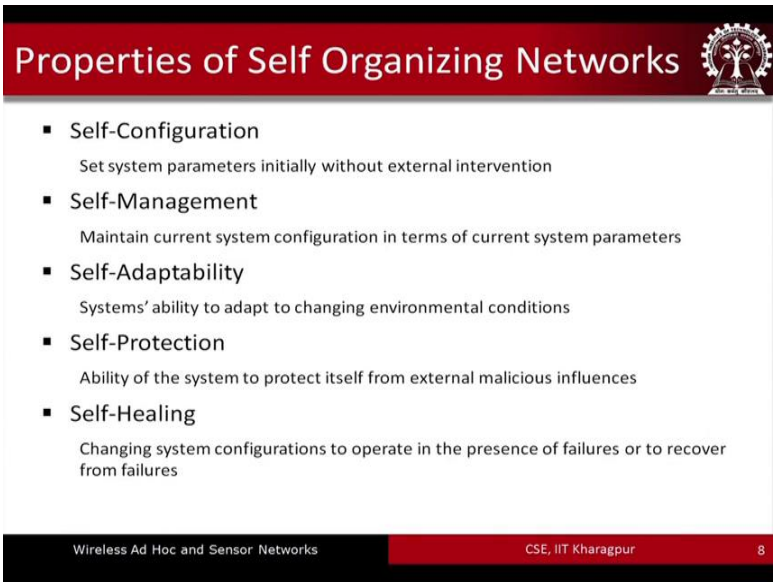
Of the self-organized systems, you know. So, the addresses addressing is local right. So this is the contrast between the networking in the conventional context and networking in the self-organized context and whereas, in the self-organized context we have implicit coordination between the different nodes. Here in the conventional context we have perfect coordination. So these are the main points of difference between the conventional or centralized approach of networking and the self-organized approach to self-organization approach to networking. So, the corresponding you know paper or the reference that one can read is given over here and in the bottom of the slide. So, one is encouraged to do.

(Refer Slide Time: 08:58)



So, in self-organized systems, these systems basically use different approximate optimization algorithms to find optimal or near optimal paths. And the benefit is of self-organization include plug and play right. So, basically you know one would be able to plug into the plug the system and the system will start operating you know on it is own it is a fully autonomous system. So, plug and play technology and where basically the new nodes which enter the network are automatically configured without needing any human intervention.

(Refer Slide Time: 09:43)

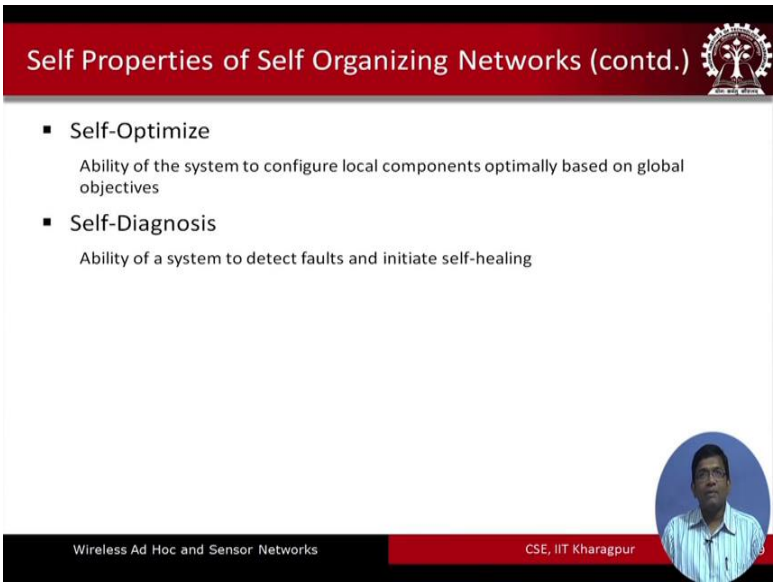


Self-organized networks have very distinct properties. Properties known as self-configuration which concerns which is basically which basically concerns setting the system parameters initially.

Without external intervention self-management is a second property which basically concerns maintaining the current system configuration in terms of the current system parameters. Self-adaptability which is basically system's ability to adapt to the changes in the environment around the system; that means, in this particular case of MANETs you know the nodes they are going to interact with the environment around them and the you know the system as a whole the nodes individually and the system as a whole would be able to adapt to the changes in the environmental conditions.

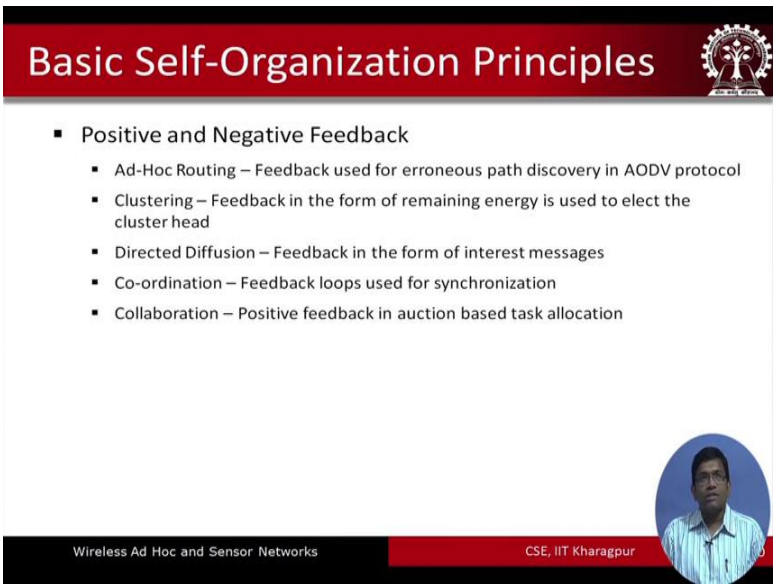
Self-protection is basically the ability of the system to protect itself from external malicious influences because in any network system and definitely in the case of MANETs. There are you know large number of different external malicious, you know attacks or you know malicious interventions that can come in, and the system should be designed the MANET should be designed in such a way that it should be able to protect itself from such kind of external malicious interventions. Self-healing behavior is about as the name suggests that whenever there is some kind of failure then the system should be able to operate in the presence of such failure and it should be able to recover from such failures.

(Refer Slide Time: 11:31)



2 other properties of self-organizing networks self-properties of self-organizing networks self-optimizing. So, it is basically the ability of the system to configure the local components optimally based on the global objectives. And self diagnosis which is basically the ability of the system to detect faults and initiate self healing.

(Refer Slide Time: 11:54)

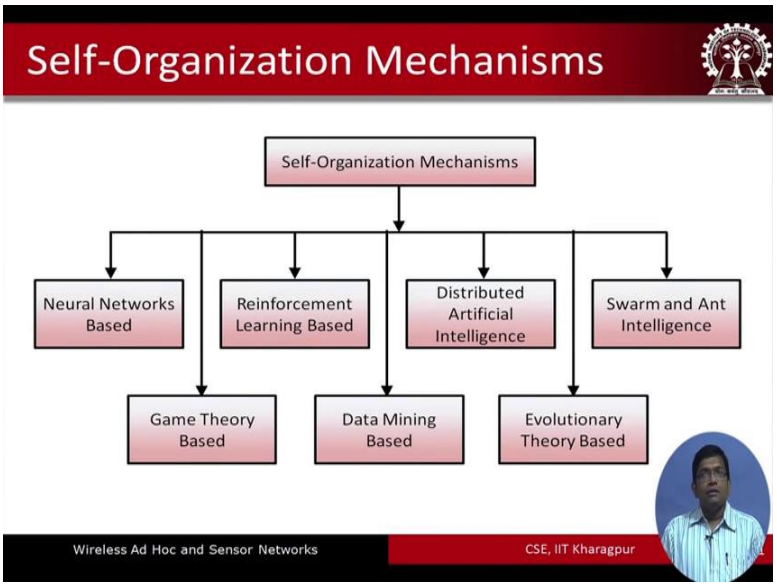


Self organized system, self organizing systems basically strive on the basis of different kinds of feedbacks that come in by interacting with the system. This feedbacks can positive feedbacks or these can be negative feedbacks. So, when we concern, when we

are concerned specifically of on routing. So, the feedback you know negative or positive is used for erroneous path discovery in the different protocols AODV as we have seen in a previous lecture is one of the very popular ad hoc routing protocol. Clustering is another where the feedback is in the form of the remaining energy that is used to elect the cluster head. So, how much energy is remaining in the different nodes and then switching between the different cluster heads this is what this kind of you know feedback is used.

For clustering in MANETs then directed diffusion is something that is used in routing in specifically in you know in the specific type of ad hoc networks known as the sensor ad hoc networks or ad hoc sensor networks, where the feedback is in the form of interest messages. So, basically the different nodes which one access to the data they are going to propagate interest messages for the data. So, we are going to look at the directed diffusion based routing when we talk about sensor networks ad hoc sensor networks in more detail in a future lecture. Coordination is another where basically feedback loops are used for synchronization between the different nodes, and collaboration is the last one where positive feedback is used for auction based task allocation.

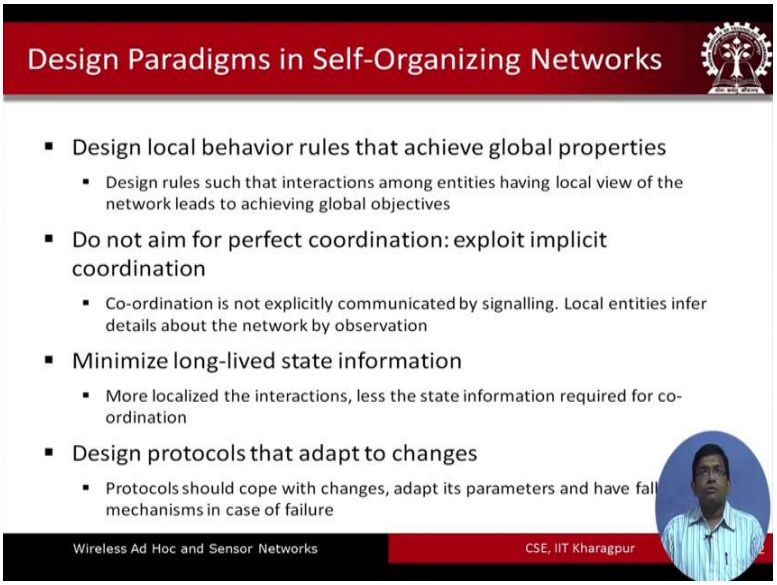
(Refer Slide Time: 13:52)



There are different mechanisms of self organization. And these can be classified into the different forms as you can see in the figure in front of you. One is the neural based neural networks based mechanism second is game theory based mechanism, third is

reinforcement learning based mechanism, next is the determining based mechanism, distributed artificial intelligence based mechanism evolutionary theory based mechanism and swarm and ant intelligence is another you know soft computing based approach or in mechanism that is typically used in powering or enabling these in the systems the self organizing systems.

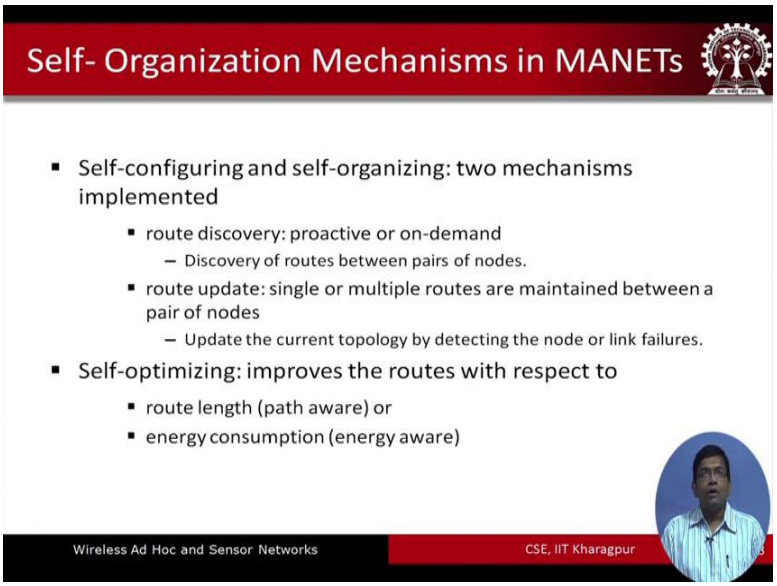
(Refer Slide Time: 14:46)



So, there are different design paradigms for self organizing systems, designing local behavior rules that achieve global properties and then you know. So, it is basically about designing rules such that the interactions among the entities have local view of the network that leads to achieving global object. This is the most important thing. So, locally you know individually locally the nodes in the MANET for instance MANET is a self organizing network is an example of that.

So, individually locally these nodes we are going to interact with one another and this local view is going to be projected at the global level for achieving the global objectives. So, this is a very important thing in in self organizing MANETs. Then there are other things like it is required not to aim for perfect coordination. And exploit the implicit coordination between the different node. So, coordination is not explicitly communicated by signaling all right. So, basically the local entities are going to infer the details about the network through different local observation and scale it up globally. So, like this there are different other you know design paradigms for use in self organizing networks.

(Refer Slide Time: 16:14)



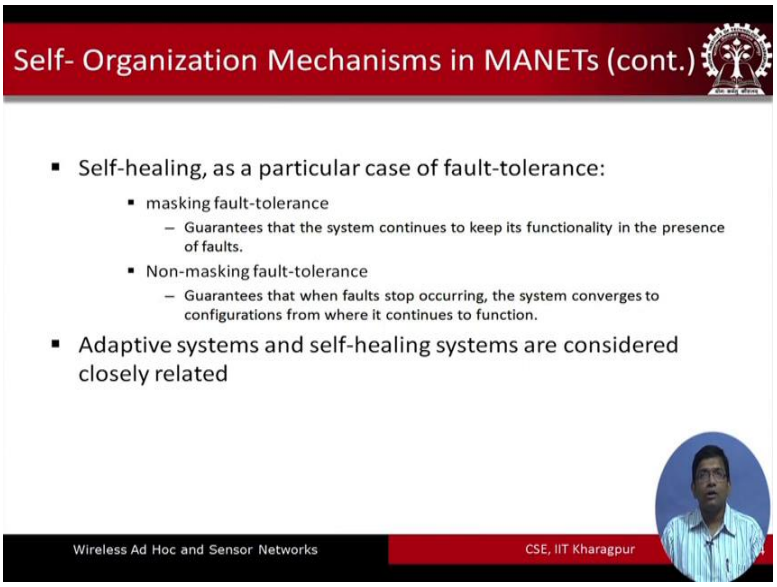
So, 2 very important mechanisms for self organizing behavior self organizing systems are known as self configuring and self organizing. So, self you know, So, these self mechanisms these 2 mechanisms they are basically you know based on typical you know approaches known as you know the first one is the route discovery approach. So, when it concerns routing. So, this is an example that that is used in the context of routing. And routing is a very important phenomena for any network system and particularly MANET systems. So, route discovery which can be done proactively on or on demand so.

Where basically the routes are discovered between a pair of different nodes, whenever there is a demand; that means, the you know the path between the source and the destination nodes are not already there it is not already cast and it is not available in the node or the nodes where the packet is currently resident, route update single or multiple routes are maintained between a pair of nodes and that you know and updating the current topology by detecting the node or link failures. So, route discovery and route update are 2 important routing mechanisms that are good examples for self configuring and self organizing behavior of MANETs. Self optimizing is the next which basically helps in improving the routes you know. Some routes between the different nodes are selected through the routing mechanisms.

Like route discovery or whatever and then self optimizing behavior characteristic what it ensures is that the routes are optimal during the future time instance. For example, with

respect to the route length you know. So, initially may be the route length or the number of hops between the 2 different nodes might be optimal, but later on also ensuring that the optimal you know path or the optimal route is used between the different nodes, that is what the self optimizing characteristic self optimizing behavior ensure. Similarly making in ensuring that it is energy called you know aware an energy efficient is also another very important thing.

(Refer Slide Time: 18:42)

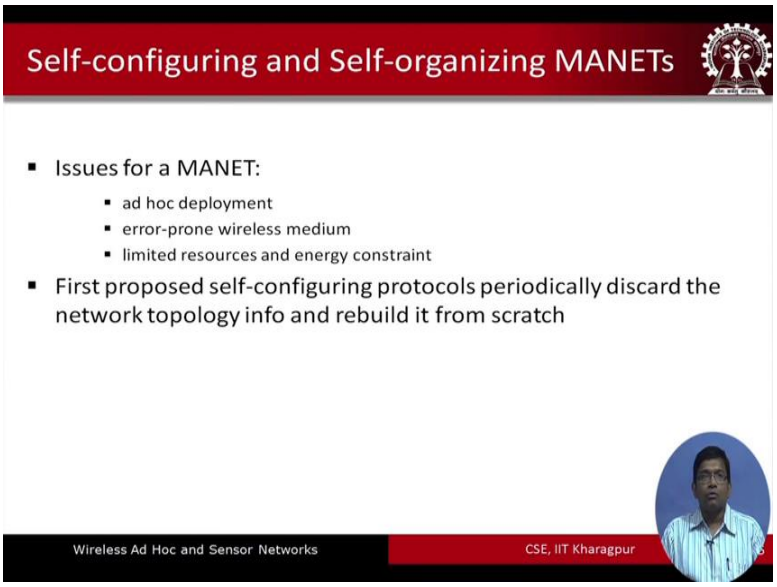


Self healing is a very important mechanism self healing characteristic is a very important one, for ensuring fault tolerance in MANETs. So, there are actually 2 types of fault tolerance, one is called the masking fault tolerance which basically guarantees that the system will continue to function the way it is supposed to in the presence of faults. And the other one is the non masking fault tolerance which basically guarantees that when false stop occurring the system converges to configurations from where it continues to function.

So these are the 2 different approaches to you know fault tolerance which are used in MANETs and these basically help in making these systems MANETs systems the self organizing MANETs systems self heal whenever there is a fault. So, adaptive systems and self healing systems are quite closely related. So, adaptive means what that whenever there is some kind of abnormality some kind of problem some unusualness that arises. So, the system will be able to adapt to it. So, that it functions the way it is

supposed to function right. So, this is what the adaptive systems does and definitely self healing systems are also supposed to do that it is supposed to, these systems are supposed to heal on their own, whenever there is a problem whenever there is a failure or there is some kind of a fault. So, the system is going to self heal.

(Refer Slide Time: 20:10)

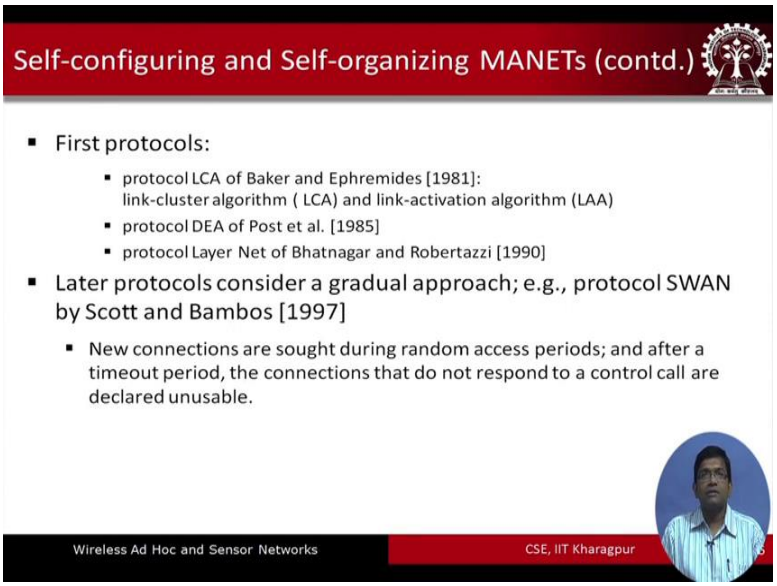


So, there are you know when we concerned about the self configuring and self organizing properties of MANETs there are different issues of MANETs that should be kept in mind. And these are the ones that we have already seen, but let us look at them once more. So, first one is that ad hoc deployment this is a very important concepts we do not have a centralized entity centralized coordinator like an access point or something like that, which can help in you know which can help the different nodes you know coordinate between talk to themselves and so on so that becomes a very important challenge a very you know challenging problem in MANETs. The other is that the medium itself is very much error tone where the nodes operate the medium is very much in an error prone and there are limited resources.

And the constraint on the energy is too high in these ad hoc networks the MANET ad hoc networks. So, the first proposed self configuring protocols basically periodically discard the network topology information and what they do is they rebuild everything from scratch; that means, they try to rebuild the topology understand the topology from scratch every time, every time the network topology changes. So, understanding the

topology from scratch building it from scratch you know every time the nodes move the topology changes and so on and so forth. So, this is what done the native you know the previous you know the conventional mechanisms this is how they achieve self organization or self configuration in MANETs.

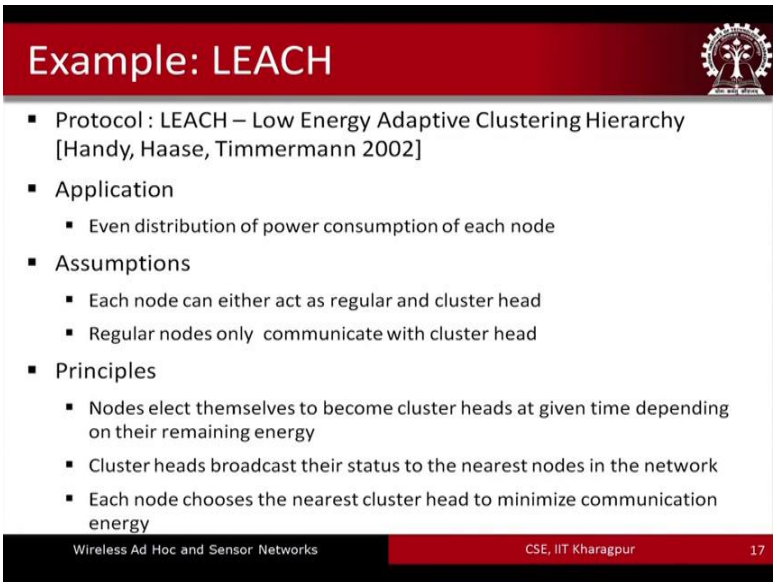
(Refer Slide Time: 21:52)



So, different protocols for example, you know the protocol LCA by baker and ephremides.

Ah and the link cluster algorithm you know say etcetera. These reference is already given over here. So, you know. So, you are encouraged to go through them. So, these are some of the protocols that basically achieved it through the mechanisms the naive mechanism that I just you know talked about. And later protocols the recent ones basically considered a more gradual approach where new connections are sought during random access periods and after a timeout period the connections that do not respond to a control call are declared unusable.

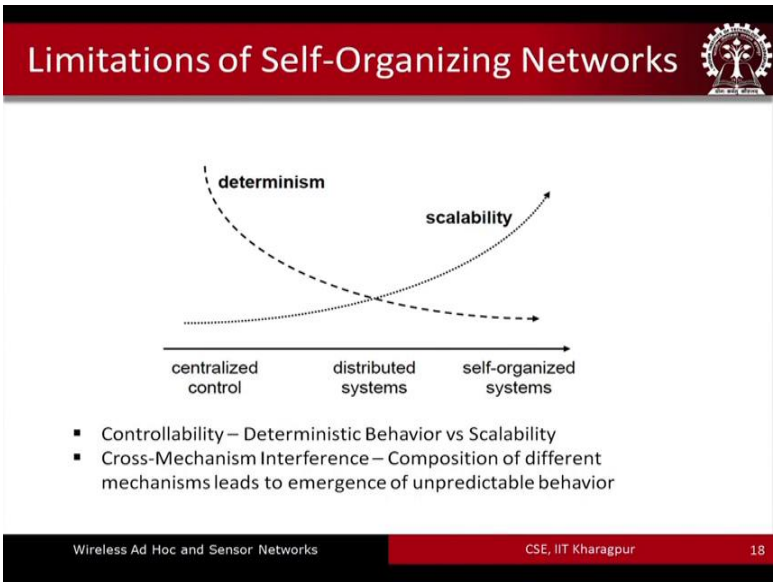
(Refer Slide Time: 22:31)



One of the very popular self organizing protocol that is used in MANETs is a routing protocol is a cloud cluster based routing protocol, which is known as leech. The protocol leach the full form of leech is basically low energy adaptive clustering hierarchy protocol and it was proposed by handy at l in 2002.

The application of leech protocol is typically found where, you know it is required to have even distribution of power consumption at the different nodes in the network. So, the leech protocol works under certain assumptions for example, assuming that each node can either act as regular or cluster head regular node or a cluster head node. The regular nodes only communicate with the cluster head this is one of the assumptions that leech makes that the regular nodes cannot communicate with one another directly, but they have to communicate higher the cluster heads. So, you know. So, they are within the one hub distance to the cluster head. The principles are like this that the nodes they elect themselves to become cluster hit is at a given time depending on their remaining energy. The cluster heads broadcast their status to the nearest nodes in the network and each node chooses the nearest cluster head to minimize communication energy.

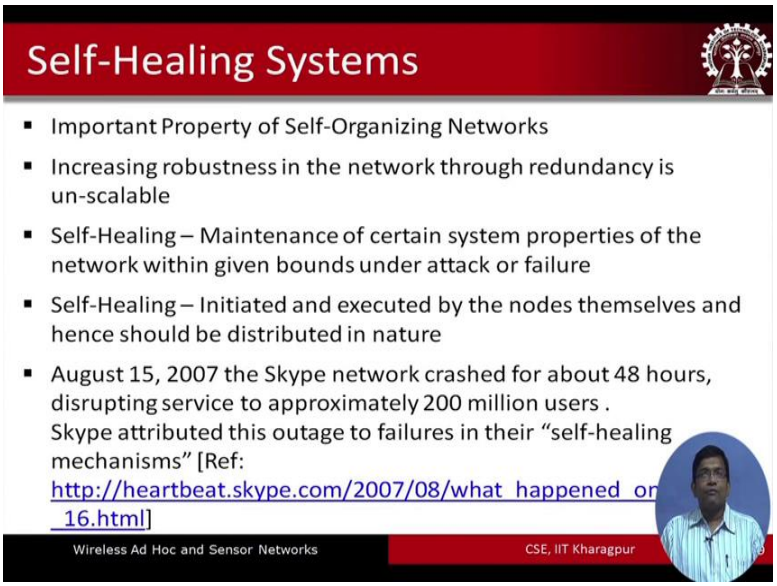
(Refer Slide Time: 23:51)



There are different limitations it is not like you know. So, far what we have seen are all the very glittering aspects of self organizing networks. And it is not that the self organizing networks all you know all gold and the glitter a lot it is not like that. There are all differently different limitations of self organizing networks. So, if you look at this particular figure in front of us what we see is that, it is a curve you know 2 curves, which basically shows the tradeoff between determinism and scalability.

With respect to systems which are highly centralized then the distributed systems and the self organizing systems and as we are as we are seeing that MANETs are self organizing systems right. So as we can see that when the systems become more and more self organized, you know the determinism basically the deterministic behavior it reduces. So, the deterministic behavior reduces from centralized systems through the distributed systems to the self organized systems whereas, the trend is completely opposite with respect to the scalability. So, with respect to scalability the central self organized systems are much more scalable compared to the distributed systems and the centralized ones.

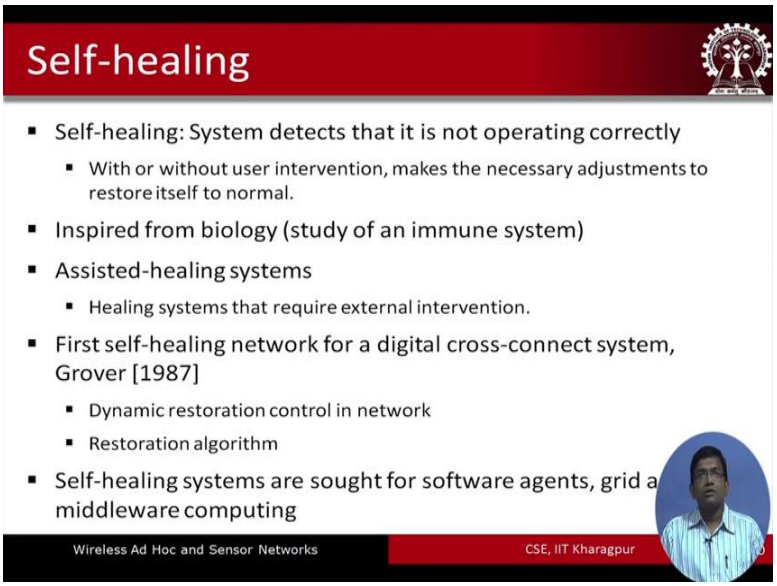
(Refer Slide Time: 25:21)



So, self healing is an important property as we have seen of any self organizing networks self healing property basically increases the robustness in the network through redundancy to redundancy. And so what it ensures is that if there is some kind of failure in the system or there is some kind of an attack the system would be able to maintain the properties of it under which you know it is supposed to operate right. So, whatever is the desirable system functionality the system would be able to operate.

Even in spite of the fact that it is under an attack or it is undergoing some kind of failure in some parts of the system or maybe in the extreme case the whole system. The different components large number of components in the system fails the system will still be able to run, this is what the self you know healing behavior tries to achieve.

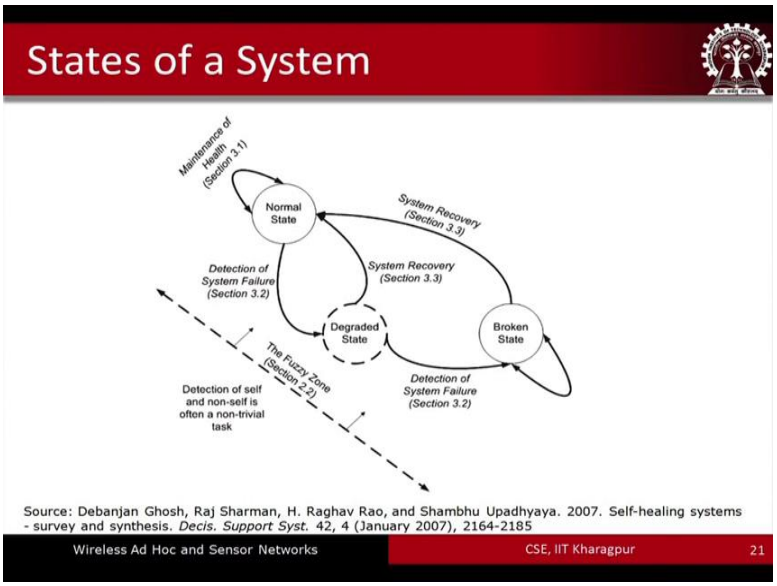
(Refer Slide Time: 26:24)



So, in self healing the system basically detects that it is not operating correctly. And with or without user intervention it makes the necessary adjustments to restore itself to normal. And most of the self healing mechanisms that you would find that are used in the self organizing systems; that means, MANETs and the like, we will see it is typically observed that most of these mechanisms are inspired from biology.

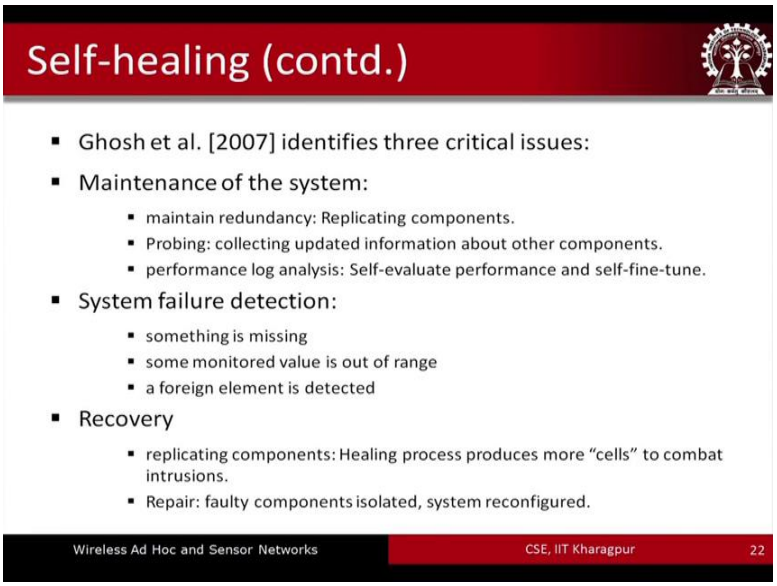
For example the human body human body or even you know other organisms also biological organisms typically have a strong immune system and for instance you know. So, if we just focus on the human system we have a very strong immune system. So, what happens is if we have a wound or cut in some part of the body typically the body is going to you know heal by itself. Or for example, if there is some kind of invasion by different microorganisms in our body the body fights and our immune system fights and the immune system would be able to heal on it is own would help our body to heal on it is own. So most of the you know self healing systems are inspired how the immune systems work in nature in biology.

(Refer Slide Time: 27:59)



A typical system any system would typically go through 3 different states as we can see in this figure. In the normal conditions the system would be in the normal state, when there is some kind of failure some systemic failure, then it goes to the degraded state and after recovery it can come back to the system you know we can recover from the degraded state and it can come back to the normal system state. Or if there is a detection of system failure then it goes to the broken state; that means, fail state. And from the broken state it can steal through the recovery processes the system can be brought to the normal state. So, this is typically what happens in any system and definitely for a self organizing system.

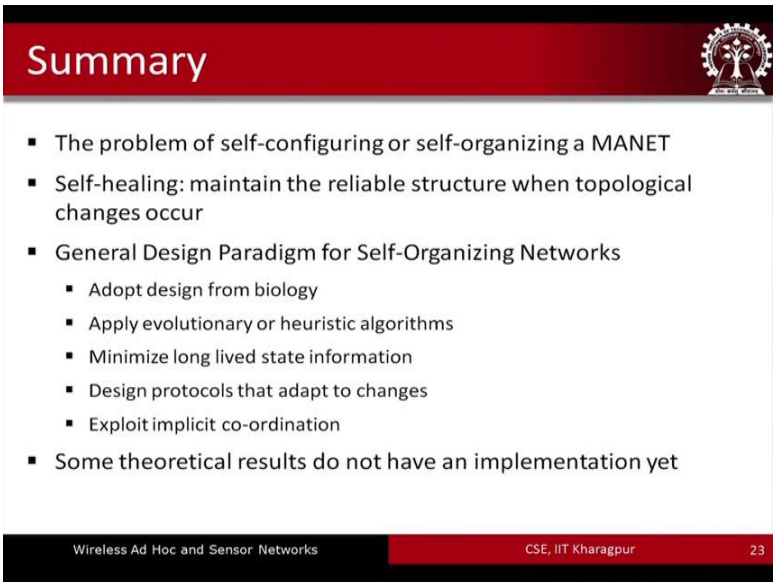
(Refer Slide Time: 29:04)



So, there are 3 different aspects or critical aspects of a self healing system maintenance of the system; that means, you know ensuring that there are some components which are replicated. Probing is another mechanism where you know data are collected about different components you know through different probes and the other one is using performance log and analyzing the performance logs. So, this basically helps in evaluating self evaluating the performance and self fine tuning the system.

So, whenever the system failure is detected, basically what happens is it is detected that something is missing or some monitored value has gone out of range or a foreign element has invaded and that invasion is detected. And the third is that recovery. So, recovery can be obtained through different mechanisms either the system can be repaired; that means, the faulty components can be isolated or the system can repair on it is own the fault that has occurred or through proactive mechanisms by ensuring that there are some components which are replicated. And whenever you know one goes down there is another component that is going to take over.

(Refer Slide Time: 30:37)



In summary the problem of self configuring and self organizing behavior in MANETs is what we have discussed today self-healing behavior is a very important behavior of these systems m a net systems and the self healing.

Behavior basically ensures maintaining the reliable structure when the topological changes occur when a link has gone down for instance when a node has gone down or maybe there is some other fault or a failure that has occurred in the system. So, there are different general design paradigms for these self-organizing networks. And these all basically adopted from inspirations from biological phenomena, or you know evolutionary mechanisms heuristic algorithms are used and so on and so forth. And so when we look at this literature we see that there are lots of theoretical approaches theoretical results that are available in in this particular context and, but you know when we look at the real implementation of them they are still not very implement you know they are not yet implemented in real life systems.

So, there is lot of opportunity of you know using them and implementing them in real life systems to make them truly self-organizing.

Thank you.