# Green Networks

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[microphone noise] Okay, so thank you so much [xxxx]. Hello I will then give a different part. We're talking about green networks or energy efficient networks. Most of you have me in IK2215, you know by now that I am sort a networking guy and that is my area of research and in that area it's it's a specific topic of its own to build energy efficient networks. So that's what I'm going to talk a little bit today. We're not going to dive deep into the technologies at all. This is more like an overview or orientation to get your your mind triggered as a preparation for the reflection seminar that you will have a little bit later on in this course. So if you take II2215, we will talk abit more about these things on a technical level. So this is about green networks or energy efficient networks.

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Why would anyone want to save energy or save power in networks in communication networks? Well they are actually quite many reasons for doing so. One of the more [important] that is we want to support units with limited power supply. Think of sensors, mobile phones, etc. - things that are normally operated on a battery or something else. We might even want to operate it on a solar panel. And that in order for that to work they need to be power efficient. You have probably heard about the Internet of Things connecting fifty billion devices to the internet in the near future. And many of these devices devices are going to be sensors with a very very limited the power supply. So that is one reason. Another one is actually to reduce greenhouse gas emissions according to the European commission's climate action. They required clearn technologies to be used is all industry sectors - including telecommunications. The third one is about deploying networks in challenging environments. Like in many places of the world, electricity is a sparse resource - for instance, building networks certain parts of Africa it's quite tough because there's no power grid. And if there is a power grid it is going to be very unstable. And still, there is a huge need for a communication infrastructure. So how do solve that. Well, we need power efficient gear to deploy there. And that is a totally different thing than building your communication network in Sweden or in Europe in general in the US. Things like that So, yet another thing that might happen even in parts of the world grid is will built out. So in Japan for instance, all of a sudden we have some sort of a natural disaster meaning that we get electrical power outages in conjunction with those disasters. And when we have such a situation communications are vital for things to work. So that means that when we don't have any power supply anymore because of this power outage, the communications infrastructure (what remains of it) is going operate on backup batteries and stuff like that. So in order for it to work as long as possible, we need it to be power efficient. and and and then a final one or a final point. Is for economic concerns, as we will see a bit later on telecom operators they can reduce their costs by consuming less power. So it is in their business interests to do so. That may also be a driving force for this. So their are many many reasons to save power in communication networks.

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We will talk about ICT and sustainability now. One source of information as you know by nowm, is the Global Sustainability Initiative. it is a source of information for ICT and sustainability. And in their reports the SMATer report from 2020 (from 2012). They do talk about smart solutions to reduce greenhouse gas emissions and you can also see in that about two percent of the global greenhouse gas emissions stems from ICT today. And it's expected to have like a four percent decrease per year. And then we think, "2%, that is not much". The aviation industry has about the same CO2 emissions as the telecom sector and nobody questions that we take measures regarding the aviation industry to reduce the green house gases. So there are actually good reasons for doing so.

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Another way to look at it. Another way compared to carbod dioxide emissions is to look at just the electricity consumption So what is the ICT sector consuming in terms of electrical power. This figure, this table up here, it is a few years old, but it is quite fresh. And as you can see there, about one third of it stems from data center. So you know these big data centers, they consume a lot of power. Another third, the redish part, is the computers we have at home. And then the green part of this tables (or the bars) related to the communication network itself. If you add them all up together, they stand for between 4 and 1/2 to 5% and it's increasing. We know the communication network they are expanding. If you want connected 50 billion devices in a couple of years you had better have an infrastructure that can support them. That's going to take about a year. These figures are going to grow.

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Okay, so what we doing then in the networking area to be of assistance. So remember again, if we step back here, there are several areas there are data centers, PCs, all these kinds of things. What I want to talk little about right now is what's happening in the networking areas. There is initiative comes from some ten years back or so about greening the internet - building an internet that is more green. And to make a long story short, it's mainly about creating and building and developing algorithms and mechanims for sleeping to maximize energy conservation in different types of equipment that we have out there. Now that can be a little bit tricky and it covers a broad range of different discipline fields to do these things. There are - there is work being done about the designing hardware for software enables sleeping. You know that your laptop is turned off or when you turn the lid down it is going to to go to sleep moode to save power. These types of techniques can be used also in communication equipment. so there are routers and switches and other thinsg like that actually have hardware that can going to sleep mode and consume a lot less power. So designing these things is one thing. So software interfaces to invoke this functionality is going to be needed as well because it's quite tricky to decide to when a certain piece of communication equipment is going to sleep or to put parts of its own [UNCLEAR WORD]. So that's one thing, another is to modify routing protocols - how we run traffic over the internet modify those to deal with load aggregation and sleeping. Deciding that instead of just spreading the traffic over the network you can actually concentrate traffic to cerntain parts and then the others go to sleep mode. If there's capacity in the network. That is not what routing is about traditionally on the contrary actually. Yet another one is to build the internet topology to support sleeping and likes like that - is

yet another subfield in this area. And if we can even think of changing communication protocols so that they adapted to these different types of sleep modes. So these are quite new things happening within the area of greening the internet.

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To give you some sort of feeling for what this is about. If you think of traditional networking objectives. What is that you want to achieve when you build a network. Well, in many many cases we use over provisioning, I mean that's really really good from a performance of view. Over provisioning of the network dimensions the network for peak hours. So that regardless of what happens during the peak hours the network can support the traffic. Then we have a really good performance, really good service, you can charge the customers, and they are all going to be happy. Okay, another thing is redundancy whatever happens out there, fibers that are being cut off for some reasons gear that goes down, gear that fails. We want to have redundancy. So that means that in many cases when we build these networks we have always on strategies to support mission critical applications. We use these things for business critical stuff these days or help critical stuff we need the network to be up and operating. In the way those things have traditionally been solved is by over provisioning and redundancy. And of course that is going to consume a lot of power - you have lots of gear that is up all the time - we lit up the fibers regardless of whether we are using them or not. And we just keep the network like that. So these objectives, traditional objectives with networking are quite opposed to the objectives with green networking and energy awareness. So it's a totally different way of running networks.

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Okay. To make it really simple here we see the basic idea of green network control or green route they decide how to route traffic through the network. The traffic way of doing this is to try to route traffic along the shortest path from A to B. That is what the routing protocols do traditionally. They don't take into account whether some parts of the network is very lightly load or maybe not loaded at all so we can shut it down. That is not what traditionally routing protocols do. So what we could do here is to adapt network capacity in terms of active nodes and links to actual traffic volumes which means we want to keep track of the traffic in the network - maybe we can find out that some links are very likely loaded, we should redirect traffic from those put them other links keep those other links up, and temprarily closed down the lightly loaded links, like in this network over here. There are a couple of links there with no traffic at all, there are no blue packets, they could maybe be temporarily brought down. Some of them every lite loads (a large distance between the packets in the figure up here) may be those links could be offloaded and may be we could turn them down as well if we can fit those single packets onto the other links that we need to maintain up and running for the moment anyway. So that is one thing you might want to think of. And then of course the recent challenges to guarantee the best trade off between performance and power consumption. Because if we only optimize for power consumption, then service is going to be pretty poor and no one is to be happy anyway. So we need to find a good trade off between these things and that's one of the main challenges here.

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Trafficking engineering is another popular subject. Traffic engineering in contrast to regular routing we often do take into account the traffic situation in the network; however, the tradition goal of traffic engineering has been to avoid hotspots in traffic engineering will figure that out and that is a relatively tricky thing, you need of the traffic situation, you need to keep track of the capabilities of the network you need someone magic formula to figure out the best tradeoff here now for some time to save power. That Is actually quite tricky. But there is research being done in the field. So then we have routing issues, then you have traffic engineering engineering,

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And then finally here: What's in the interest of the operators? How much power do they consume? But these are some (now they are starting to a couple of years old) energy figures from some of the large operators whose names you have seen before Telcom Italisa, British Telecom, France Telecom, Beutsche Telecom, Verizon. They consume a few or several Terawatt-hours per year in terms of electricity. And, of course, this is why it is costly for them, so if they can save 10, 15% of this that's a huge savings in costs. And at the same time they can appear as good and really green companies which may have a very good PR value. So so there are things happening in this area. There are several operators who have actually put a great deal of effort into these things.

An [MUMBLE] in a report from the European Commission, they estimate that as of 2010 21.4 TWh stems from operators of telco networks. And they expected this to grow up to 35.8 TeraWatthours in 2020. You no green technologies we be adopted. Som hopefully the operators will continue to apply green technologies the networks, then we can actually get these figures down. But as you can see there's a strong incentive for these companies to do things to reduce the power consumption. So that's it. Hopefully, it's sort of triggers some thinking in this area - without going too deep into the technology itself. That is sort of the topic for other courses. Any questions about these things? Okay. Okay [APPLAUSE] One of the big things that has been done is sleeping and the European Union has a set of policies for customer premise equipment which basically requires that things modems and so forth must have sleep mode, but a master's student several years ago worked for Ericsson looking at could you really make use of this to substantially reduce the power consumption. And the bad news is actually no operators ever enable sleeping in their modems and the reason is that if modems go to sleep, when they start back up to send traffic again - what's the first thing that they do? Anyone know? They send a big burst of noise down into the channel to measure the channel's properties to, of course, adapt to the property of the line. What does? Yes, it interferes with all of the other signals that are passing on adjacent cables in all the trunks. Which causes all of those modems to go and retrain, and so the net result is that suddenly huge amounts of power are being consumed - it's all these different modems who are frantically retraining and all the other users who had nice performance, yes, suddenly see their performance drop to zero. So the result is the first thing they do is disable that. So he spent his entire master's thesis trying to look "are there a set of parameters you can change to use not fully only turning on and off - but stepping down the amount of power consumption and adapting to that as the amount of traffic that the user actually wants to carry changes" The difficulty is in the course of his 20 week exjobb - he was still unable to find any set of parameters that actually produced better performance and could meet the energy objective. So it's a very very hard problem to actually do these things in practice, So keep in mind on

Wednesday you all should be able to present your topics. You should have your groups formed and you should be prepared to talk about the ethics and sustainability aspects of each of your projects. Do watch the videos they're out on the course web site. Enjoy!