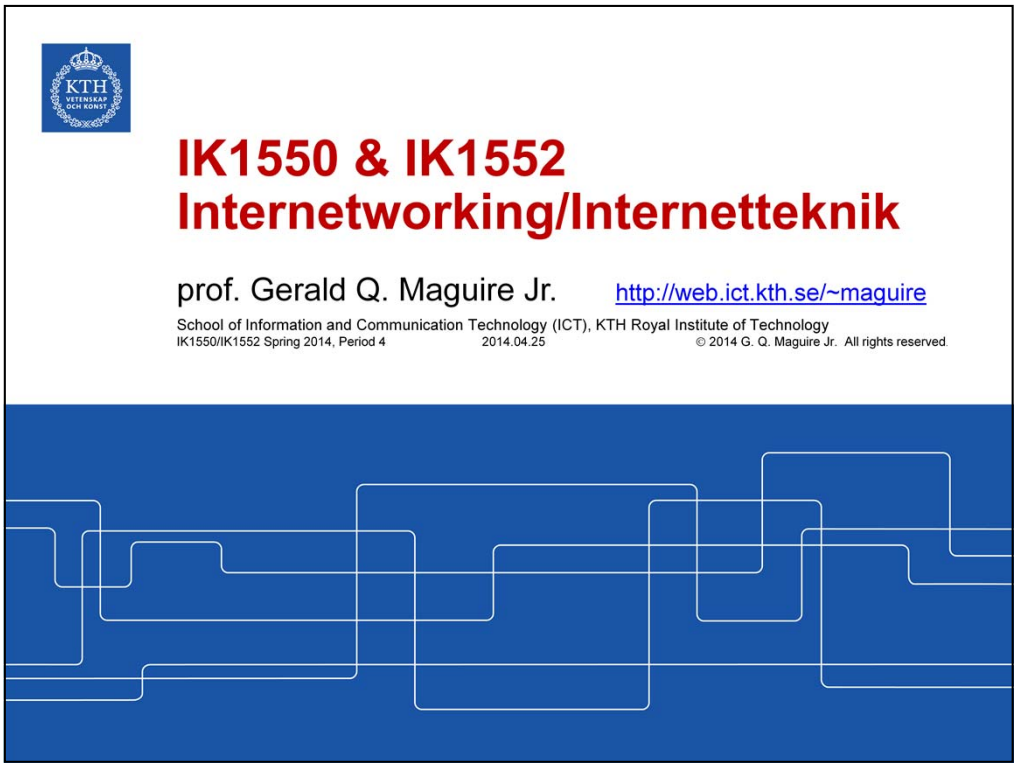
KTH
VETENSKAP
OCH KONST
IK1550 & IK1552
Internetworking/Internetteknik
prof. Gerald Q. Maguire Jr.
http://web.ict.kth.se/~maguire
School of Information and Communication Technology (ICT), KTH Royal Institute of Technology
IK1550/IK1552 Spring 2014, Period 4
2014.04.25
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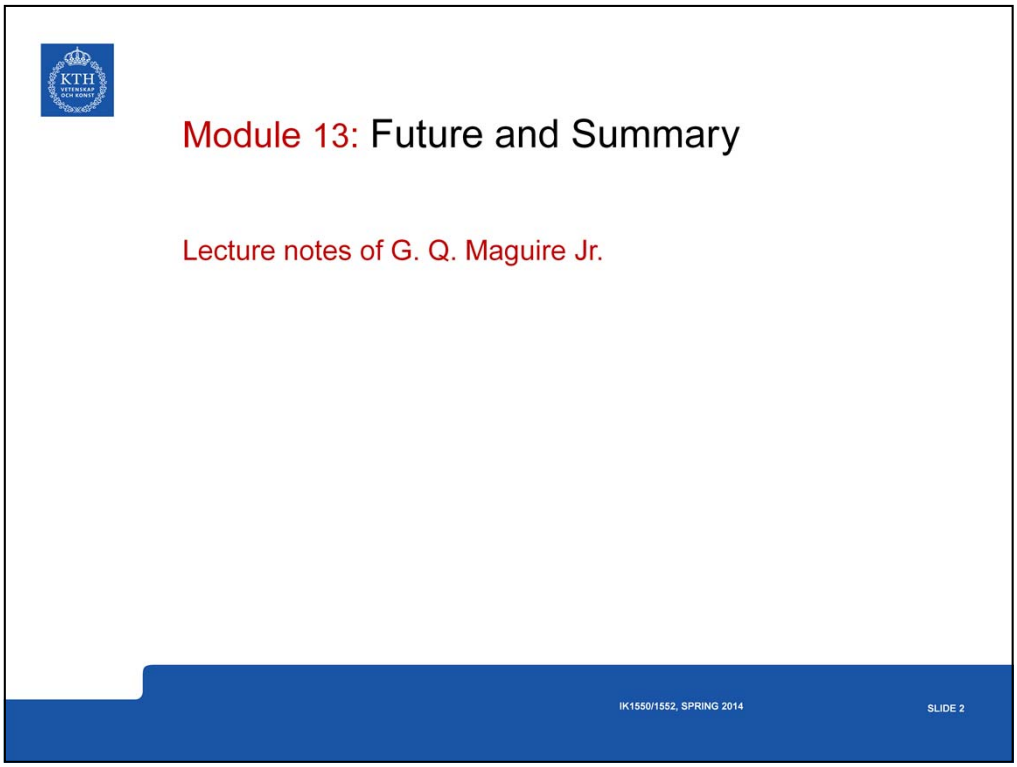
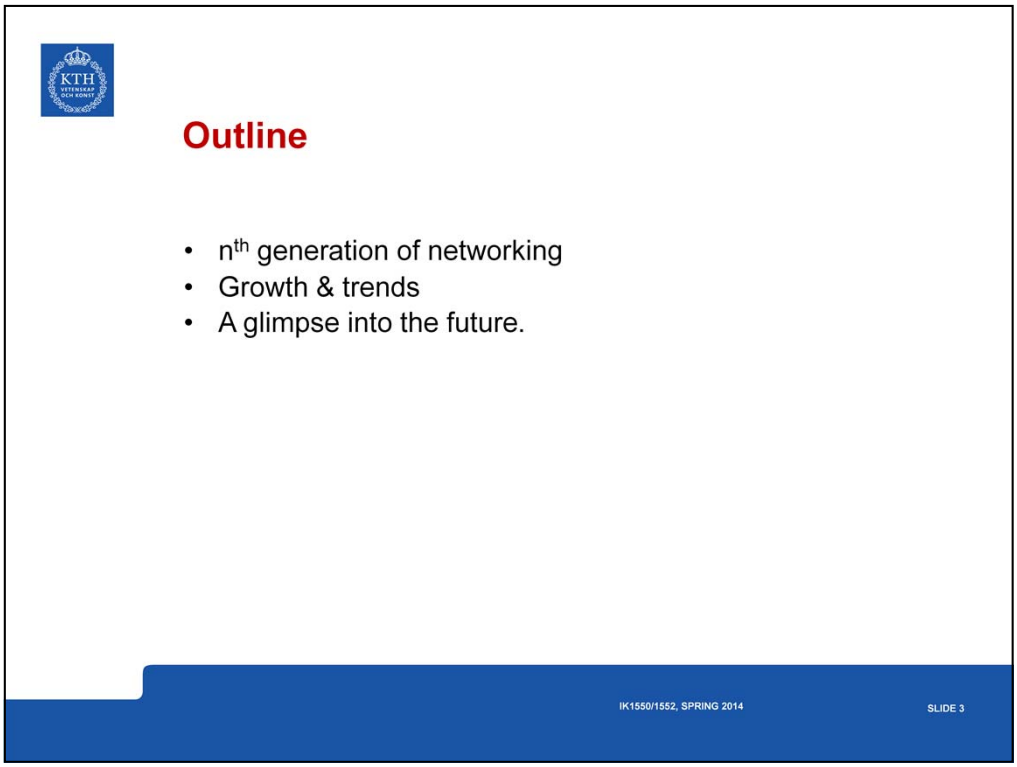
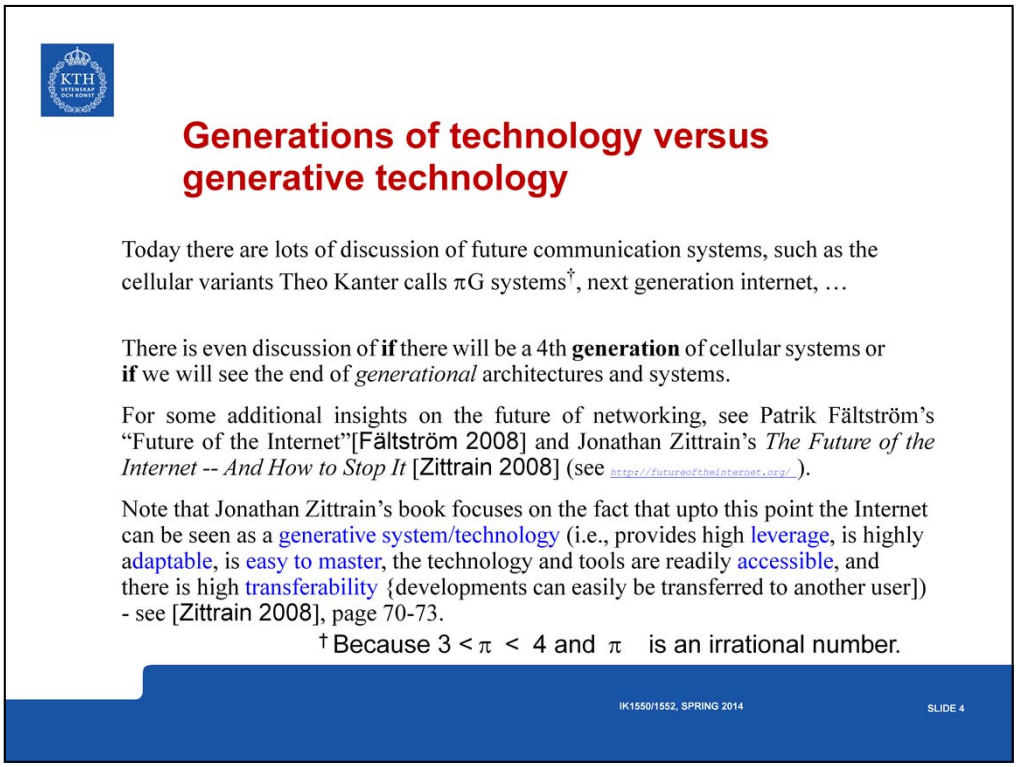
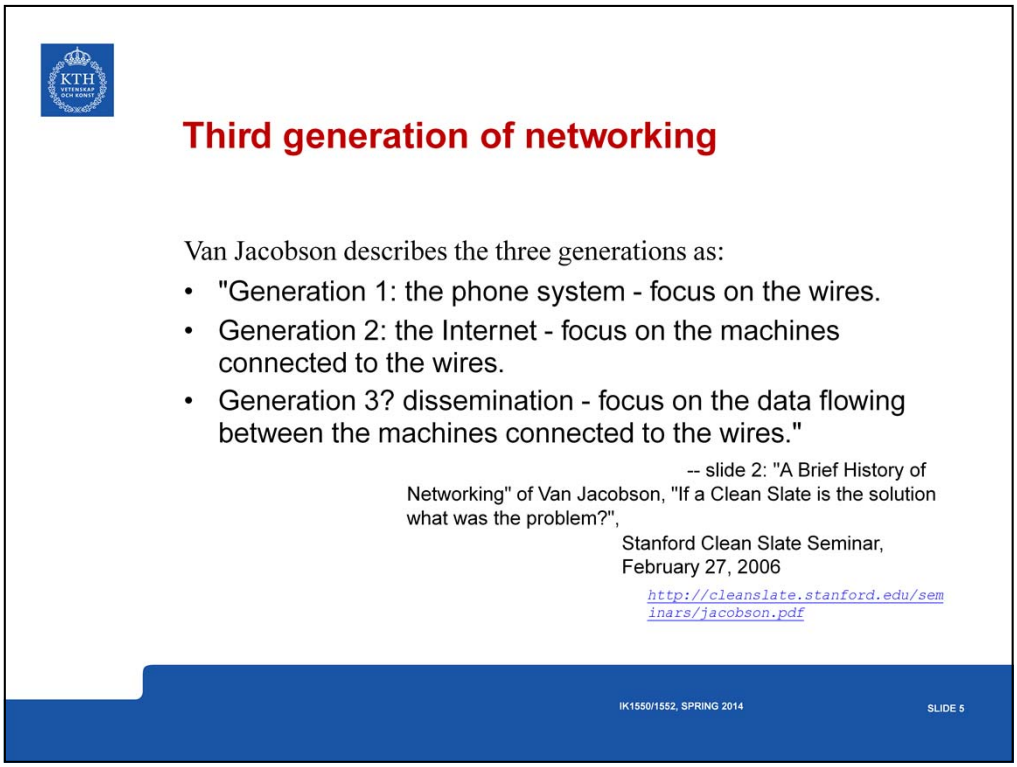

Module 13: Future and Summary
Lecture notes of G. Q. Maguire Jr.
IK1550/1552, SPRING 2014
SLIDE 2

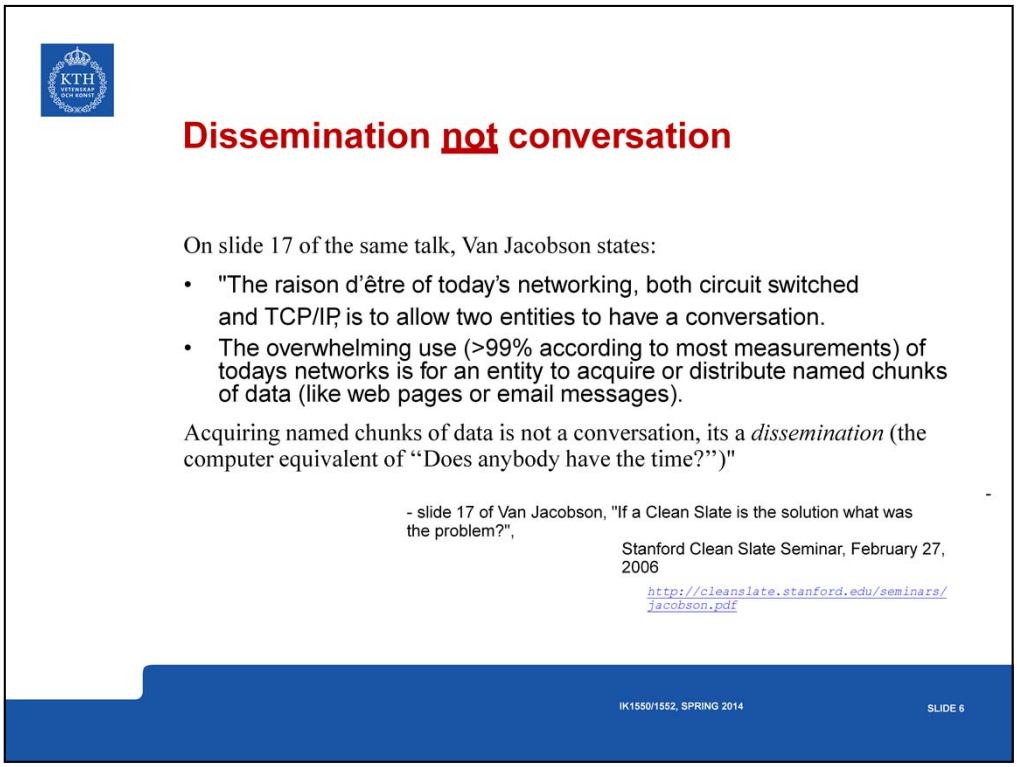

Outline
• nth generation of networking
• Growth & trends
• A glimpse into the future.
IK1550/1552, SPRING 2014
SLIDE 3

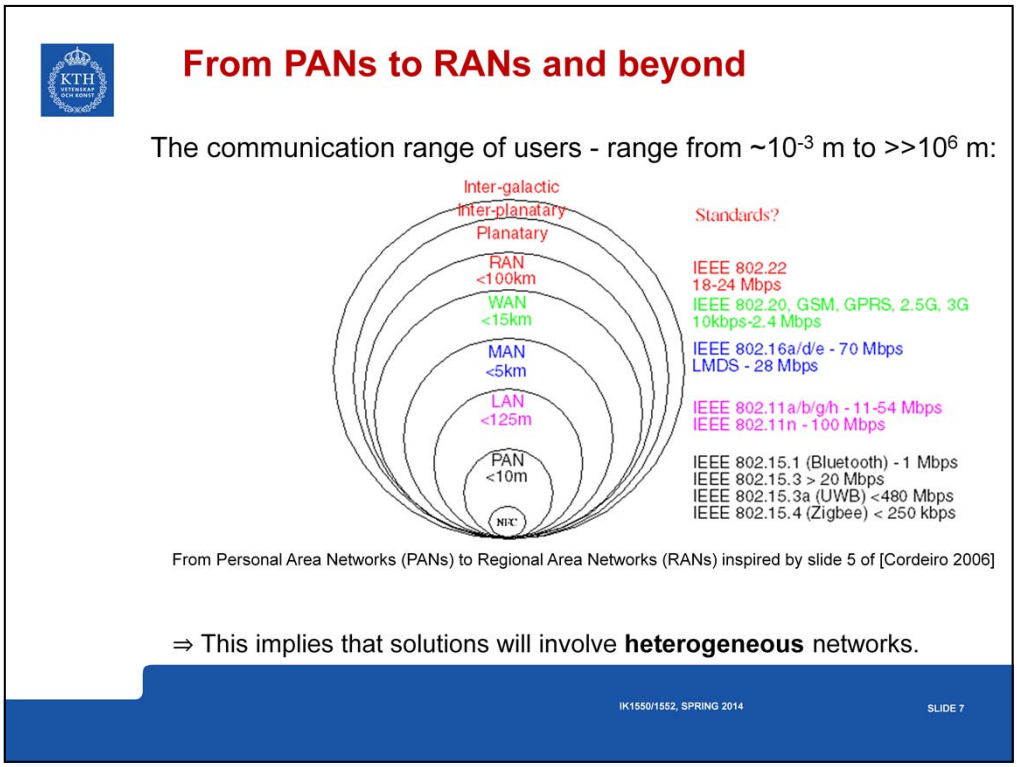


Patrik Fältström, "Future of the Internet", Lecture slides, 27 March 2008, *http://stupid.domain.name/stuff/future-internet.pdf*

Jonathan Zittrain, *The Future of the Internet -- And How to Stop it*, New Haven: Yale University Press, 342 pages, 2008. ISBN 978-0-300-12487-3, Web site of the book and blog: *http://futureoftheinternet.org/* ; the author's web site: *http://www.jz.org/*

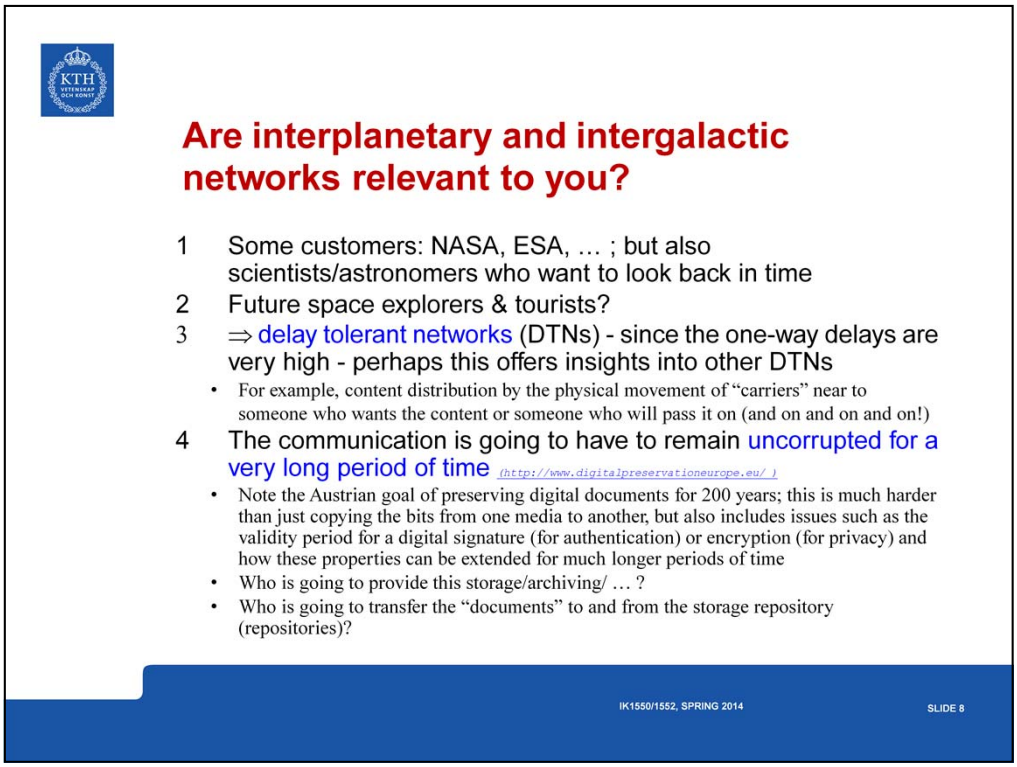

Third generation of networking
Van Jacobson describes the three generations as:
• "Generation 1: the phone system - focus on the wires.
• Generation 2: the Internet - focus on the machines connected to the wires.
• Generation 3? dissemination - focus on the data flowing between the machines connected to the wires."
-- slide 2: "A Brief History of Networking" of Van Jacobson, "If a Clean Slate is the solution what was the problem?",
Stanford Clean Slate Seminar, February 27, 2006
http://cleanslate.stanford.edu/seminars/jacobson.pdf
IK1550/1552, SPRING 2014
SLIDE 5


Dissemination not conversation
On slide 17 of the same talk, Van Jacobson states:
• "The raison d'être of today's networking, both circuit switched and TCP/IP, is to allow two entities to have a conversation.
• The overwhelming use (>99% according to most measurements) of todays networks is for an entity to acquire or distribute named chunks of data (like web pages or email messages).
Acquiring named chunks of data is not a conversation, its a *dissemination* (the computer equivalent of "Does anybody have the time?")"
- slide 17 of Van Jacobson, "If a Clean Slate is the solution what was the problem?",
Stanford Clean Slate Seminar, February 27, 2006
http://cleanslate.stanford.edu/seminars/jacobson.pdf
IK1550/1552, SPRING 2014
SLIDE 6



Carlos Cordeiro, Report on IEEE 802.22, IEEE J-SAC, and IEEE DySPAN 2007 tutorials, TCCN meeting at Globecom on November 27, 2006 http://www.eecs.ucf.edu/tccn/meetings/Report_06.ppt

See also Figure 1.3 on page 5 of Carlos de Morais Cordeiro and Dharma Prakash Agrawal, Ad Hoc and Sensor Networks : Theory and Applications, 2nd ed. Singapore: World Scientific Publishing Company, 2011.


Are interplanetary and intergalactic networks relevant to you?
1 Some customers: NASA, ESA, … ; but also scientists/astronomers who want to look back in time
2 Future space explorers & tourists?
3 ⇒ delay tolerant networks (DTNs) - since the one-way delays are very high - perhaps this offers insights into other DTNs
• For example, content distribution by the physical movement of "carriers" near to someone who wants the content or someone who will pass it on (and on and on and on!)
4 The communication is going to have to remain uncorrupted for a very long period of time (http://www.digitalpreservationeurope.eu/)
• Note the Austrian goal of preserving digital documents for 200 years; this is much harder than just copying the bits from one media to another, but also includes issues such as the validity period for a digital signature (for authentication) or encryption (for privacy) and how these properties can be extended for much longer periods of time
• Who is going to provide this storage/archiving/ … ?
• Who is going to transfer the "documents" to and from the storage repository (repositories)?
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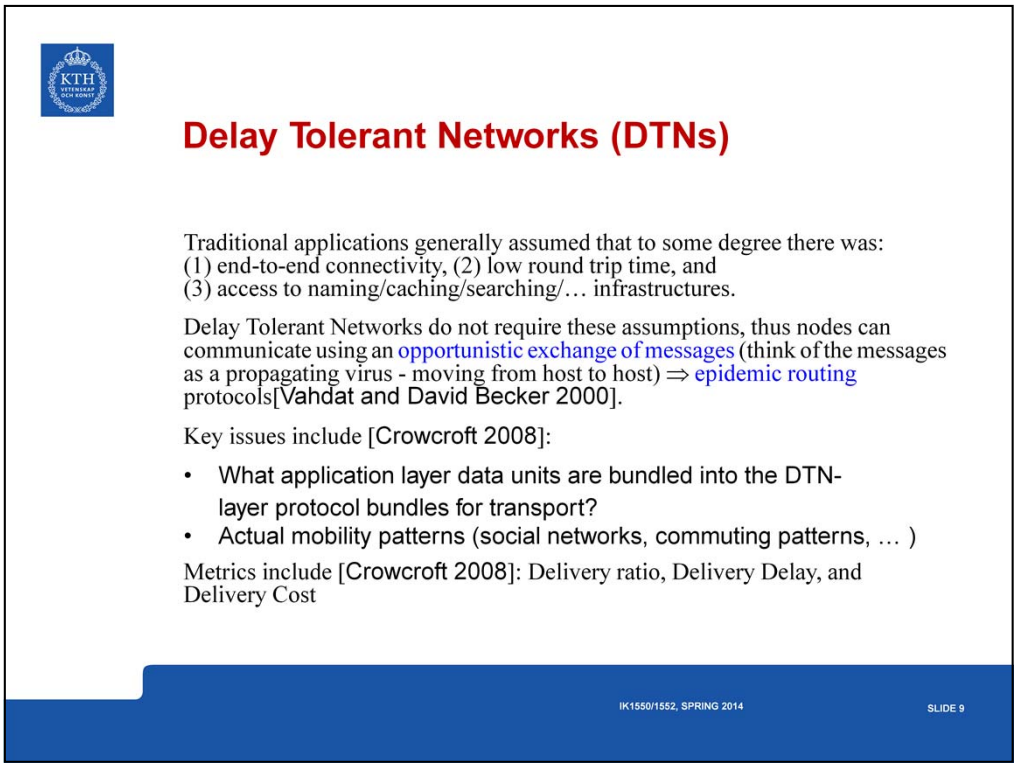
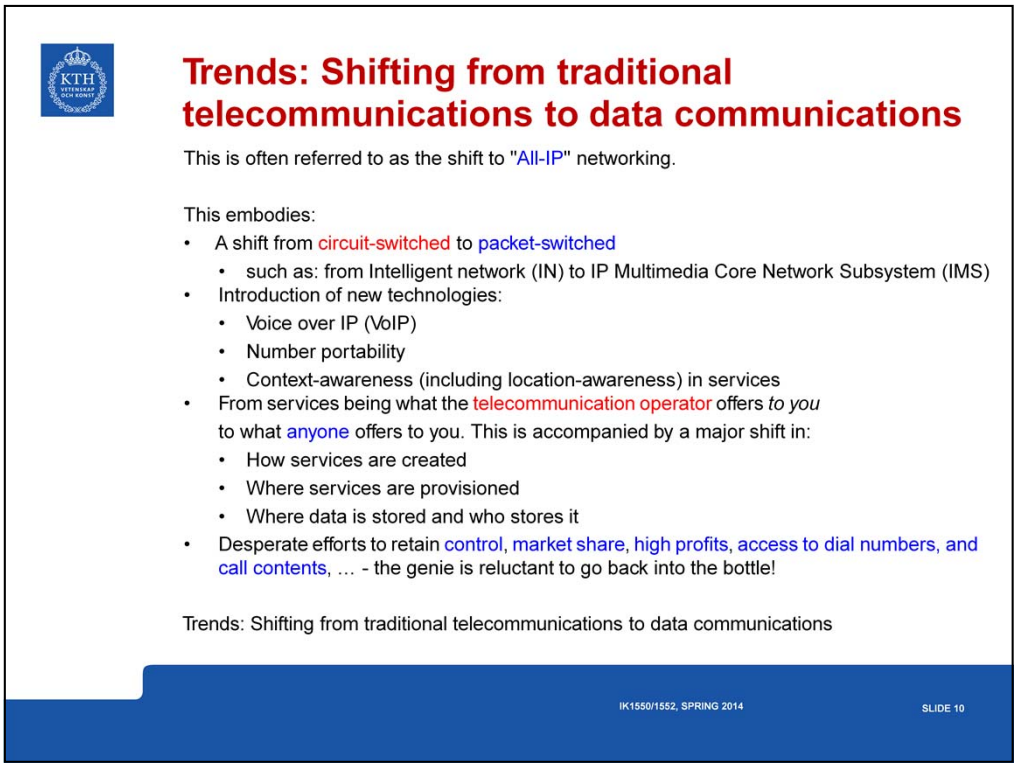
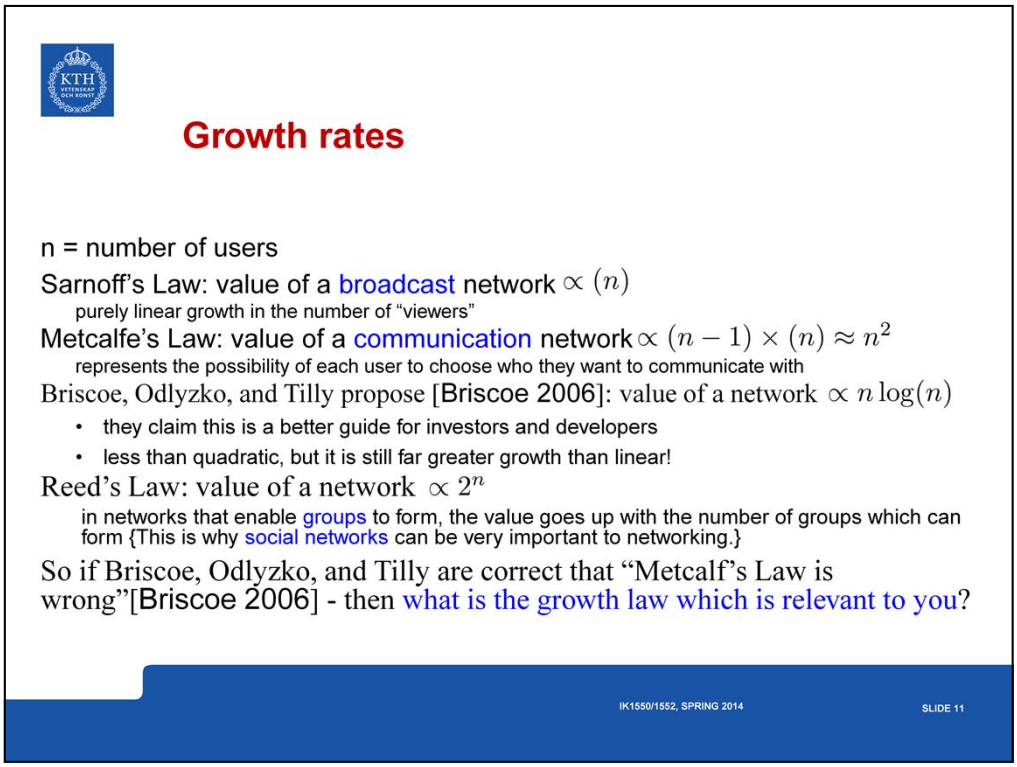
SLIDE 8



Amin Vahdat and David Becker, “Epidemic Routing for Partially-Connected Ad Hoc Networks”, Technical Report CS-2000-06, Duke University, July 2000. *http://issg.cs.duke.edu/epidemic/epidemic.pdf*

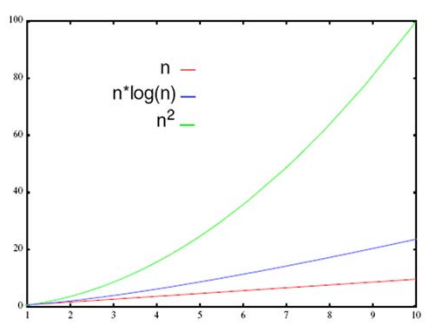
Jon Crowcroft, Eiko Yoneki, Pan Hui, and Tristan Henderson, Promoting Tolerance for Delay Tolerant Network Research, Editorial Note, Computer Communication Review, Volume 38, number 5, October 2008, pp. 63-68. *http://ccr.sigcomm.org/online/files/p63-crowcroft.pdf*

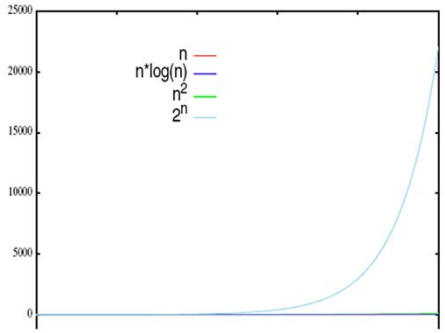

Trends: Shifting from traditional telecommunications to data communications
This is often referred to as the shift to "All-IP" networking.
This embodies:
A shift from circuit-switched to packet-switched
such as: from Intelligent network (IN) to IP Multimedia Core Network Subsystem (IMS)
Introduction of new technologies:
Voice over IP (VoIP)
Number portability
Context-awareness (including location-awareness) in services
From services being what the telecommunication operator offers to you
to what anyone offers to you. This is accompanied by a major shift in:
How services are created
Where services are provisioned
Where data is stored and who stores it
Desperate efforts to retain control, market share, high profits, access to dial numbers, and call contents, … - the genie is reluctant to go back into the bottle!
Trends: Shifting from traditional telecommunications to data communications
IK1550/1552, SPRING 2014
SLIDE 10



Bob Briscoe, Andrew Odlyzko, and Benjamin Tilly, Metcalfe's Law is Wrong, IEEE Spectrum, 43(7):34-39, July 2006, DOI: 10.1109/MSPEC.2006.1653003
http://www.spectrum.ieee.org/jul06/4109

Visualizing these laws





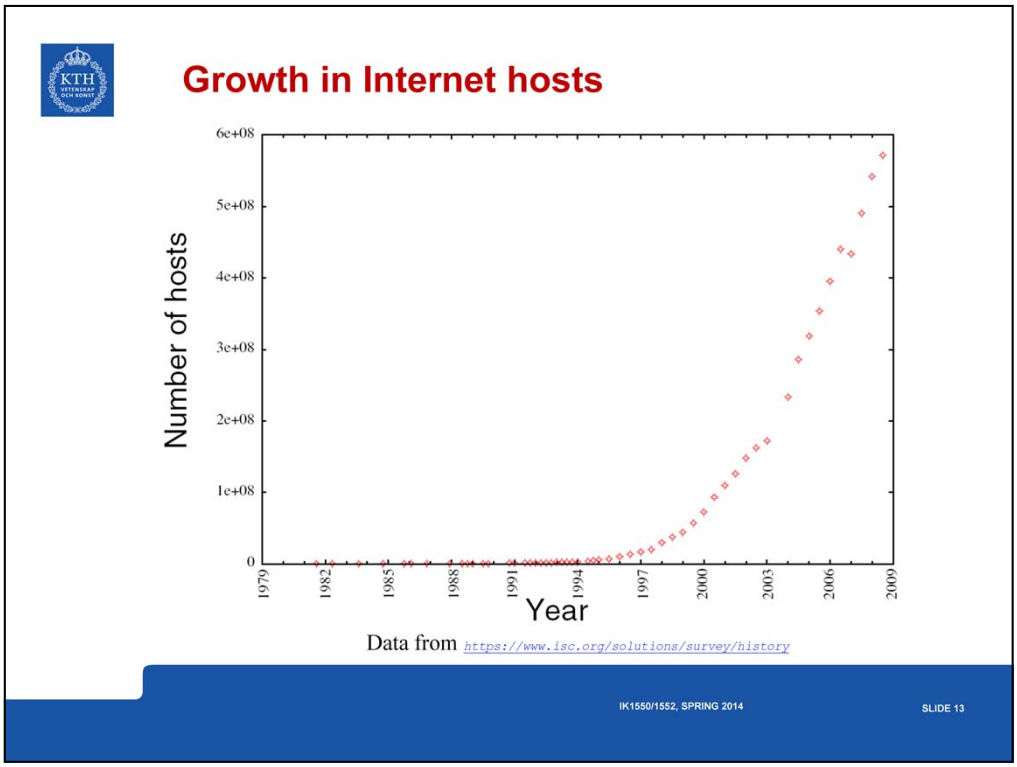
linear, n log n, n^2, and 2^n

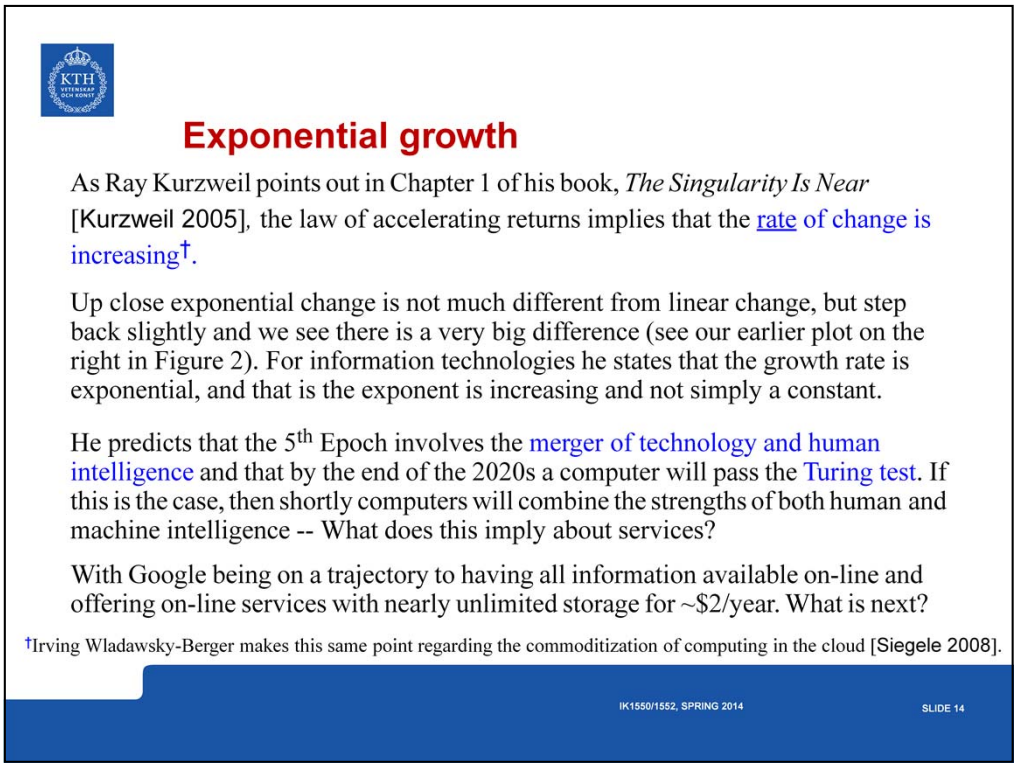
It is important to not simply think and act linearly (The Lewis model of Cultural types [Lewis 2000]: linear active vs. multi-active vs. reactive). Note that Lewis has extended this model to include context[Lewis 2005].

IK1550/1552, SPRING 2014 SLIDE 12

Richard D. Lewis, When Cultures Collide: Managing Successfully Across Cultures, Nicholas Brealey Publishing, 2000, 462 pages, ISBN 1857880870, 9781857880878

Richard D. Lewis, When Cultures Collide: Leading Across Cultures, Nicholas Brealey Publishing, 2005, ISBN 1904838022, 9781904838029

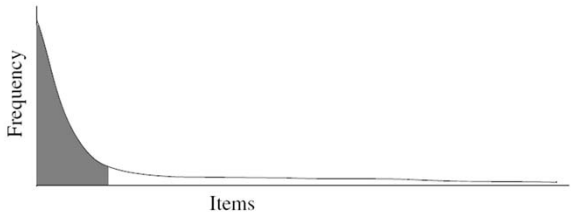

Growth in Internet hosts
Number of hosts
6e+08
5e+08
4e+08
3e+08
2e+08
1e+08
0
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year
Data from https://www.isc.org/solutions/survey/history
IK1550/1552, SPRING 2014
SLIDE 13



Ray Kurzweil, The Singularity Is Near: When Humans Transcend Biology, Viking, 2005

Ludwig Siegele, Let it Rise: A special report on corporate IT, The Economist, October 25th 2008
http://www.economist.com/specialreports/displayStory.cfm?story_id=12411882

Long tail



Long tail distribution

Book stores stock books that they expect to sell at least one of per year, but Amazon.com has near zero cost of "shelf space" - so they sell well into the tail!

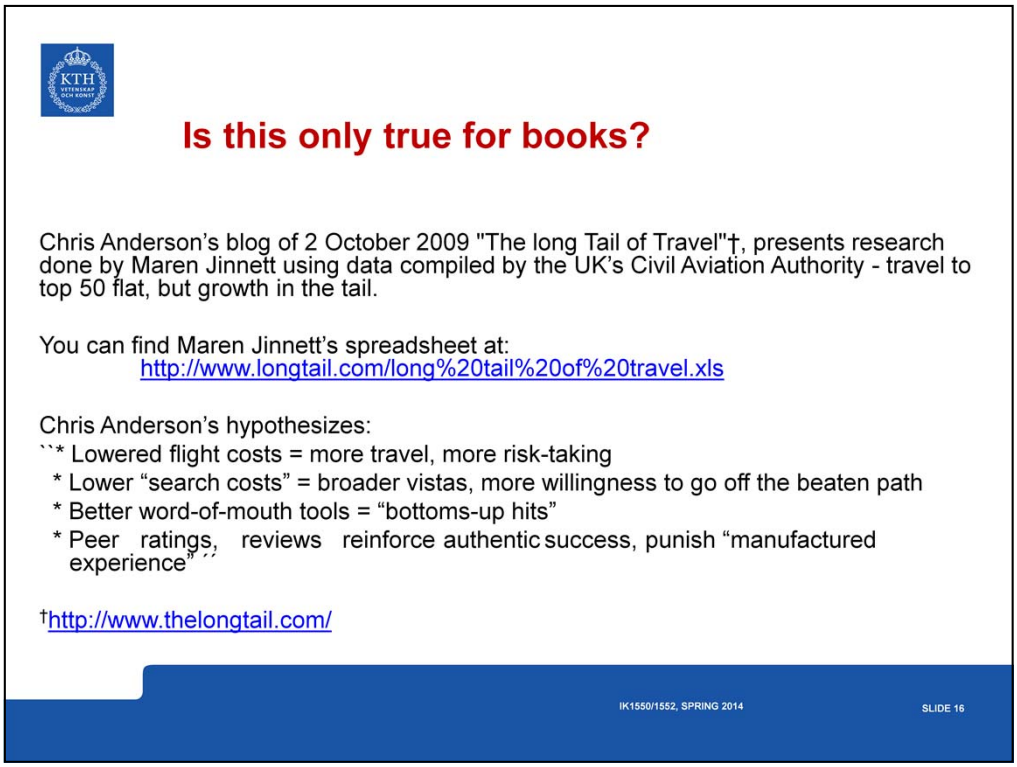
Chris Anderson's *The Long Tail: Why the Future of Business Is Selling Less of More* [Anderson 2008] and his earlier article in Wired Magazine discussed the power law relationship between the volume of sales ($r^{-\beta}$) and a product's rank (r); with a β of 1.214, the sales hits are ~20% of 100 offerings, but 80% of the sales; but as the number of unique items increases the market share shifts from the head of the distribution to the tail (i.e., there is more money in the sum of the sales from the tail than from the head)†,. see http://www.thelongtail.com/

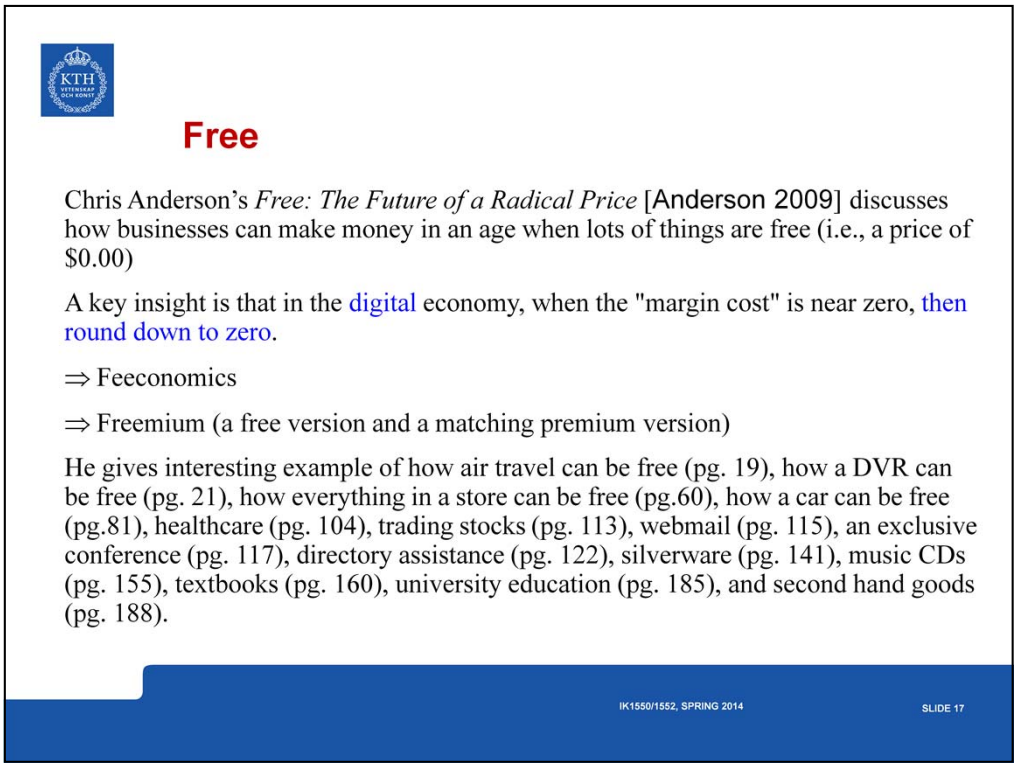
†See http://demonstrations.wolfram.com/TheLongTail/ for an interactive demo

IK1550/1552, SPRING 2014 SLIDE 15

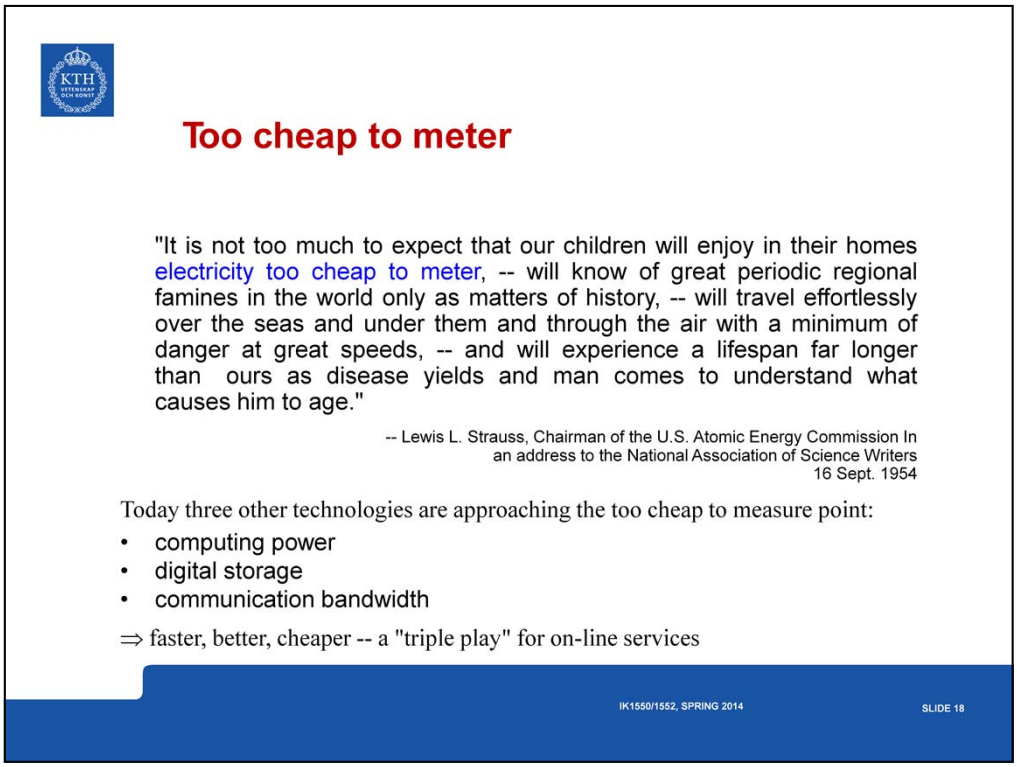
Chris Anderson, The Long Tail: Why the Future of Business Is Selling Less of More, Hyperion, New York, 2006. ISBN 1-4013-0237-8 or Revised and

Updated edition, July 8, 2008: ISBN-10: 1401309666, http://www.thelongtail.com/


Is this only true for books?
Chris Anderson's blog of 2 October 2009 "The long Tail of Travel"†, presents research done by Maren Jinnett using data compiled by the UK's Civil Aviation Authority - travel to top 50 flat, but growth in the tail.
You can find Maren Jinnett's spreadsheet at:
http://www.longtail.com/long%20tail%20of%20travel.xls
Chris Anderson's hypothesizes:
``* Lowered flight costs = more travel, more risk-taking
* Lower "search costs" = broader vistas, more willingness to go off the beaten path
* Better word-of-mouth tools = "bottoms-up hits"
* Peer ratings, reviews reinforce authentic success, punish "manufactured experience"''
†http://www.thelongtail.com/
IK1550/1552, SPRING 2014
SLIDE 16



Chris Anderson, Free: The Future of a Radical Price, Hyperion, July 7, 2009, 288 pages, ISBN-10: 1401322905, ISBN-13: 978-1401322908 or paper back ISBN 978-1-9052-1148-7


Too cheap to meter
"It is not too much to expect that our children will enjoy in their homes electricity too cheap to meter, -- will know of great periodic regional famines in the world only as matters of history, -- will travel effortlessly over the seas and under them and through the air with a minimum of danger at great speeds, -- and will experience a lifespan far longer than ours as disease yields and man comes to understand what causes him to age."
-- Lewis L. Strauss, Chairman of the U.S. Atomic Energy Commission In an address to the National Association of Science Writers 16 Sept. 1954
Today three other technologies are approaching the too cheap to measure point:
• computing power
• digital storage
• communication bandwidth
⇒ faster, better, cheaper -- a "triple play" for on-line services
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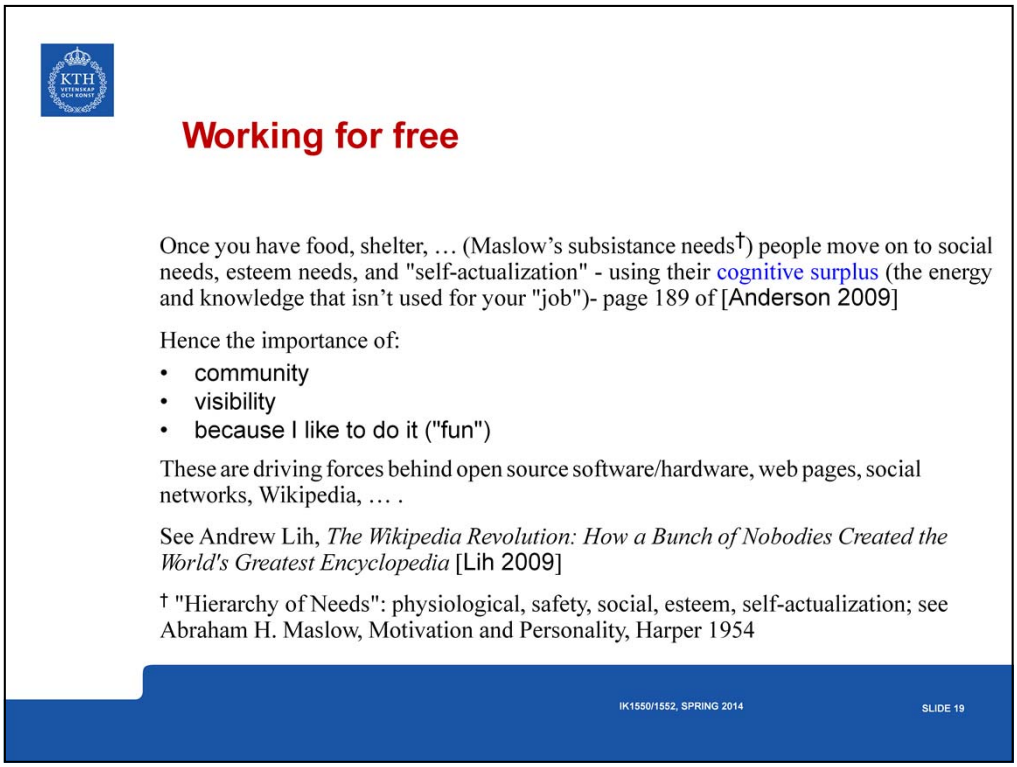
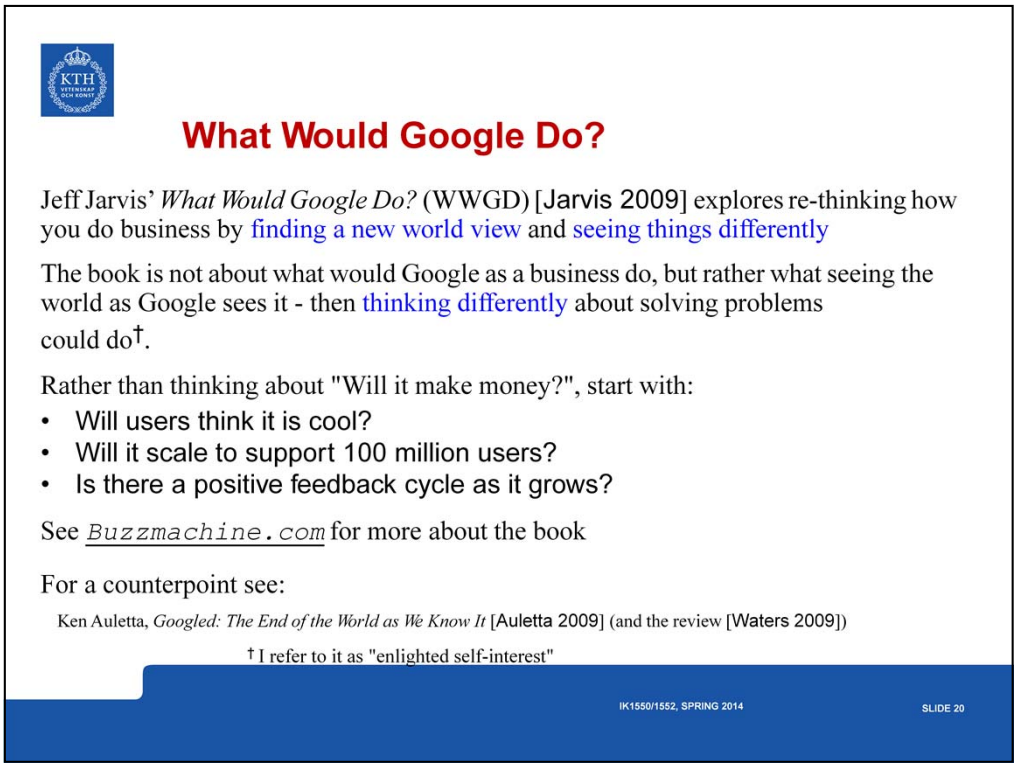


Chris Anderson, Free: The Future of a Radical Price, Hyperion, July 7, 2009, 288 pages, ISBN-10: 1401322905, ISBN-13: 978-1401322908 or paper back ISBN 978-1-9052-1148-7

Andrew Lih, The Wikipedia Revolution: How a Bunch of Nobodies Created the World's Greatest Encyclopedia, Hyperion 2009, 272 pages, ISBN-10: 1401303714 and ISBN-13: 978-1401303716 *http://wikipediarevolution.com/The_Book.html*



What Would Google Do?

Jeff Jarvis' *What Would Google Do?* (WWGD) [Jarvis 2009] explores re-thinking how you do business by finding a new world view and seeing things differently

The book is not about what would Google as a business do, but rather what seeing the world as Google sees it - then thinking differently about solving problems could do†.

Rather than thinking about "Will it make money?", start with:

- Will users think it is cool?
- Will it scale to support 100 million users?
- Is there a positive feedback cycle as it grows?

See Buzzmachine.com for more about the book

For a counterpoint see:

Ken Auletta, *Googled: The End of the World as We Know It* [Auletta 2009] (and the review [Waters 2009])

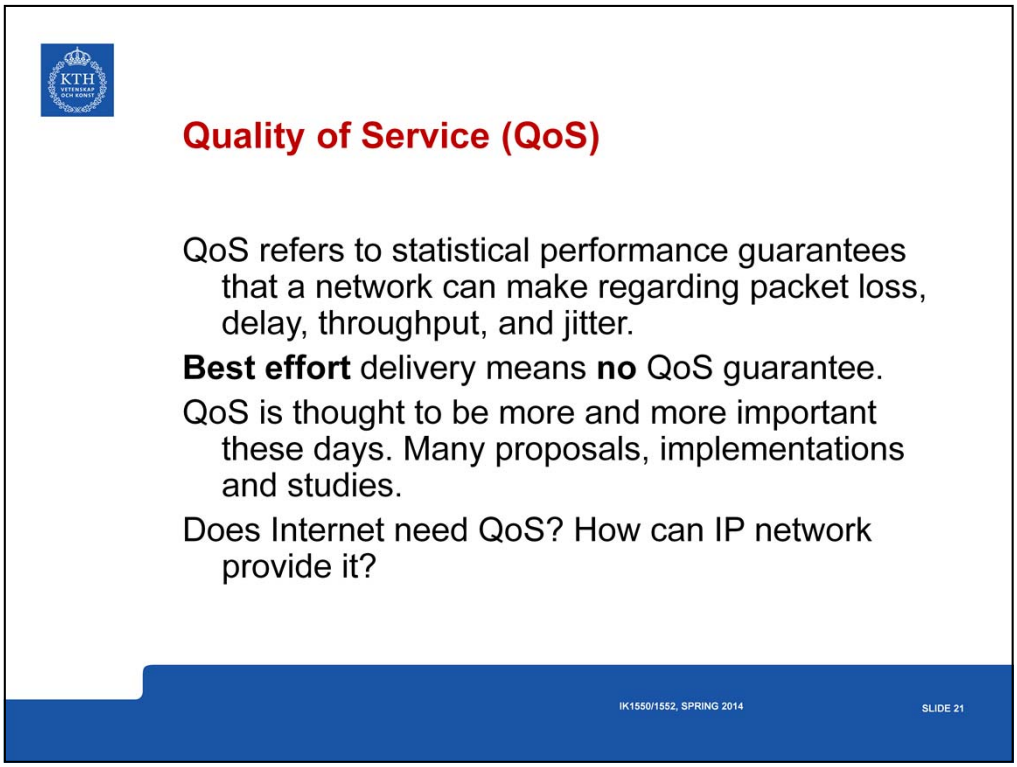
† I refer to it as "enlighted self-interest"

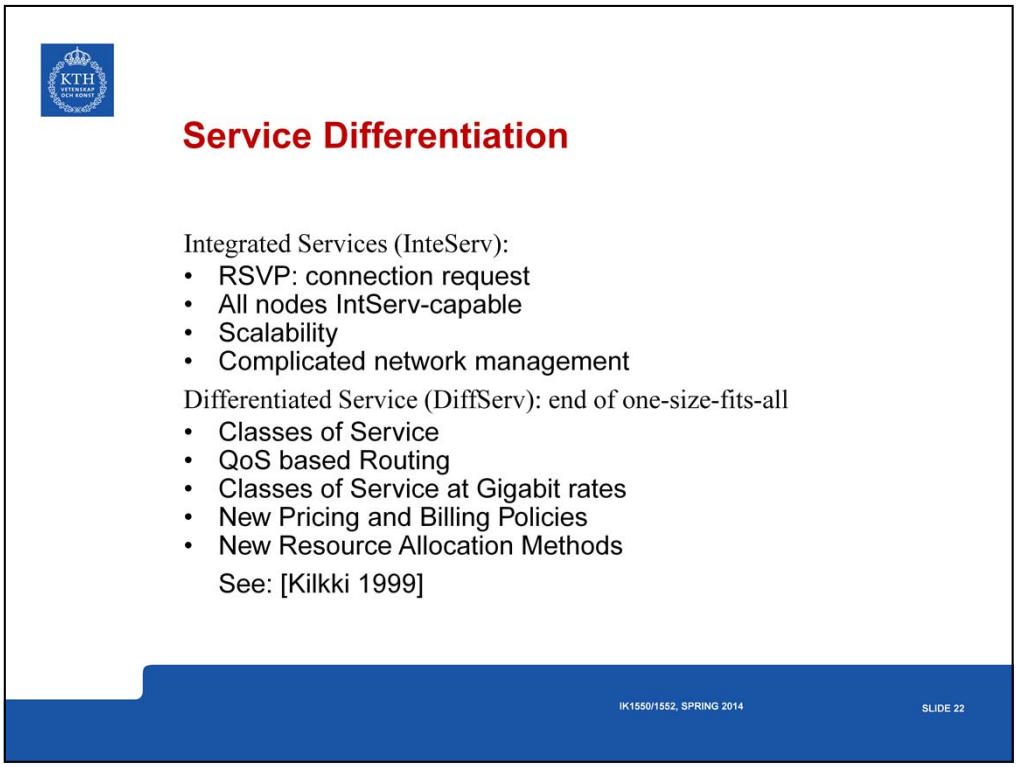
IK1550/1552, SPRING 2014 SLIDE 20

Jeff Jarvis, What Would Google Do?, Collins Business, 2009, ISBN 978-0-06-170971-5.

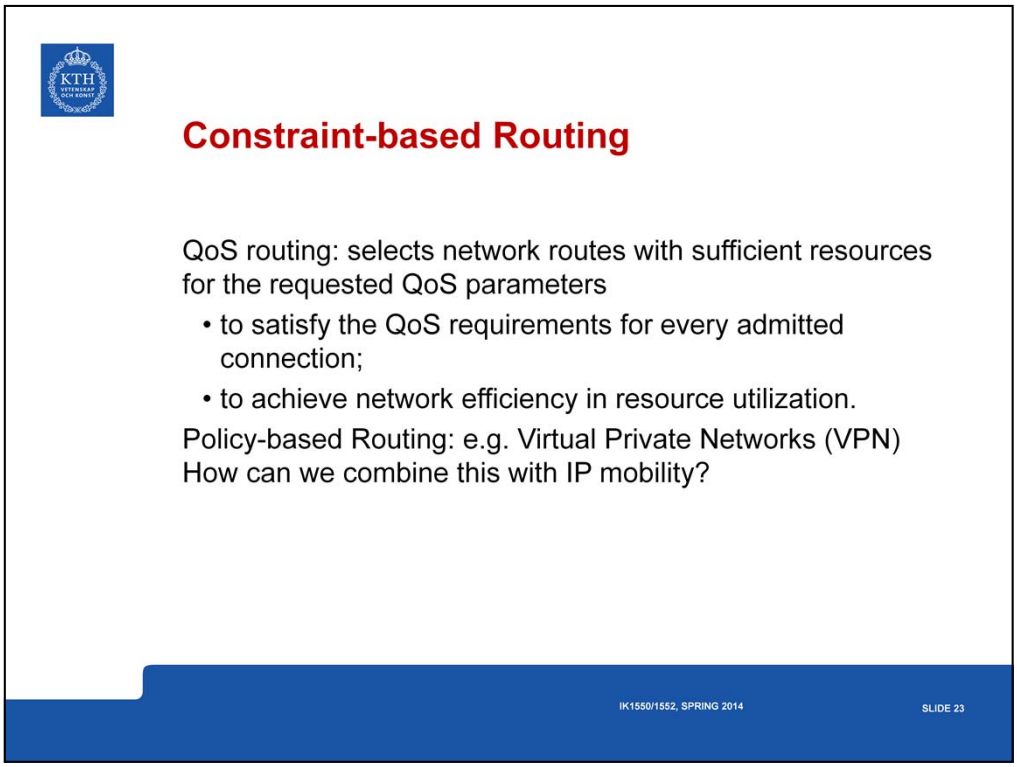
Ken Auletta, Googled: The End of the World as We Know It, Penguin Press HC, (November 3, 2009), 400 pages, ISBN-10: 1594202354, ISBN-13: 978-1594202353 - also in paperback from Virgin Books

Richard Waters, Three brilliant idealists awaiting wisdom, Book review of Googled: The End of the World as We Know It, by Ken Auletta, Financial Times, November 11 2009 20:17, *http://www.ft.com/cms/s/0/35a36ada-cef6-11de-8a4b-00144feabdc0.html*


Quality of Service (QoS)
QoS refers to statistical performance guarantees that a network can make regarding packet loss, delay, throughput, and jitter.
Best effort delivery means no QoS guarantee.
QoS is thought to be more and more important these days. Many proposals, implementations and studies.
Does Internet need QoS? How can IP network provide it?
IK1550/1552, SPRING 2014
SLIDE 21



Kalevi Kilkki, Differentiated Services for the Internet, Macmillan Technical Publishing, 384 pages, June 1999, ISBN: 1578701325.


Constraint-based Routing
QoS routing: selects network routes with sufficient resources for the requested QoS parameters
• to satisfy the QoS requirements for every admitted connection;
• to achieve network efficiency in resource utilization.
Policy-based Routing: e.g. Virtual Private Networks (VPN)
How can we combine this with IP mobility?
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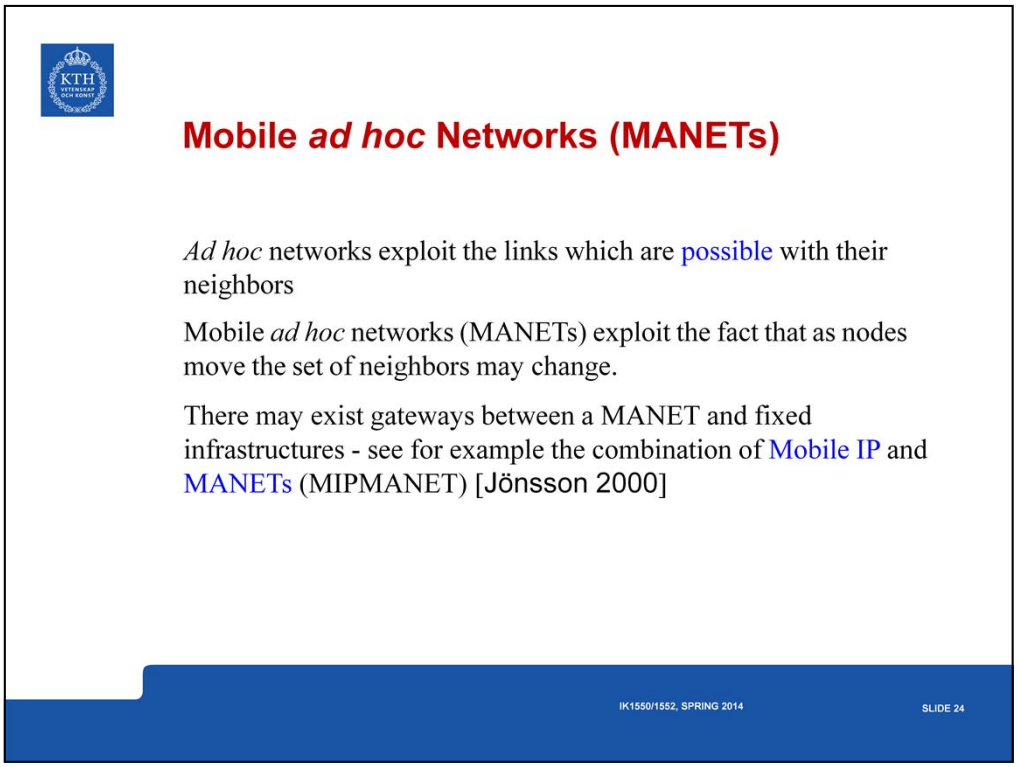
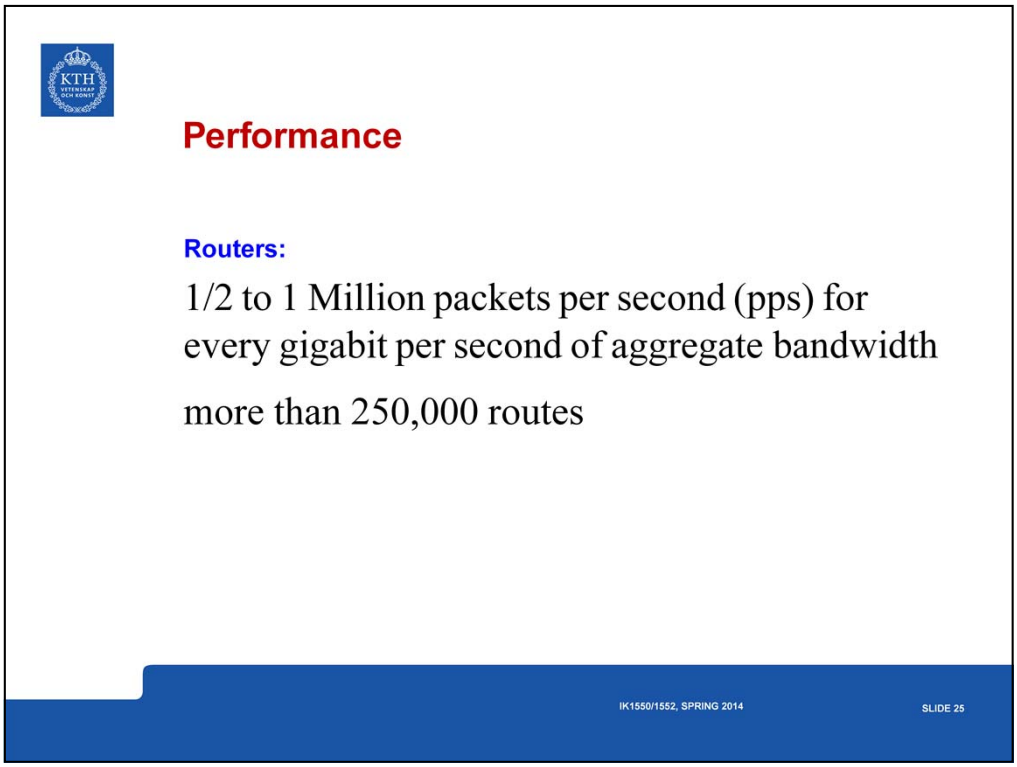
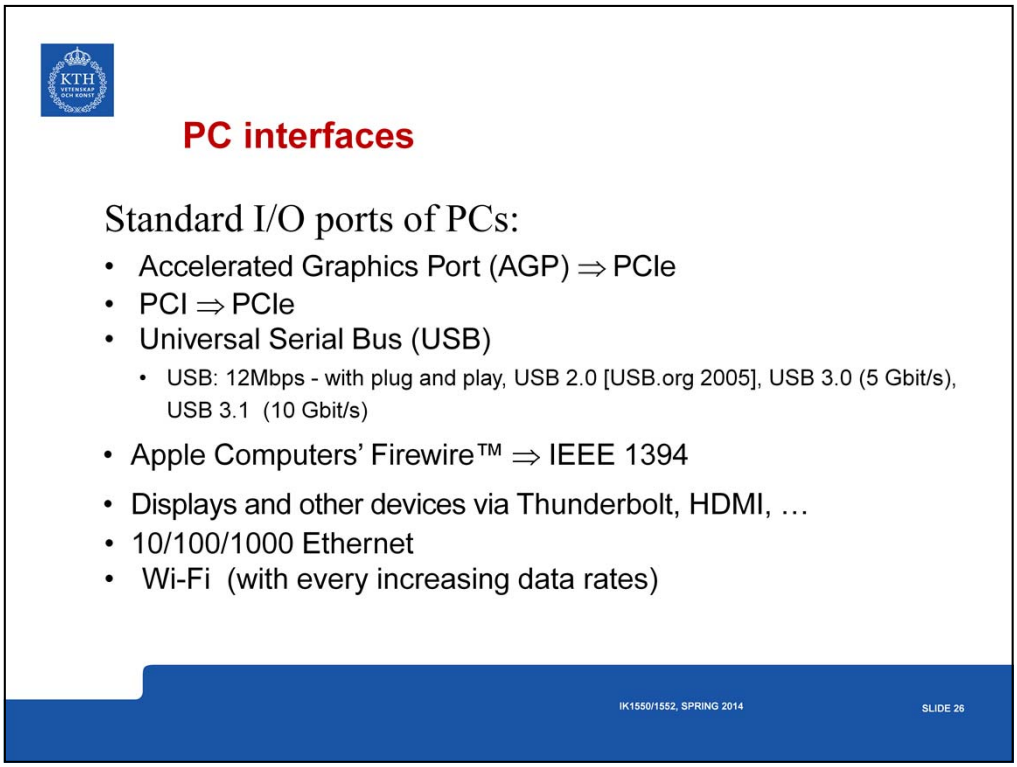
SLIDE 23



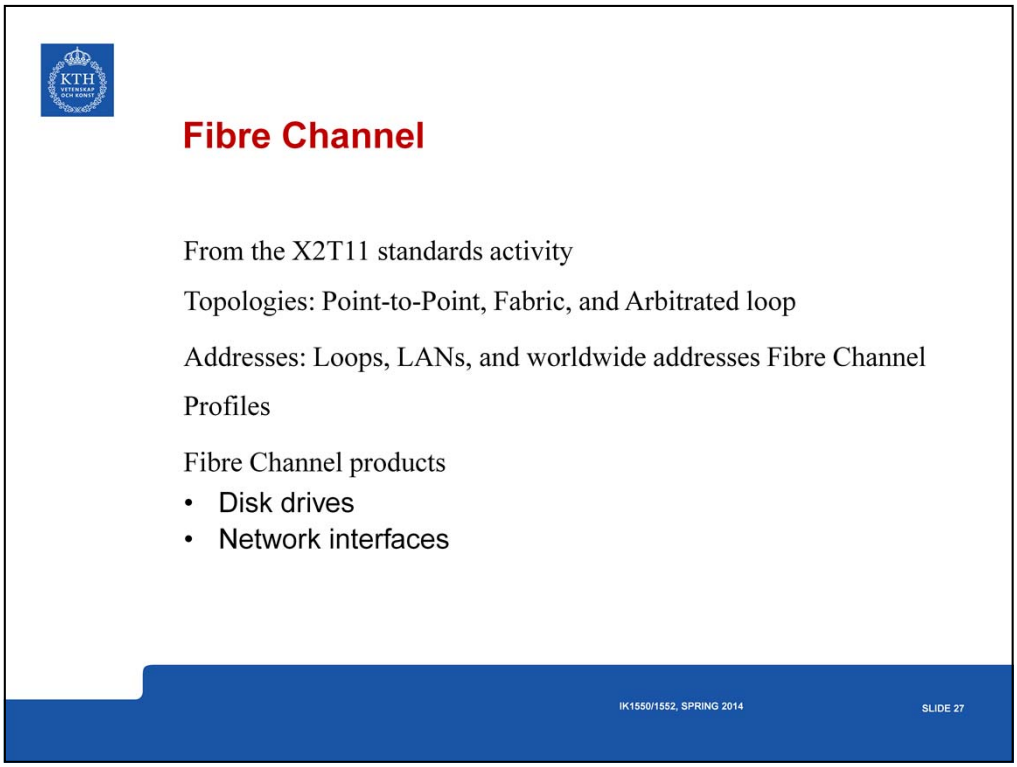
Ulf Jönsson, Fredrik Alriksson, Tony Larsson, Per Johansson, and Gerald Q. Maguire Jr, MIPMANET - Mobile IP for Mobile Ad Hoc Networks, First Annual Workshop on Mobile Ad Hoc Networking & Computing, IEEE/ACM, August 11, 2000, Boston, Massachusetts. http://doi.acm.org/10.1145/514151.514163

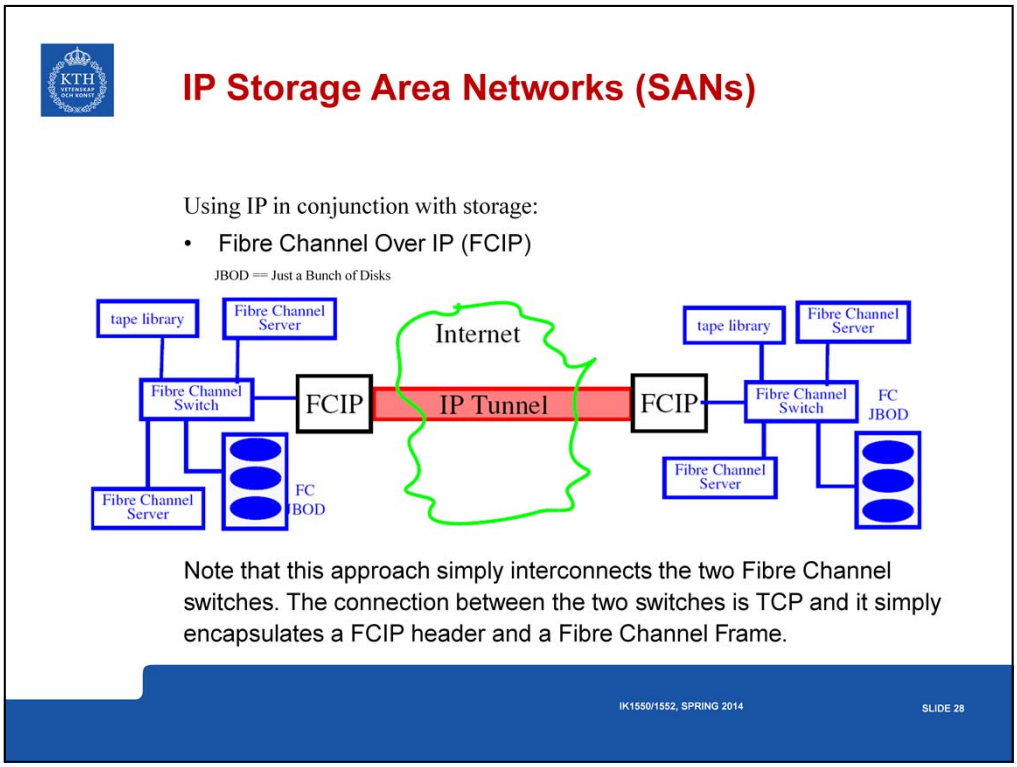

Performance
Routers:
1/2 to 1 Million packets per second (pps) for every gigabit per second of aggregate bandwidth
more than 250,000 routes
IK1550/1552, SPRING 2014
SLIDE 25



PCI-SIG, PCI-X 2.0: High Performance, Backward Compatible PCI for the Future, May 19, 2005 *http://www.pcisig.com/specifications/pcix_20*

USB.org, Universal Serial Bus Revision 2.0 specification, May 19, 2005 *http://www.usb.org/developers/docs/usb_20_02212005.zip*


Fibre Channel
From the X2T11 standards activity
Topologies: Point-to-Point, Fabric, and Arbitrated loop
Addresses: Loops, LANs, and worldwide addresses Fibre Channel
Profiles
Fibre Channel products
• Disk drives
• Network interfaces
IK1550/1552, SPRING 2014
SLIDE 27


IP Storage Area Networks (SANs)
Using IP in conjunction with storage:
• Fibre Channel Over IP (FCIP)
JBOD == Just a Bunch of Disks
tape library
Fibre Channel Server
Fibre Channel Switch
FCIP
Internet
IP Tunnel
FCIP
tape library
Fibre Channel Server
Fibre Channel Switch
FC JBOD
Fibre Channel Server
Fibre Channel Server
FC JBOD
Note that this approach simply interconnects the two Fibre Channel switches. The connection between the two switches is TCP and it simply encapsulates a FCIP header and a Fibre Channel Frame.
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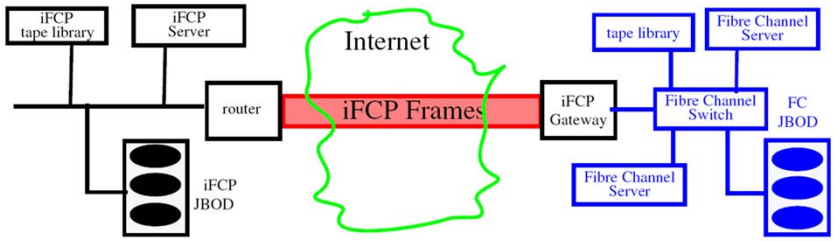
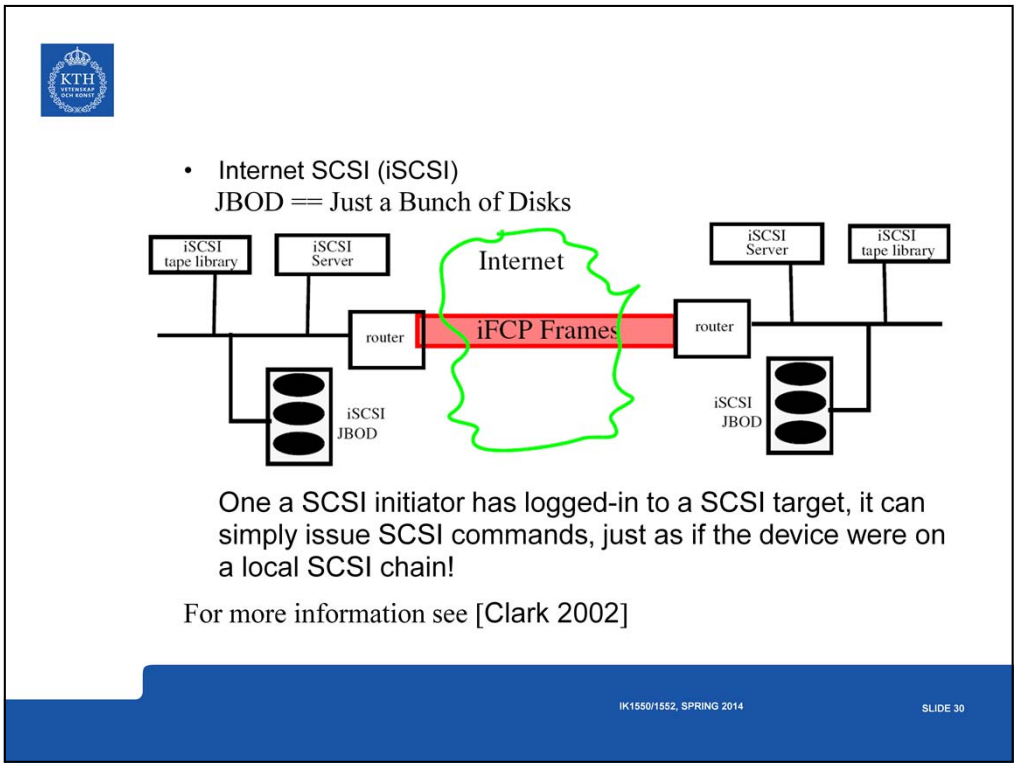
SLIDE 28

- Internet Fibre Channel Protocol (iFCP)

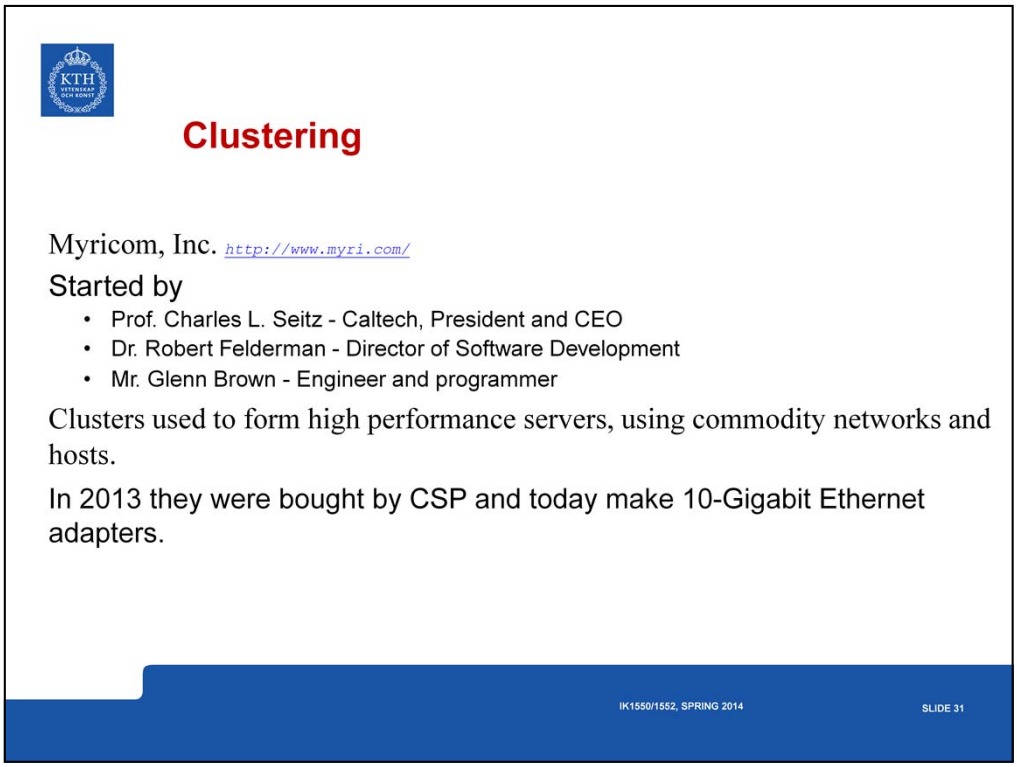
JBOD == Just a Bunch of Disks



Note that this approach interconnects Fibre Channel devices. The connection between the two switches is TCP and it encapsulates a iFCP header and a Fibre Channel Frame; note that iFCP devices can simply be attached to the internet or an intranet. This means that there has to be a mapping between Fibre Channel addresses an IP addresses.



Tom Clark, *IP SANS: A Guide to iSCSI, iFCP, and TCIP Protocols for Storage Area Networks*, Addison-Wesley, 288 pages, 2002, ISBN: 0-201-75277-8


Clustering
Myricom, Inc. http://www.myri.com/
Started by
• Prof. Charles L. Seitz - Caltech, President and CEO
• Dr. Robert Felderman - Director of Software Development
• Mr. Glenn Brown - Engineer and programmer
Clusters used to form high performance servers, using commodity networks and hosts.
In 2013 they were bought by CSP and today make 10-Gigabit Ethernet adapters.
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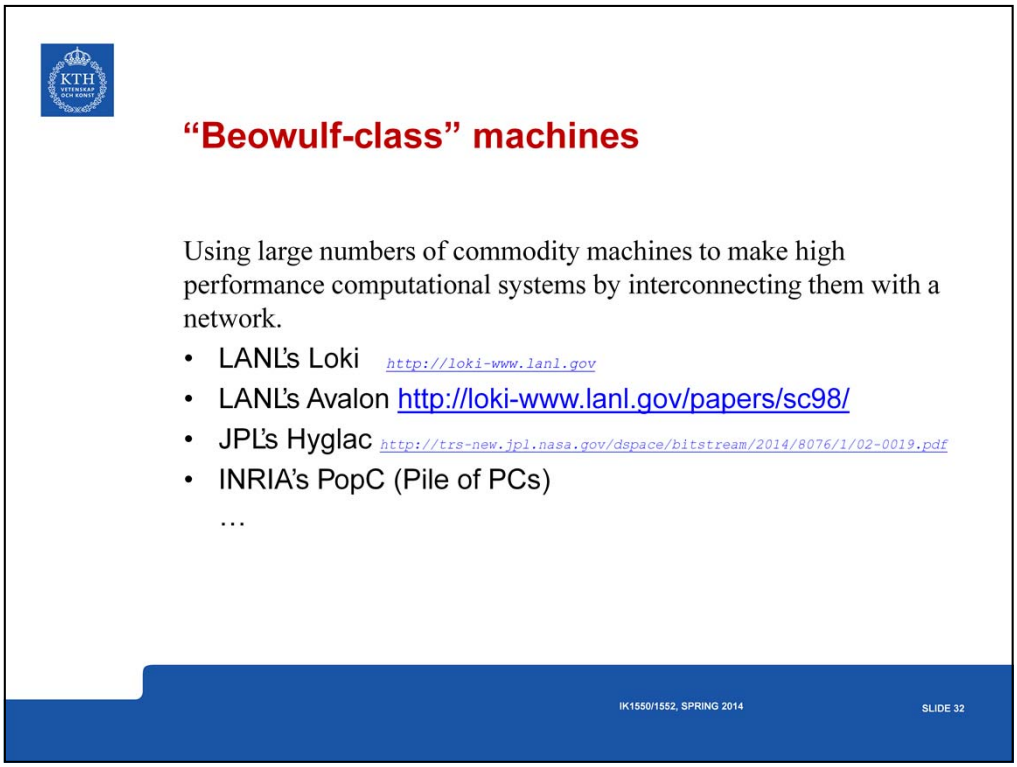
"Beowulf-class" machines
Using large numbers of commodity machines to make high performance computational systems by interconnecting them with a network.
• LANL's Loki http://loki-www.lanl.gov
• LANL's Avalon http://loki-www.lanl.gov/papers/sc98/
• JPL's Hyglac http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/8076/1/02-0019.pdf
• INRIA's PopC (Pile of PCs)
…
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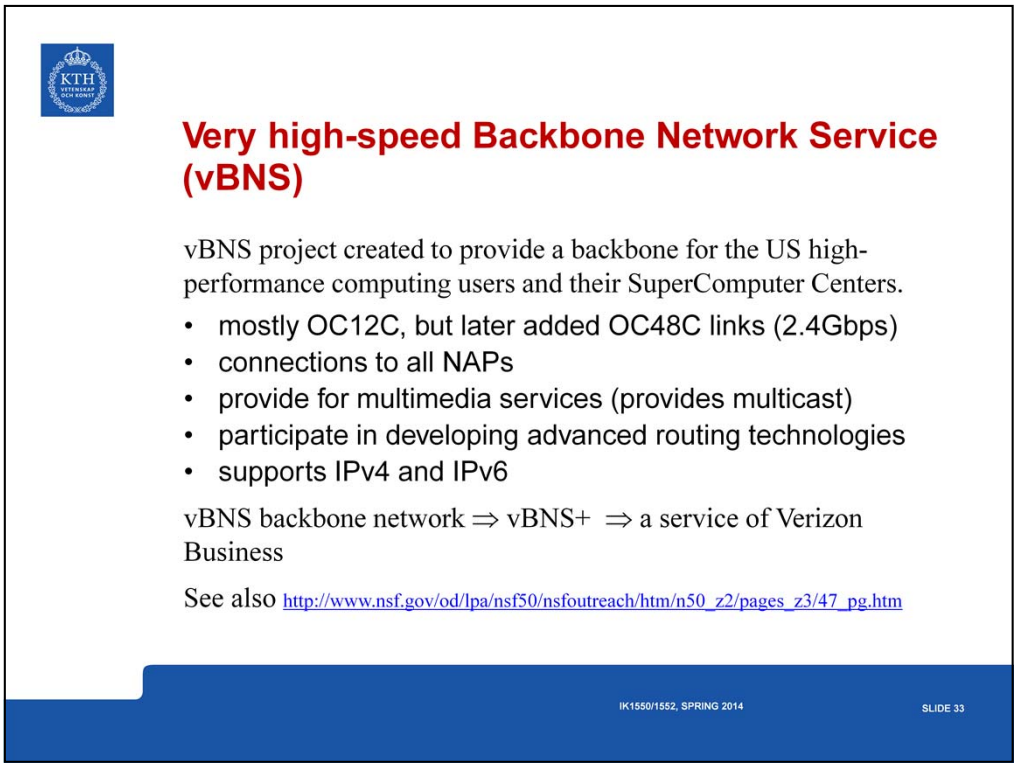
Very high-speed Backbone Network Service (vBNS)
vBNS project created to provide a backbone for the US high-performance computing users and their SuperComputer Centers.
• mostly OC12C, but later added OC48C links (2.4Gbps)
• connections to all NAPs
• provide for multimedia services (provides multicast)
• participate in developing advanced routing technologies
• supports IPv4 and IPv6
vBNS backbone network ⇒ vBNS+ ⇒ a service of Verizon Business
See also http://www.nsf.gov/od/lpa/nsf50/nsfoutreach/htm/n50_z2/pages_z3/47_pg.htm
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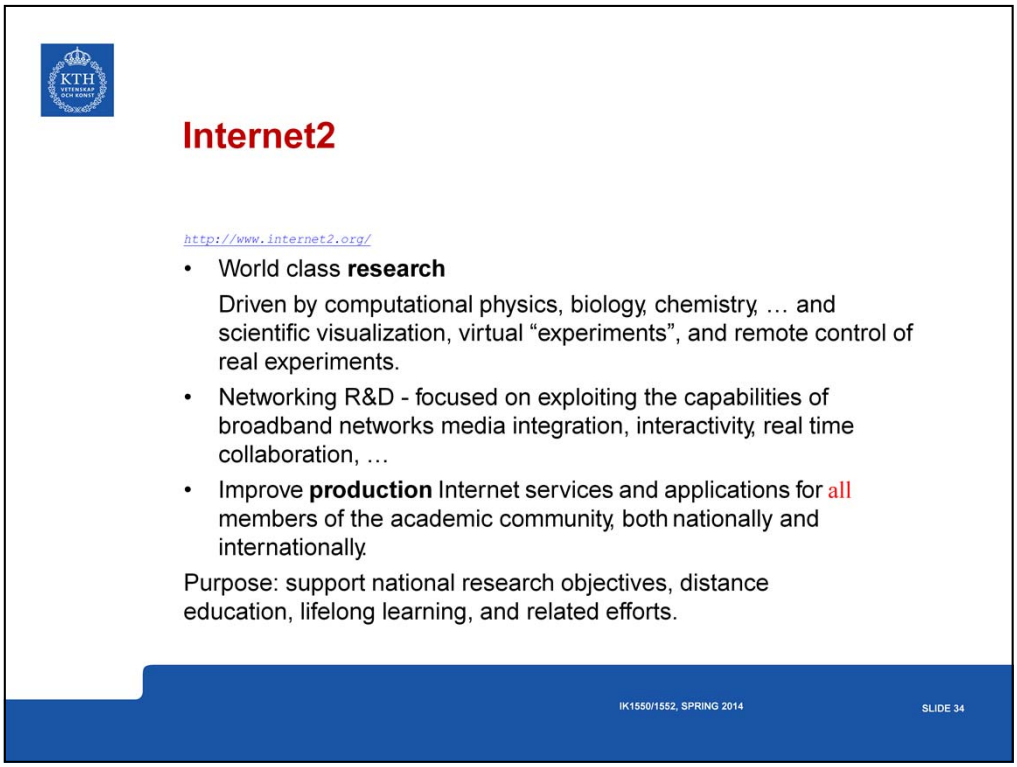
Internet2
http://www.internet2.org/
• World class **research**
Driven by computational physics, biology, chemistry, … and scientific visualization, virtual "experiments", and remote control of real experiments.
• Networking R&D - focused on exploiting the capabilities of broadband networks media integration, interactivity, real time collaboration, …
• Improve **production** Internet services and applications for all members of the academic community, both nationally and internationally.
Purpose: support national research objectives, distance education, lifelong learning, and related efforts.
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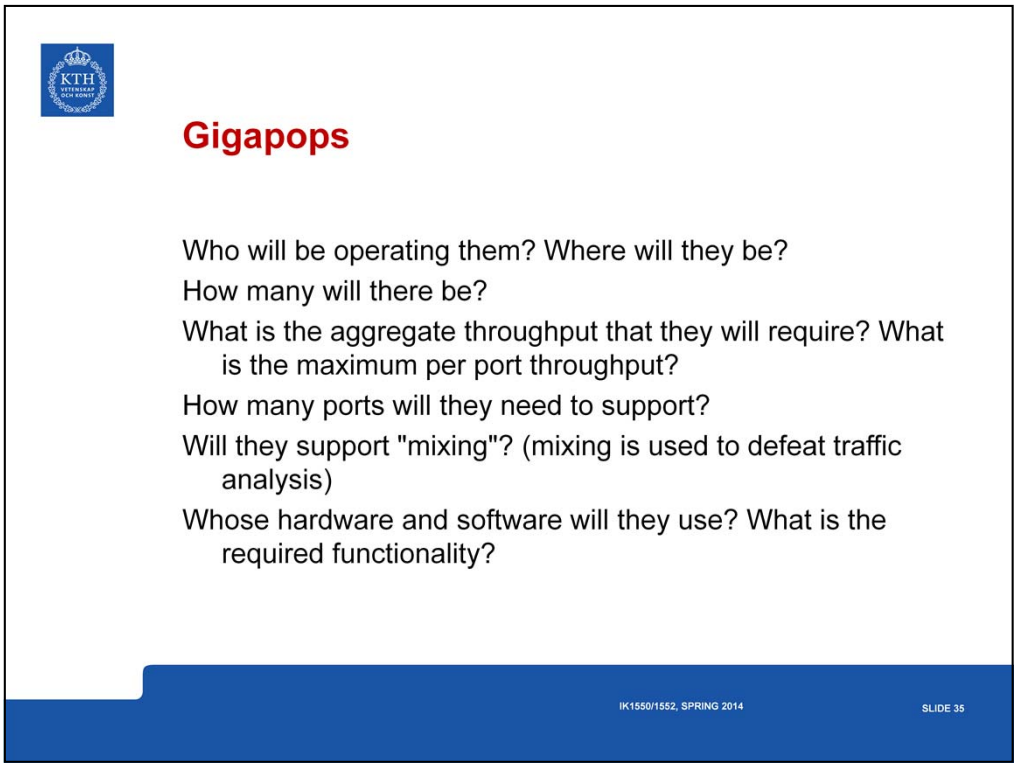
Gigapops
Who will be operating them? Where will they be?
How many will there be?
What is the aggregate throughput that they will require? What is the maximum per port throughput?
How many ports will they need to support?
Will they support "mixing"? (mixing is used to defeat traffic analysis)
Whose hardware and software will they use? What is the required functionality?
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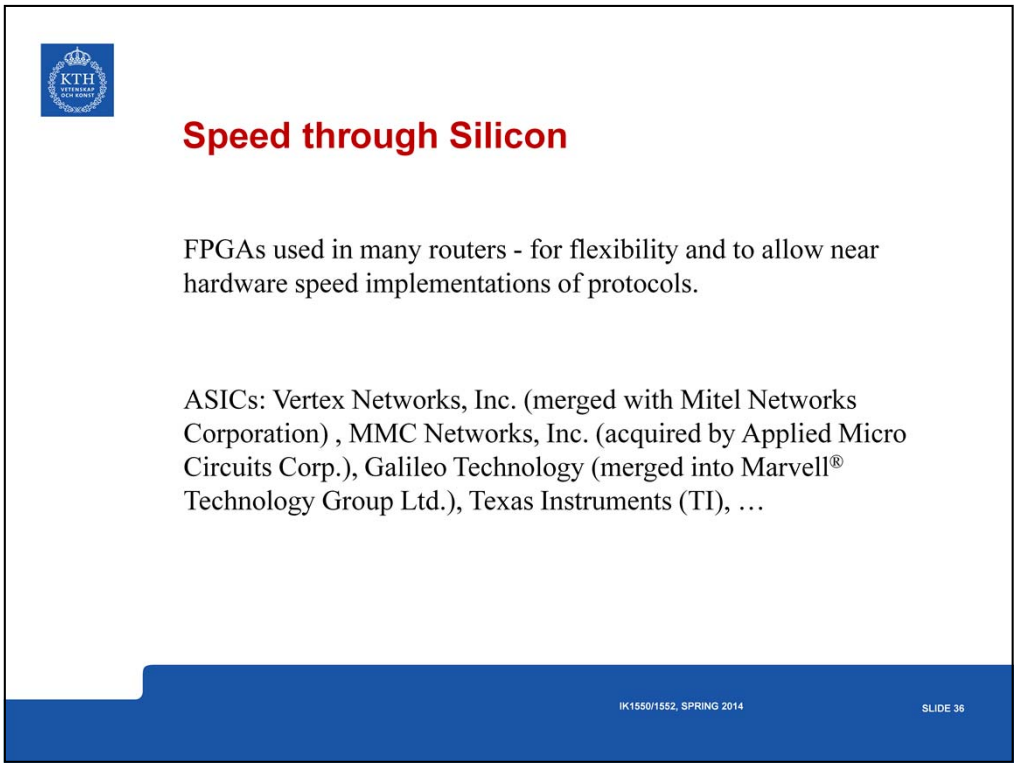
Speed through Silicon
FPGAs used in many routers - for flexibility and to allow near hardware speed implementations of protocols.
ASICs: Vertex Networks, Inc. (merged with Mitel Networks Corporation) , MMC Networks, Inc. (acquired by Applied Micro Circuits Corp.), Galileo Technology (merged into Marvell® Technology Group Ltd.), Texas Instruments (TI), …
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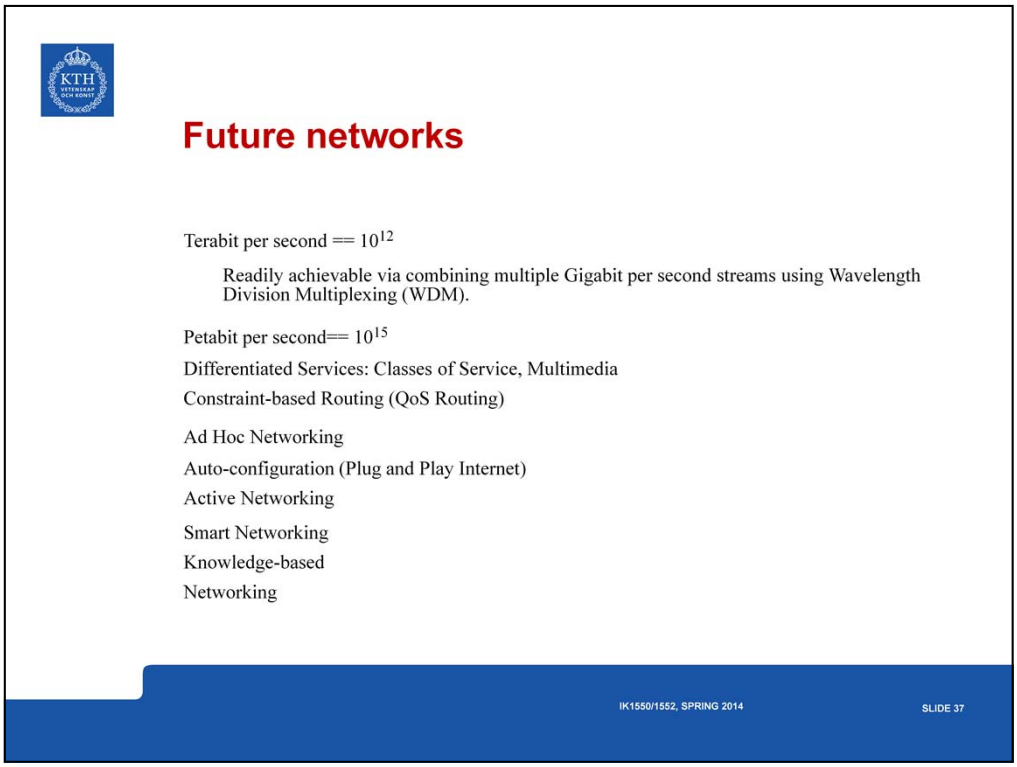
Future networks
Terabit per second == 10^{12}
Readily achievable via combining multiple Gigabit per second streams using Wavelength Division Multiplexing (WDM).
Petabit per second== 10^{15}
Differentiated Services: Classes of Service, Multimedia
Constraint-based Routing (QoS Routing)
Ad Hoc Networking
Auto-configuration (Plug and Play Internet)
Active Networking
Smart Networking
Knowledge-based
Networking
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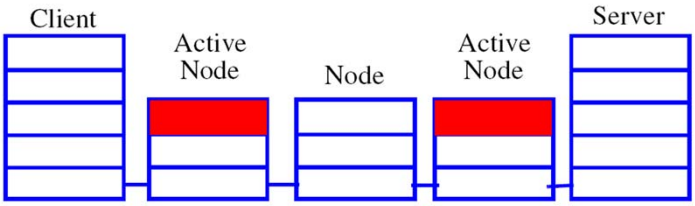
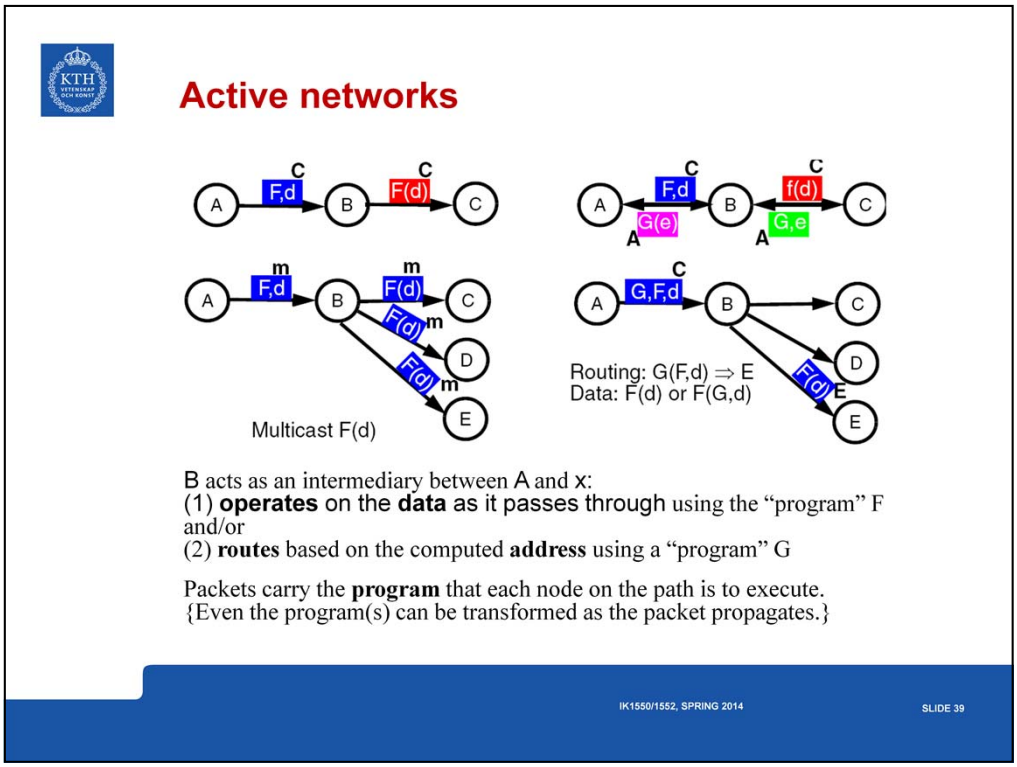
Active Networks

- Network nodes can perform customized computations on the messages flowing through them.
- Can change, modify the contents of the messages.
- Potentially Mobility Enabling Routing using active network concept




Active networks
A
B
C
D
E
F,d
F(d)
f(d)
G(e)
G,e
G,F,d
m
Multicast F(d)
Routing: G(F,d) ⇒ E
Data: F(d) or F(G,d)
B acts as an intermediary between A and x:
(1) operates on the data as it passes through using the "program" F and/or
(2) routes based on the computed address using a "program" G
Packets carry the program that each node on the path is to execute.
{Even the program(s) can be transformed as the packet propagates.}
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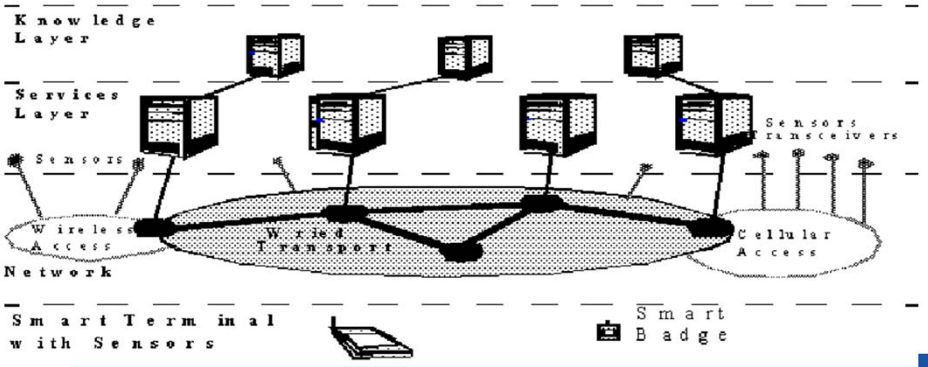
Smart Networks with Sensors

(Ren and Maguire, KTH)

- Context/situation-aware Systems
- Smart services: active + user-awareness networking
- Knowledge-based Networking



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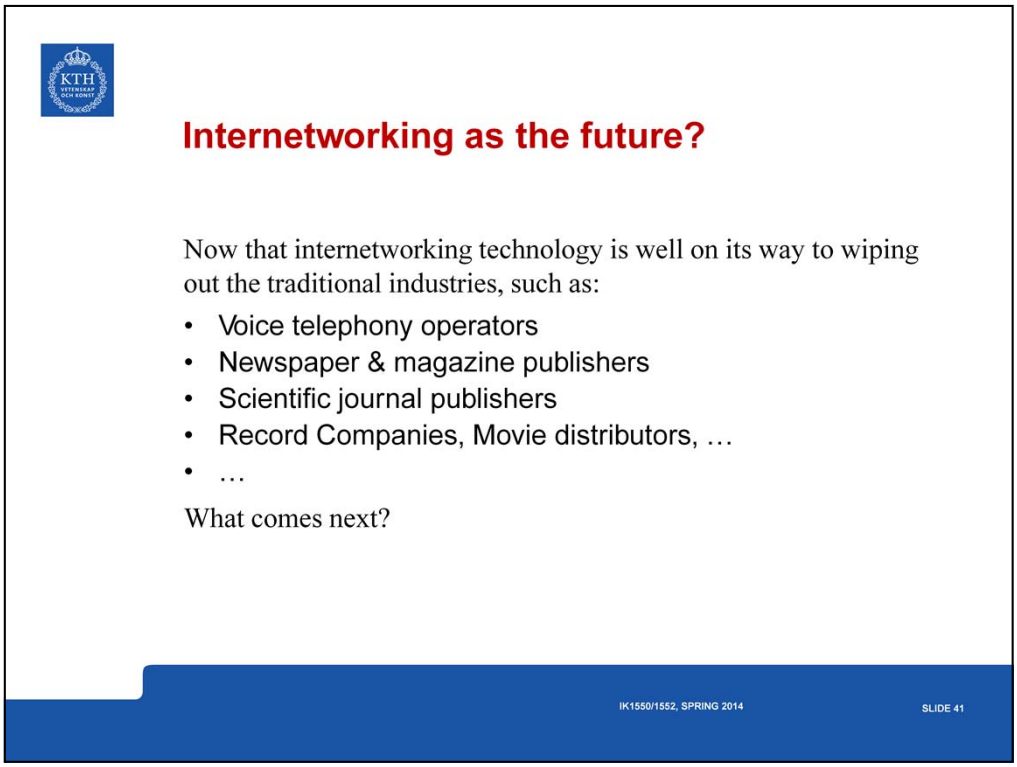
Internetworking as the future?
Now that internetworking technology is well on its way to wiping out the traditional industries, such as:
• Voice telephony operators
• Newspaper & magazine publishers
• Scientific journal publishers
• Record Companies, Movie distributors, …
• …
What comes next?
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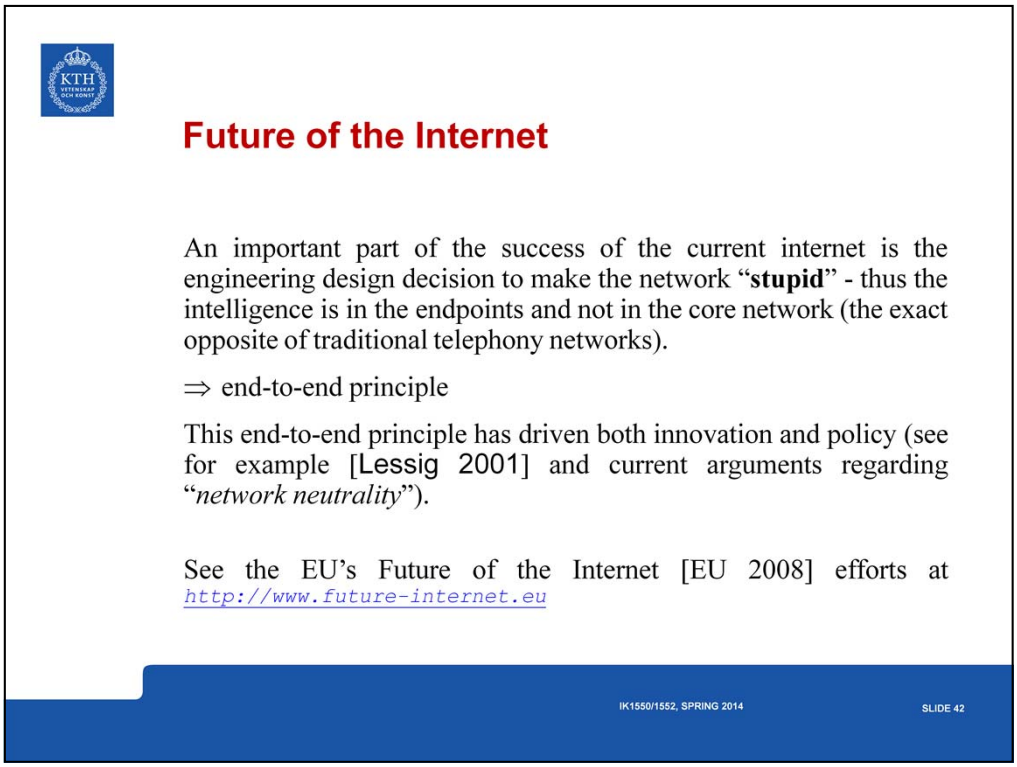
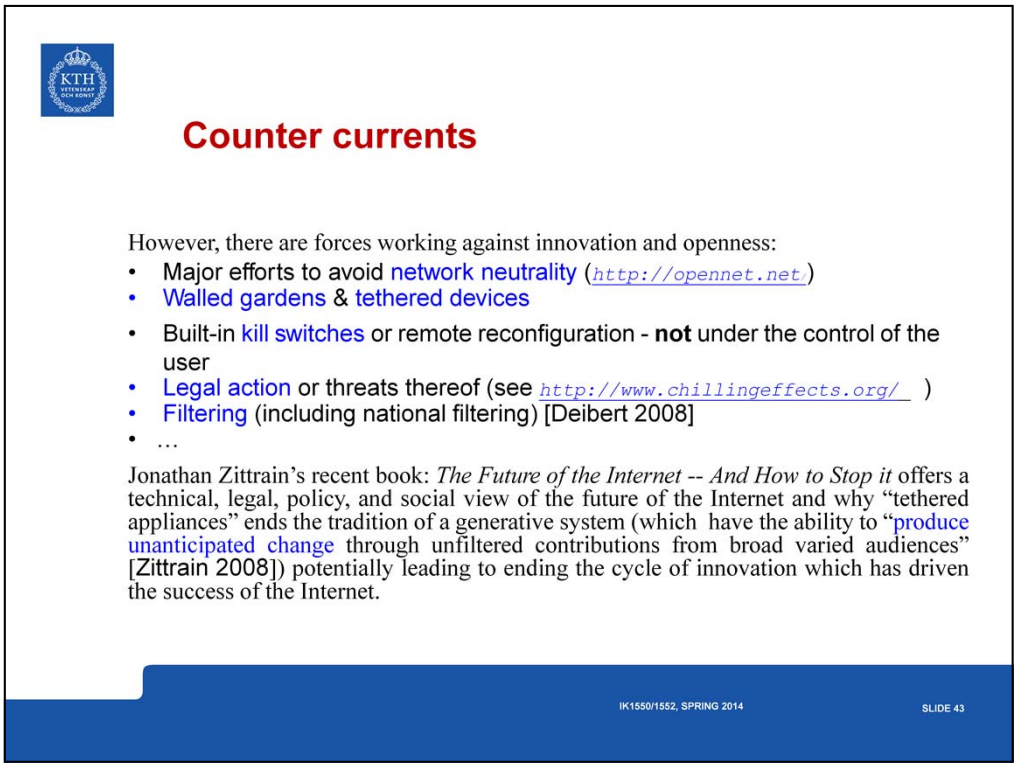


Lawrence Lessig, The Future of Ideas: The Fate of the Commons in a Connected World, New York: Random House, 352 pages, 2001.

The Future of the Internet: A Compendium of European Projects on ICT Research Supported by the EU 7th Framework Programme for RTD, Brochure by the European Commission, Information Society and Media DG, May 2008, ISBN 978-92-79-08008-1 *ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/ch1-g848-280-future-internet_en.pdf*



Jonathan Zittrain, *The Future of the Internet -- And How to Stop it*, New Haven: Yale University Press, 342 pages, 2008. ISBN 978-0-300-12487-3, Web site of the book and blog: *http://futureoftheinternet.org/* ; the author's web site: *http://www.jz.org/*

Ronald Deibert, John Palfrey, Rafal Rohozinski, and Jonathan Zittrain, eds., Access Denied: The Practice and Policy of Global Internet Filtering, (Cambridge: MIT Press) 2008. *http://opennet.net/accessdenied*


Clean slate re-design of the Internet
Many have questioned one or more of the basic concepts and currently several groups are attempting to do a clean slate re-design of the Internet.
Consider for example the two research questions that researchers at Stanford University are asking as part of their Clean Slate program:
"With what we know today, if we were to start again with a clean slate, how would we design a global communications infrastructure?", and
"How should the Internet look in 15 years?"
-- Quoted from http://cleanslate.stanford.edu/
See also: http://cleanslate.stanford.edu/about_cleanslate.php
This is only one of many such projects, see also:
U. S. National Science Foundation GENI: http://geni.net
European Union Future Internet Research and Experimentation (FIRE): http://cordis.europa.eu/fp7/ict/fire/
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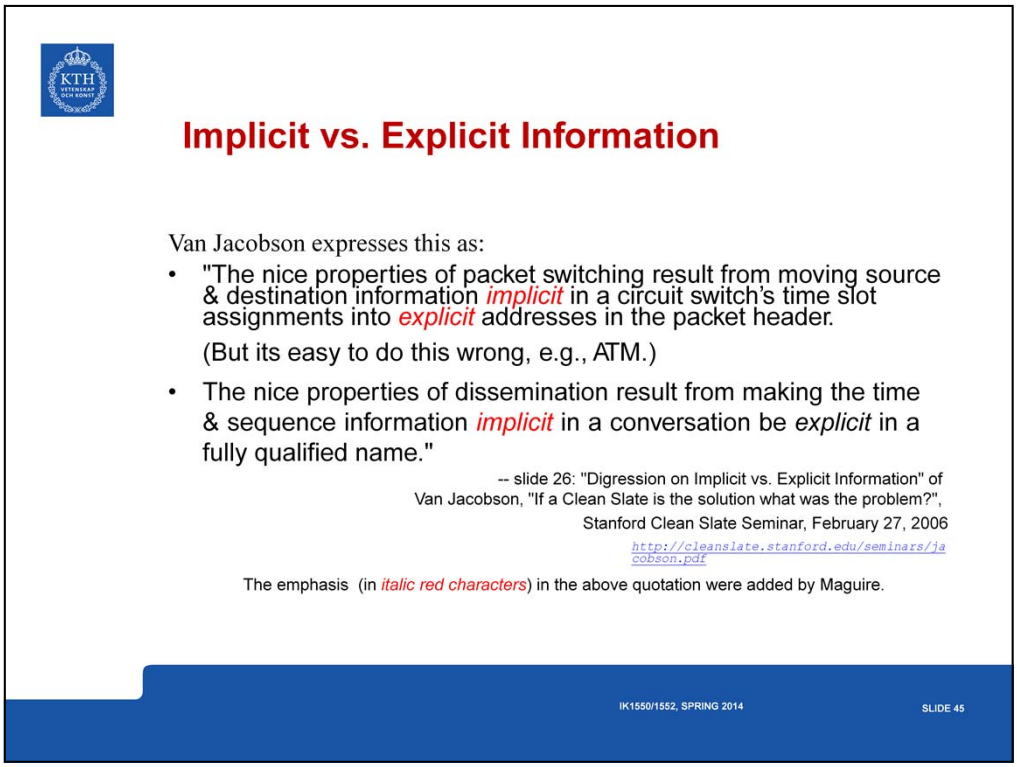
Implicit vs. Explicit Information
Van Jacobson expresses this as:
• "The nice properties of packet switching result from moving source & destination information implicit in a circuit switch's time slot assignments into explicit addresses in the packet header.
(But its easy to do this wrong, e.g., ATM.)
• The nice properties of dissemination result from making the time & sequence information implicit in a conversation be explicit in a fully qualified name."
-- slide 26: "Digression on Implicit vs. Explicit Information" of
Van Jacobson, "If a Clean Slate is the solution what was the problem?",
Stanford Clean Slate Seminar, February 27, 2006
http://cleanslate.stanford.edu/seminars/jacobson.pdf
The emphasis (in italic red characters) in the above quotation were added by Maguire.
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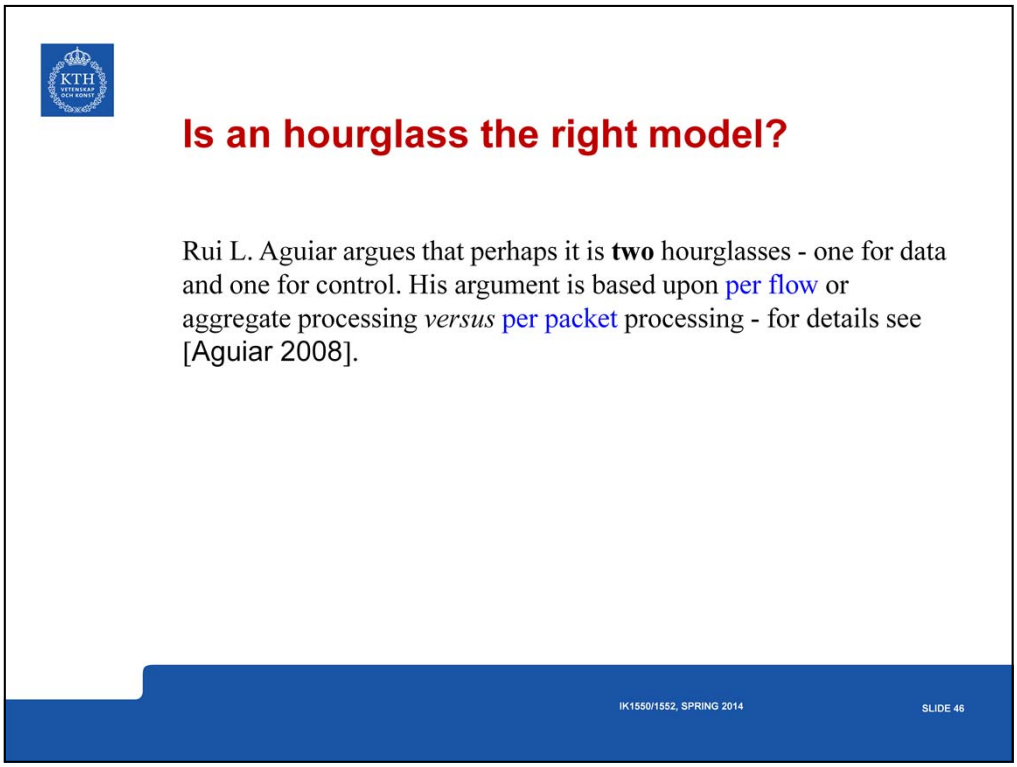
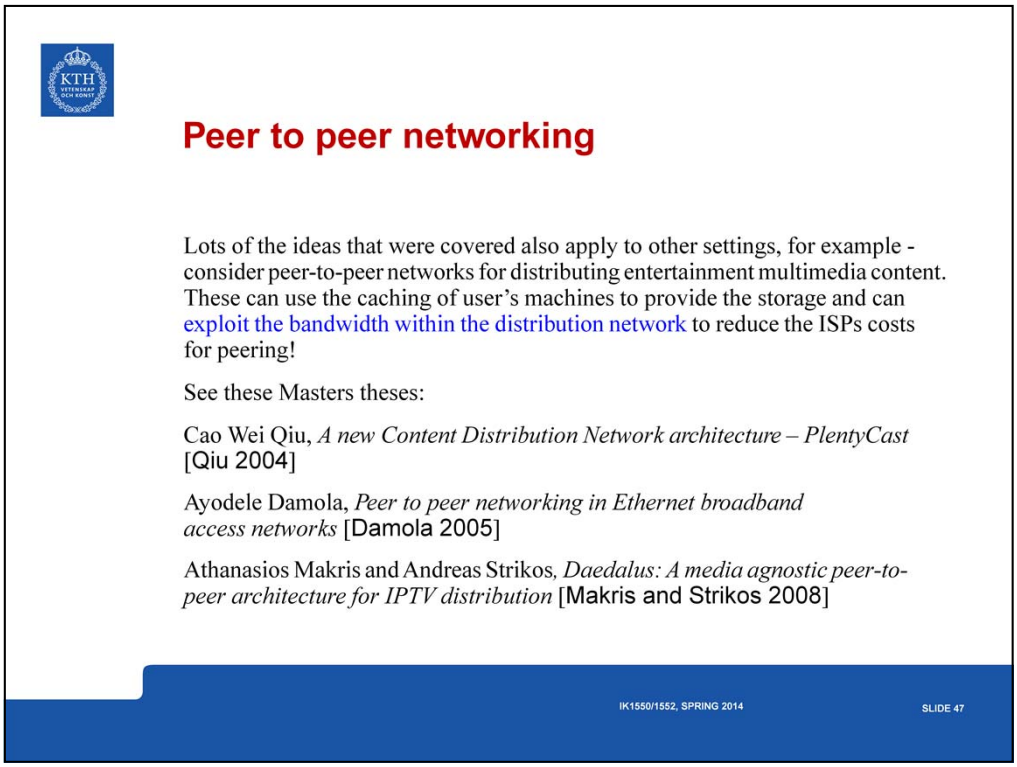


Rui L. Aguiar, “Somme Commented on Hourglasses”, Editorial Note, Computer Communication Review, Volume 38, number 5, October 2008, pp. 69-72. *http://ccr.sigcomm.org/online/files/p69-aguiar.pdf*



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Ayodele Damola, Peer to peer networking in Ethernet broadband access networks, Masters thesis, KTH, IMIT, IMIT/LCN 2005-10, May 2005

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Athanasios Makris and Andreas Strikos, Daedalus: A media agnostic peer-to-peer architecture for IPTV distribution, Masters thesis, Royal Institute of Technology (KTH), School of Information and Communication Technology, Stockholm, Sweden, COS/CCS 2008-11, June 2008

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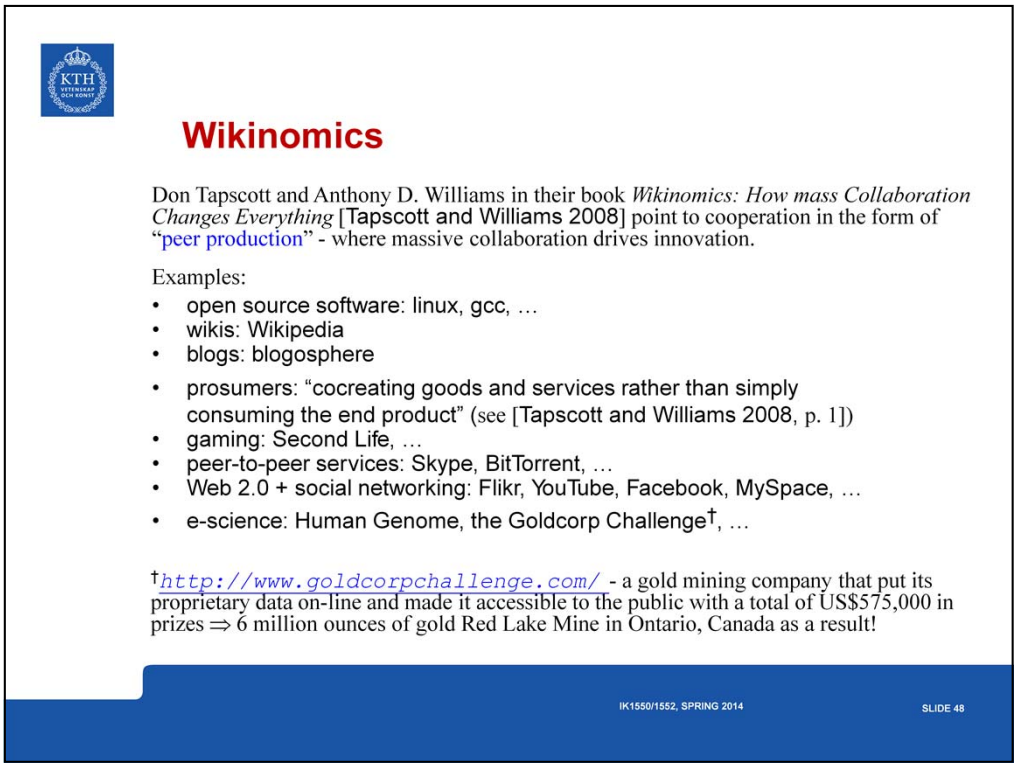
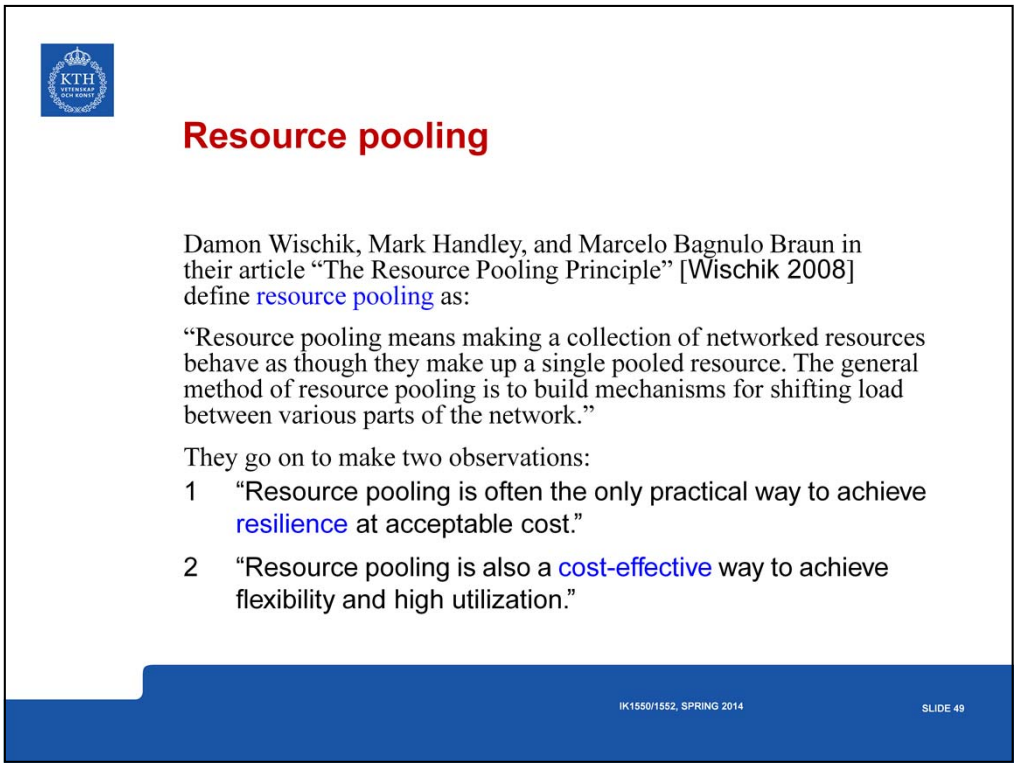
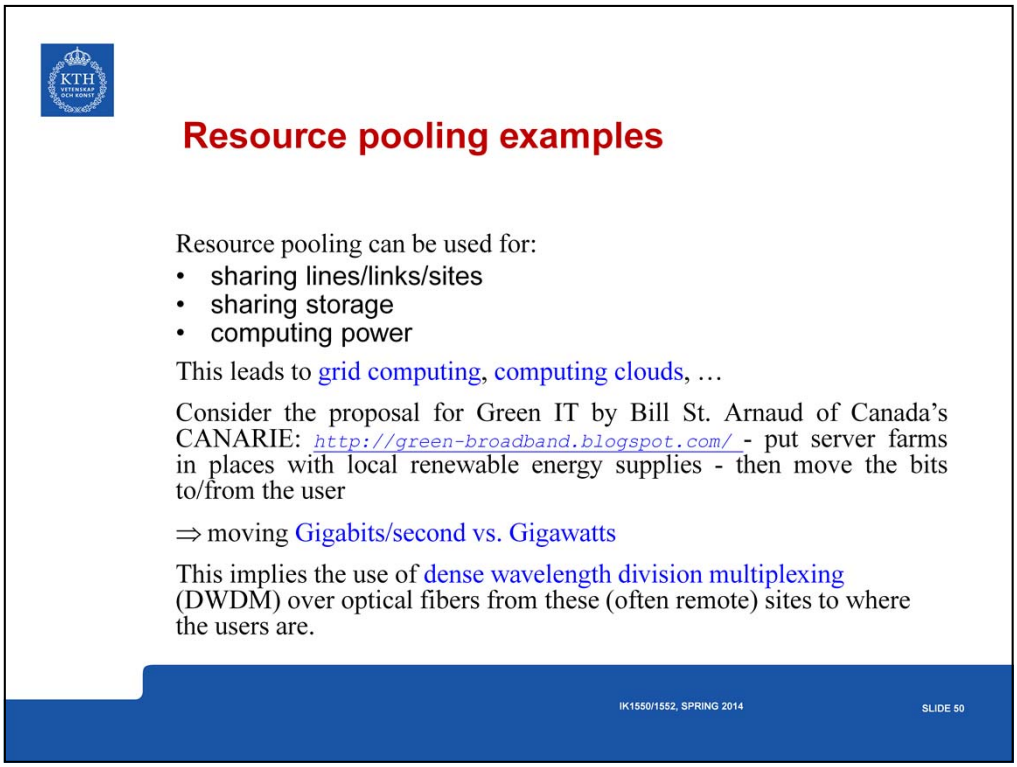


Don Tapscott and Anthony D. Williams, Wikinomics: How mass Collaboration Changes Everything, Portfolio, 2008, ISBN-13: 978-1591841937
http://www.wikinomics.com/book/



Damon Wischik, Mark Handley, and Marcelo Bagnulo Braun, "The Resource Pooling Principle", ACM/SIGCOMM Computer Communication Review, Volume 38, Number 5, October 2008, pp. 47-52 *http://ccr.sigcomm.org/online/files/p47-handleyA4.pdf*


Resource pooling examples
Resource pooling can be used for:
• sharing lines/links/sites
• sharing storage
• computing power
This leads to grid computing, computing clouds, …
Consider the proposal for Green IT by Bill St. Arnaud of Canada's CANARIE: http://green-broadband.blogspot.com/ - put server farms in places with local renewable energy supplies - then move the bits to/from the user
⇒ moving Gigabits/second vs. Gigawatts
This implies the use of dense wavelength division multiplexing (DWDM) over optical fibers from these (often remote) sites to where the users are.
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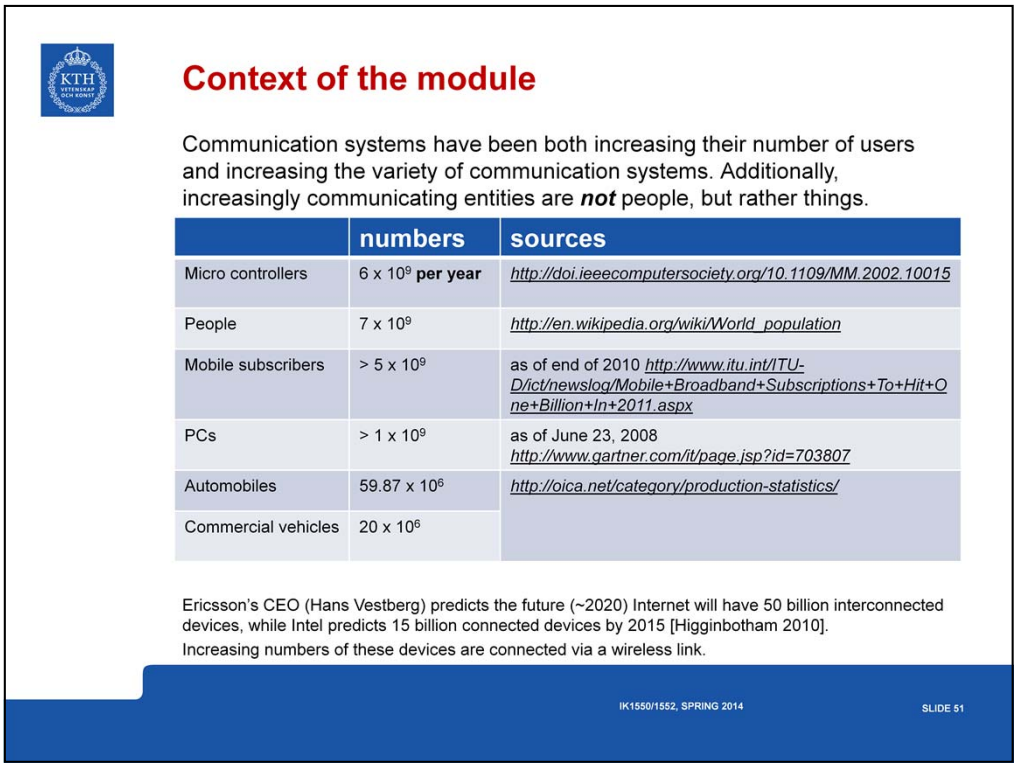

Context of the module

Communication systems have been both increasing their number of users and increasing the variety of communication systems. Additionally, increasingly communicating entities are ***not*** people, but rather things.

	numbers	sources
Micro controllers	6 x 10^9 **per year**	http://doi.ieeecomputersociety.org/10.1109/MM.2002.10015
People	7 x 10^9	http://en.wikipedia.org/wiki/World_population
Mobile subscribers	> 5 x 10^9	as of end of 2010 http://www.itu.int/ITU-D/ict/newslog/Mobile+Broadband+Subscriptions+To+Hit+One+Billion+In+2011.aspx
PCs	> 1 x 10^9	as of June 23, 2008 http://www.gartner.com/it/page.jsp?id=703807
Automobiles	59.87 x 10^6	http://oica.net/category/production-statistics/
Commercial vehicles	20 x 10^6	

Ericsson's CEO (Hans Vestberg) predicts the future (~2020) Internet will have 50 billion interconnected devices, while Intel predicts 15 billion connected devices by 2015 [Higginbotham 2010].
Increasing numbers of these devices are connected via a wireless link.

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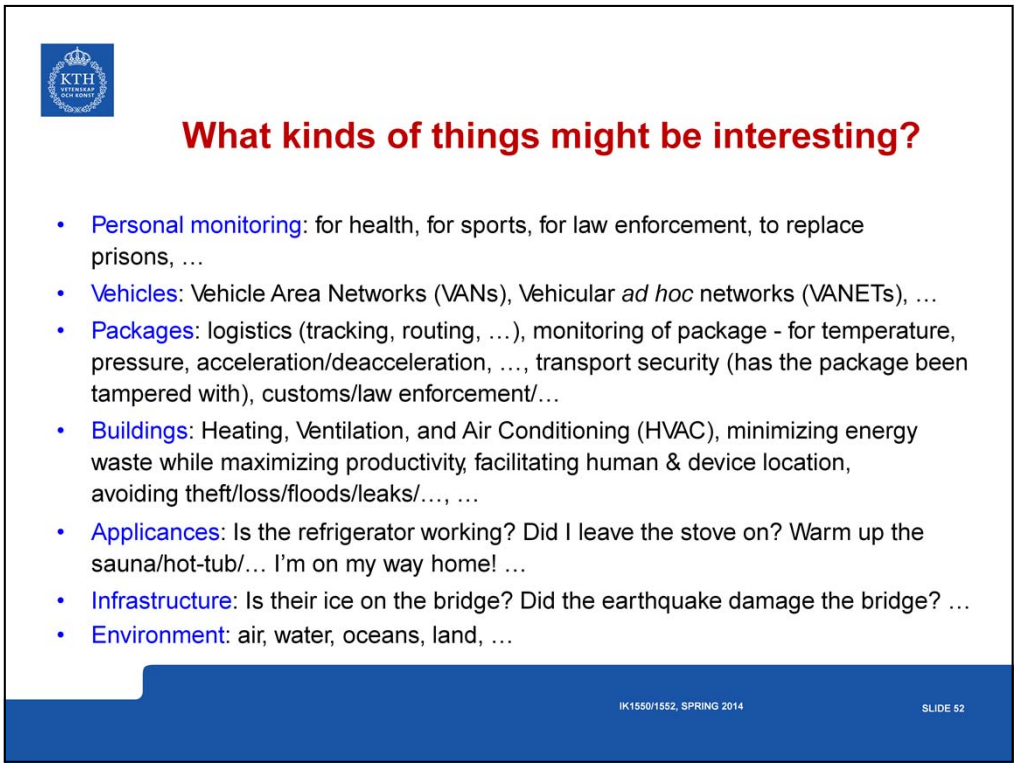
Stacey Higginbotham, Ericsson CEO Predicts 50 Billion Internet Connected Devices by 2020, GigaOM , Apr. 14, 2010, 10:08am PT, *http://gigaom.com/2010/04/14/ericsson-sees-the-internet-of-things-by-2020/*


What kinds of things might be interesting?
• Personal monitoring: for health, for sports, for law enforcement, to replace prisons, …
• Vehicles: Vehicle Area Networks (VANs), Vehicular ad hoc networks (VANETs), …
• Packages: logistics (tracking, routing, …), monitoring of package - for temperature, pressure, acceleration/deacceleration, …, transport security (has the package been tampered with), customs/law enforcement/…
• Buildings: Heating, Ventilation, and Air Conditioning (HVAC), minimizing energy waste while maximizing productivity, facilitating human & device location, avoiding theft/loss/floods/leaks/…, …
• Applicances: Is the refrigerator working? Did I leave the stove on? Warm up the sauna/hot-tub/… I'm on my way home! …
• Infrastructure: Is their ice on the bridge? Did the earthquake damage the bridge? …
• Environment: air, water, oceans, land, …
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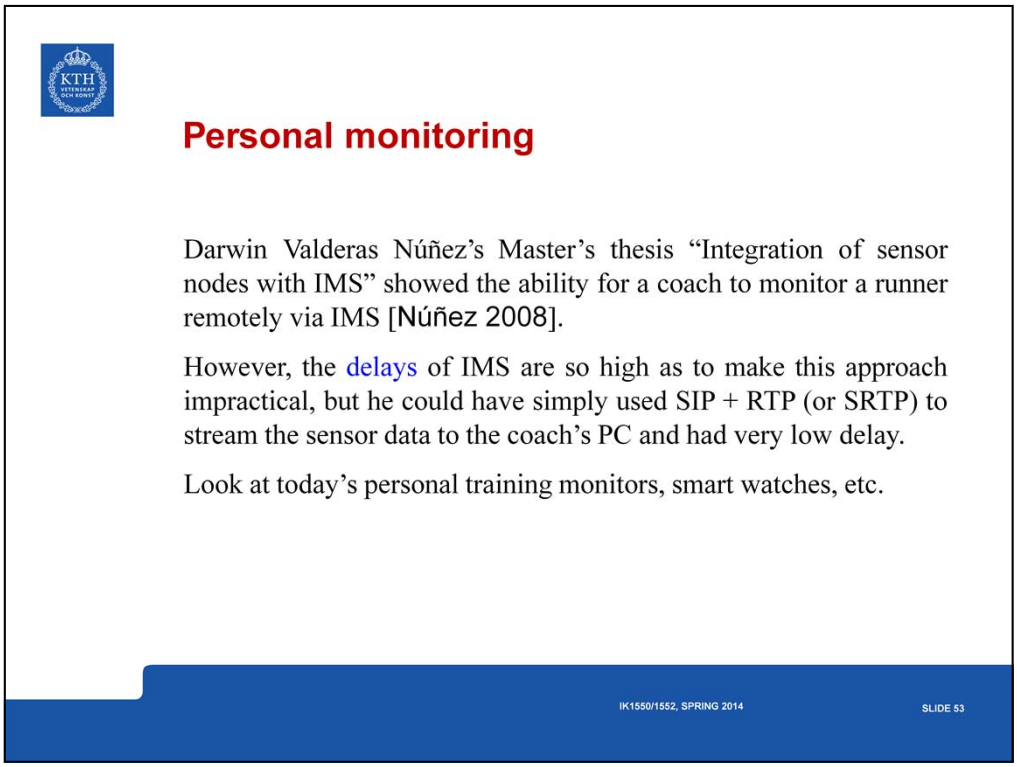

Darwin Valderas Núñez, "Integration of sensor nodes with IMS", Master's thesis, KTH Royal Institute of Technology, School of Information and Communication Technology, Stockholm, Sweden, , COS/CCS 2008-22, October 2008

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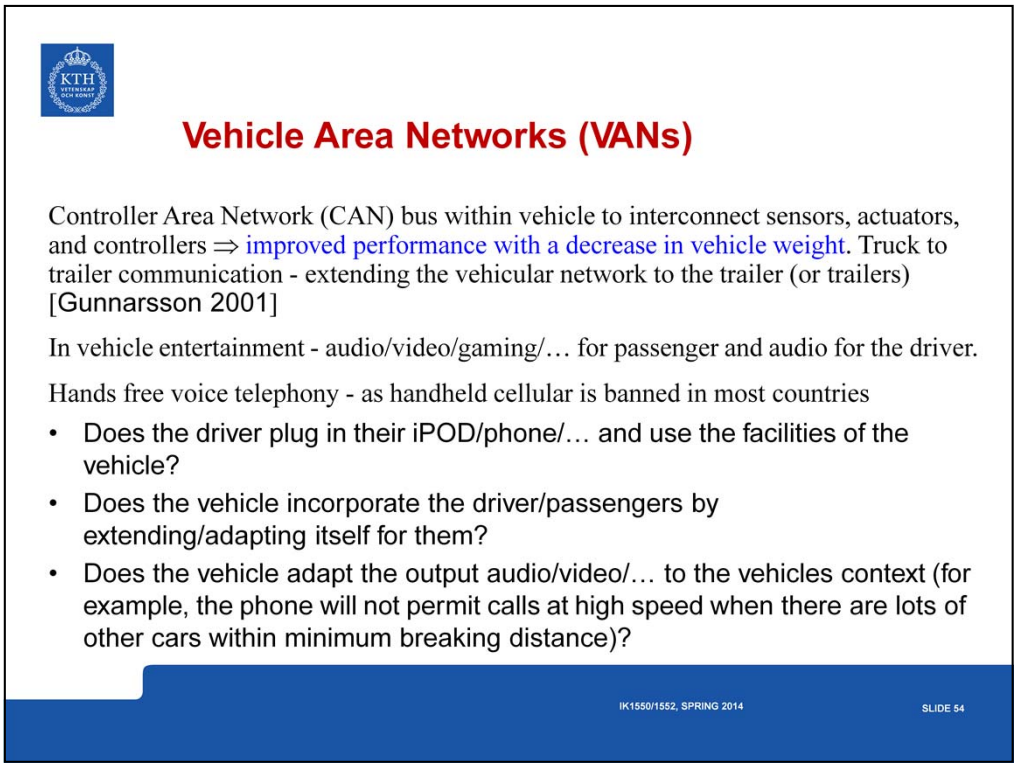

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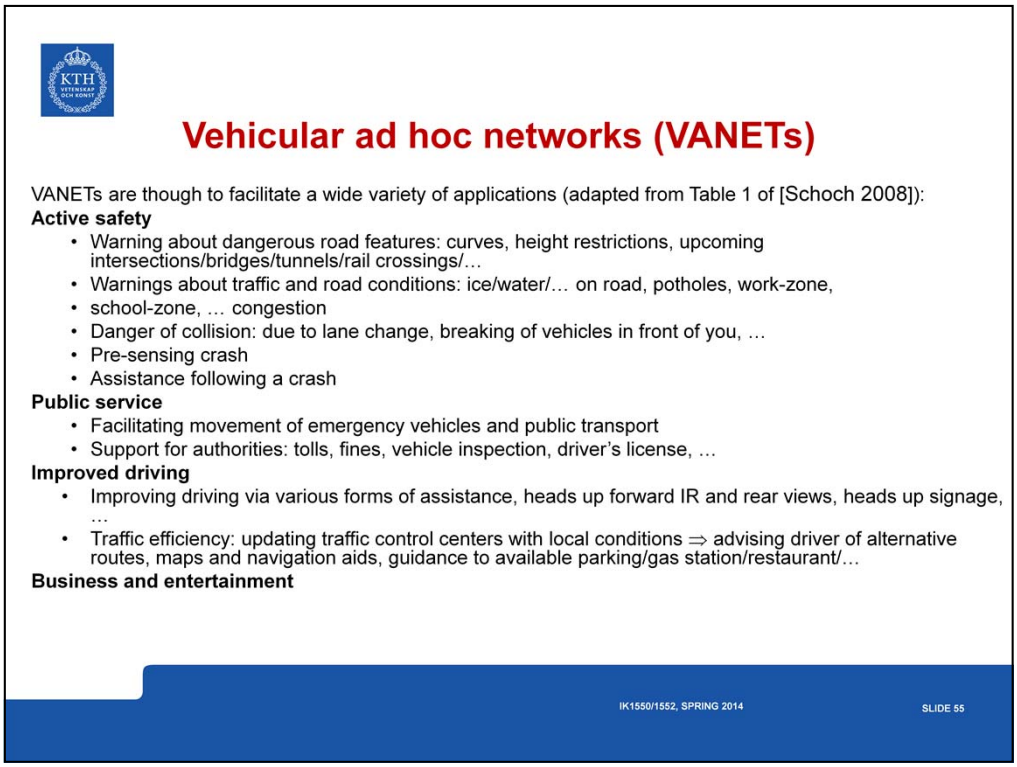
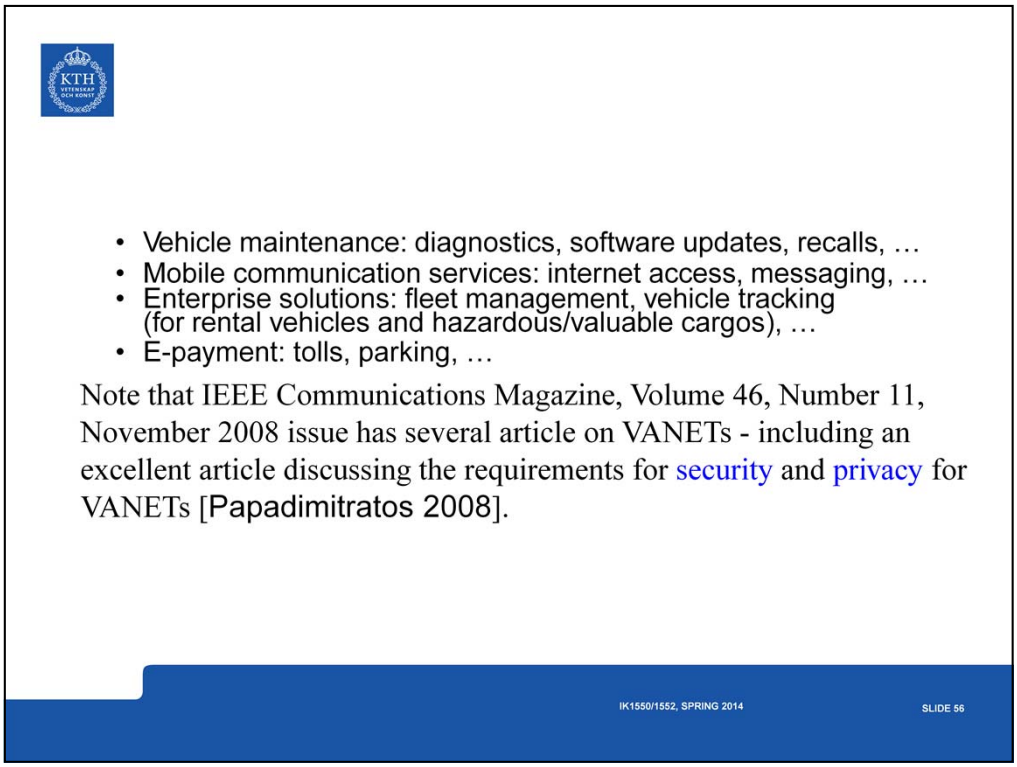
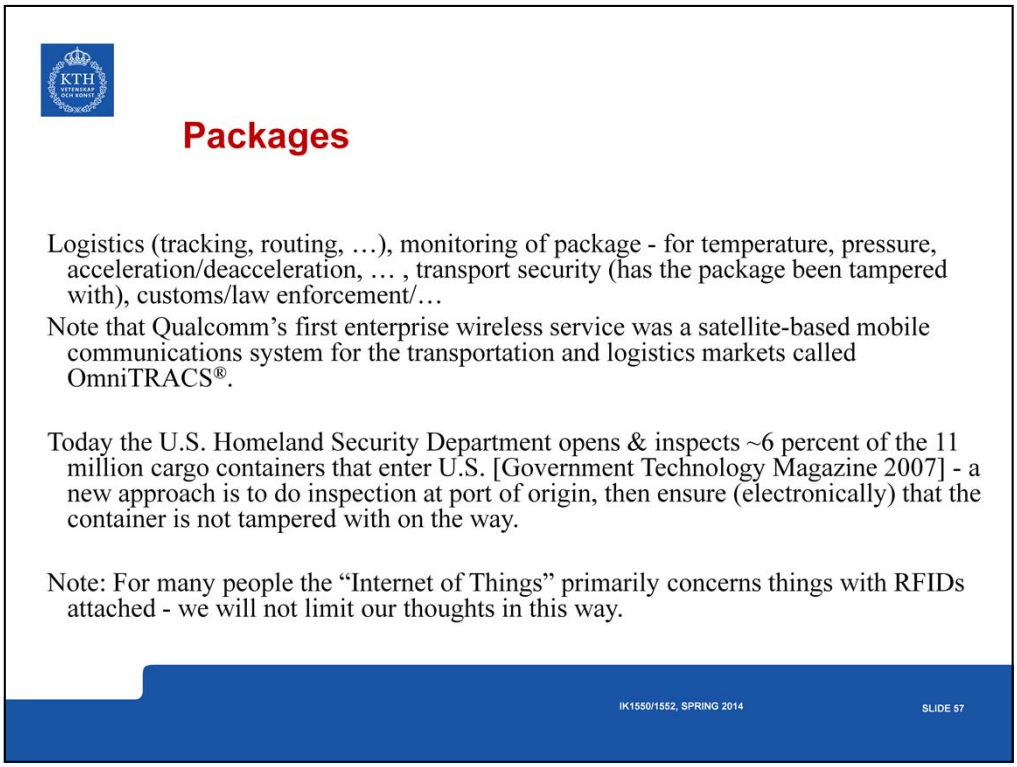


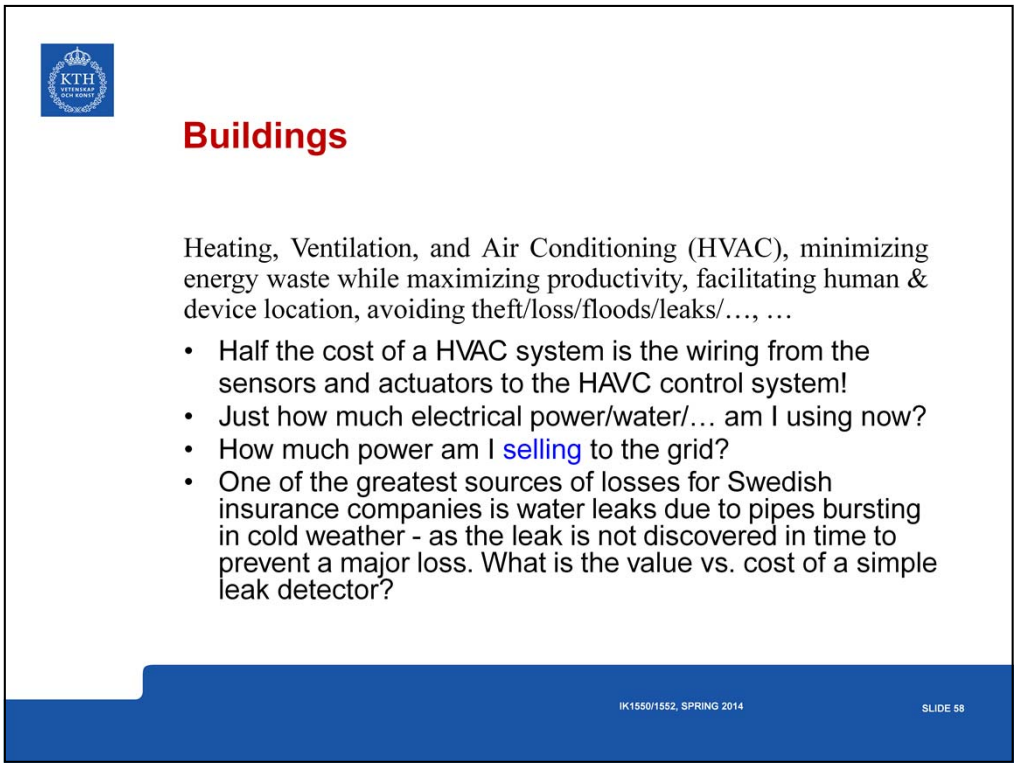
Elmar Schoch, Frank Kargl, Michael Weber, and Tim Leinmüller, "Communication Patterns in VANETs", IEEE Communications Magazine, Volume 46, number 11, November 2008, pp. 119-125.



Panagiotis Papadimitratos, Levente Buttyan, Tamás Holczer, Elmar Schoch, Julien Freudiger, Maxim Raya, Zhendong Ma, Frank Kargl, Antonio Kung, and Jean-Pierre Hubaux, Secure Vehicular Communication Systems: Design and Architecture,IEEE Communications Magazine, Volume 46, number 11, November 2008, pp. 100-109. *http://infoscience.epfl.ch/getfile.py?docid=21529&name=sevecom1&format=pdf&version=1*



WiFi Wireless Secures New Patents for Cargo Tracking and Monitor Systems, News Report, Government Technology Magazine, Folsom, CA, USA, April 11, 2007, http://www.govtech.com/gt/articles/104903


Buildings
Heating, Ventilation, and Air Conditioning (HVAC), minimizing energy waste while maximizing productivity, facilitating human & device location, avoiding theft/loss/floods/leaks/…, …
• Half the cost of a HVAC system is the wiring from the sensors and actuators to the HAVC control system!
• Just how much electrical power/water/… am I using now?
• How much power am I selling to the grid?
• One of the greatest sources of losses for Swedish insurance companies is water leaks due to pipes bursting in cold weather - as the leak is not discovered in time to prevent a major loss. What is the value vs. cost of a simple leak detector?
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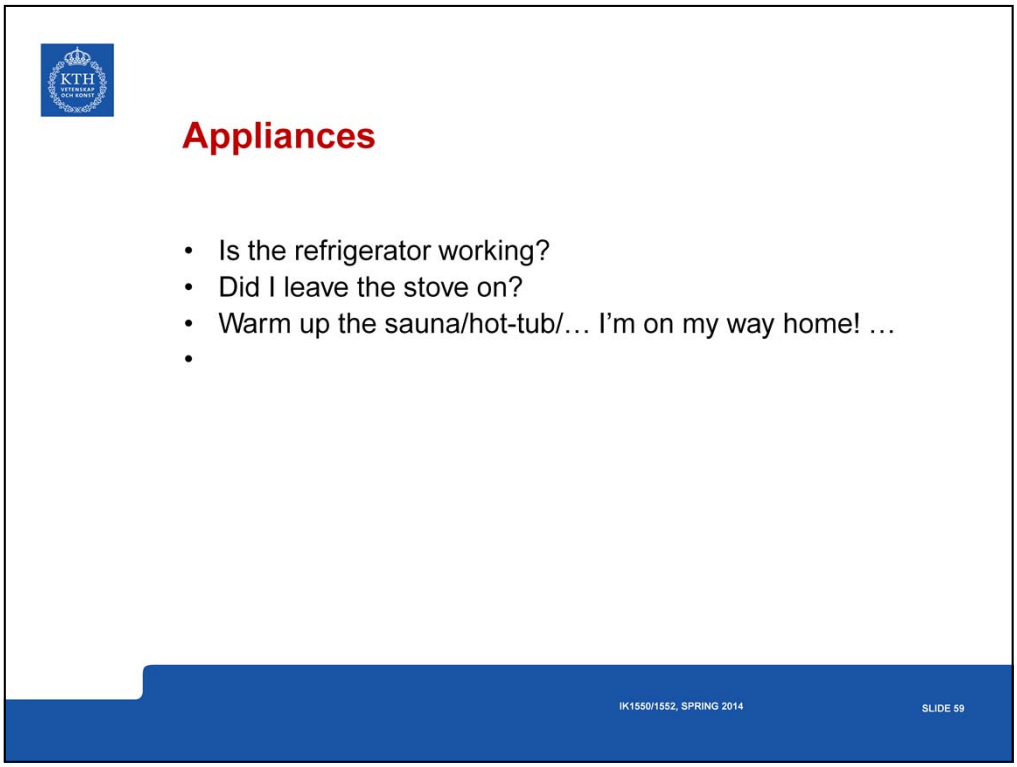
Appliances
• Is the refrigerator working?
• Did I leave the stove on?
• Warm up the sauna/hot-tub/… I'm on my way home! …
•
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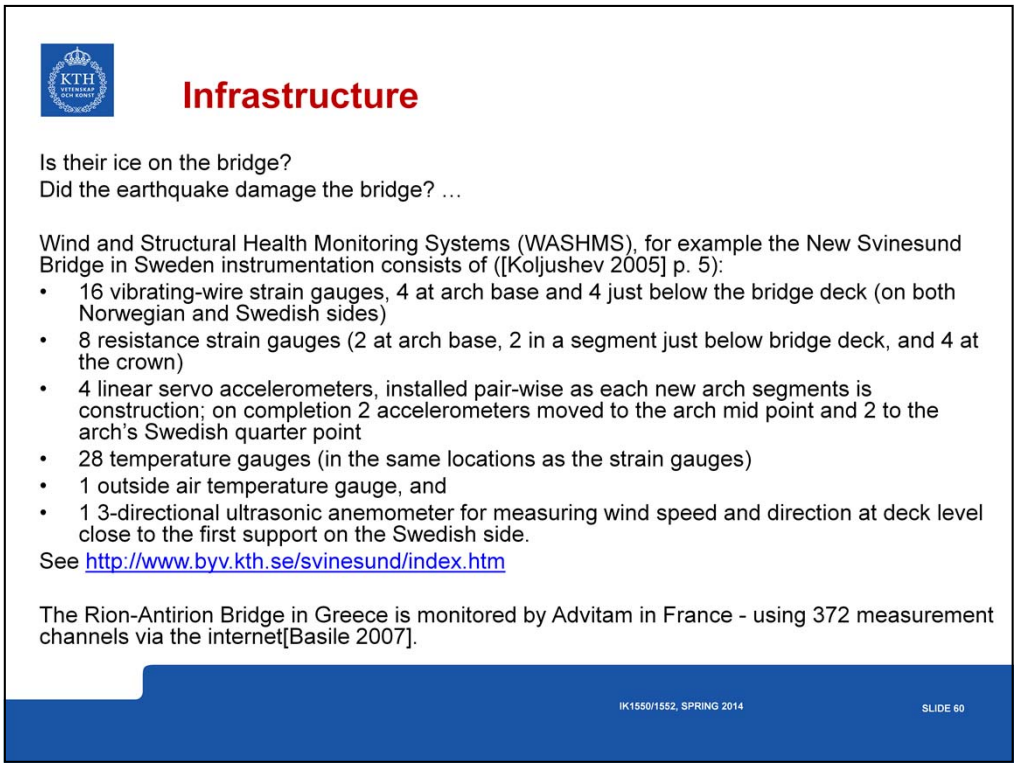

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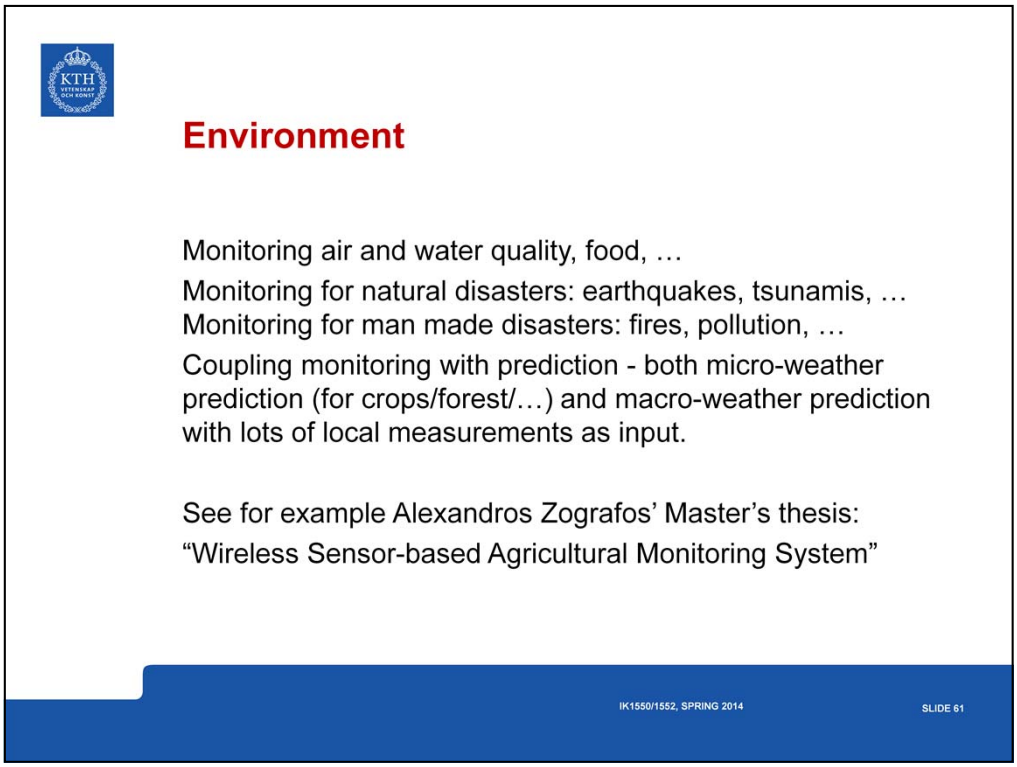
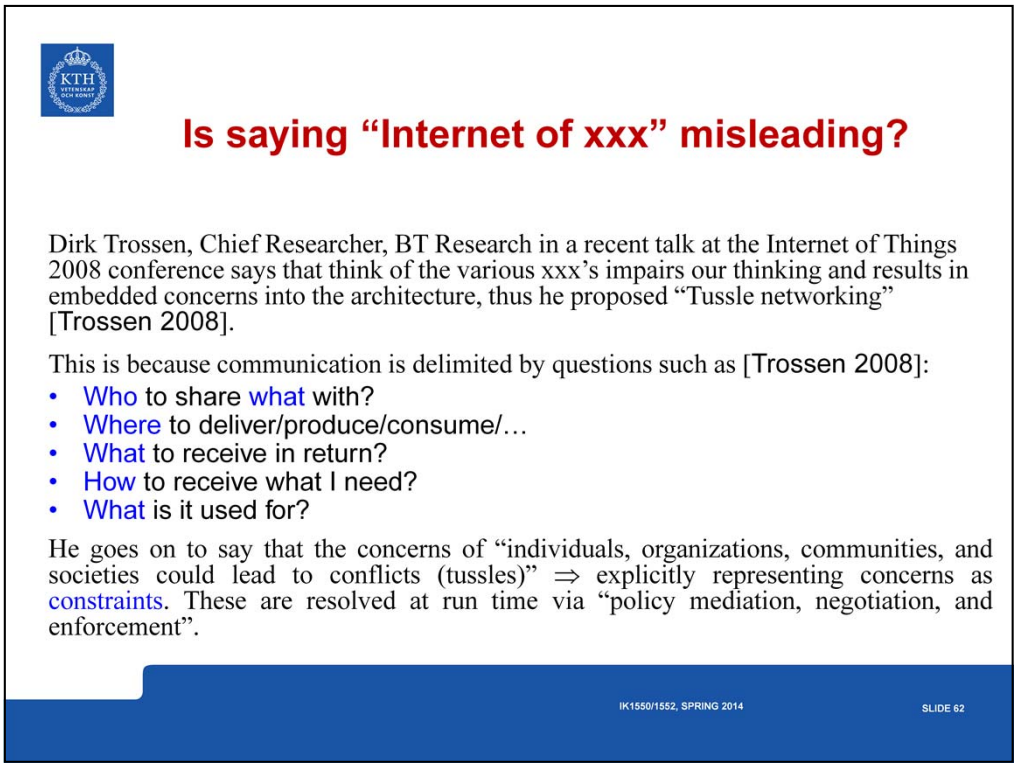
http://www.futurtec.fi/downloads/BM5%2520April%25202005%2520reprint.pdf

Bernard Basile, "Monitoring the Structural Health of the Rion-Antirion Bridge Using LabVIEW Real-Time", National Instruments Corporation, 4 August 2007.
http://sine.ni.com/cs/app/doc/p/id/cs-68

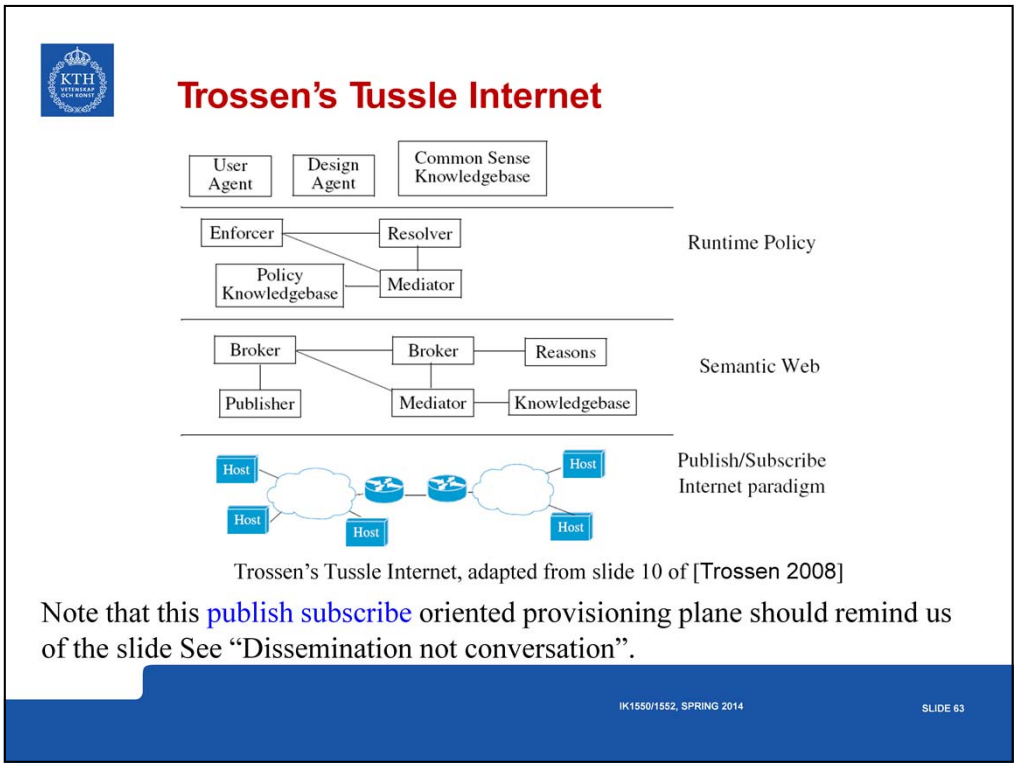


Alexandros Zografos, Wireless Sensor-based Agricultural Monitoring System, Master's thesis, KTH Royal Institute of Technology, School of Information and Communication Technology, Stockholm, Sweden, TRITA-ICT-EX-2014:25, March 2014

http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-143633



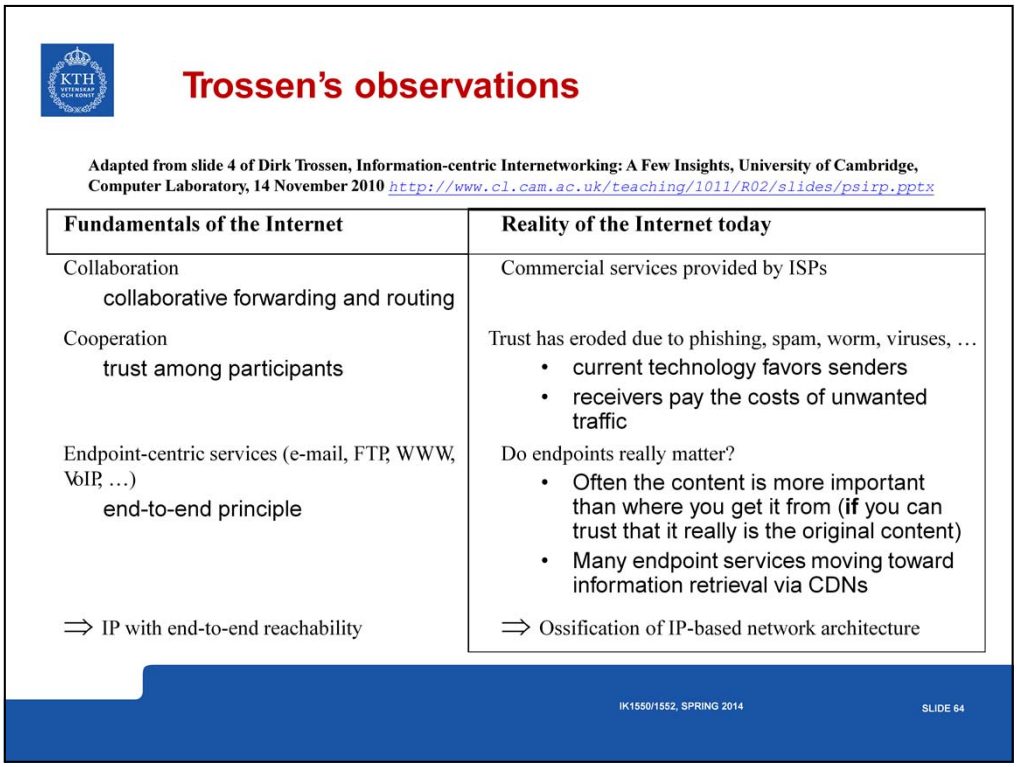
Dirk Trossen, "From The Internet of ??? To The Future Internet", Internet of Things 2008 conference, Zurich *http://www.the-internet-of-things.org/prg/slides/trossen.pdf*



Trossen's Tussle Internet, adapted from slide 10 of [Trossen 2008]

Note that this publish subscribe oriented provisioning plane should remind us of the slide See "Dissemination not conversation".

Dirk Trossen, "From The Internet of ??? To The Future Internet", Internet of Things 2008 conference, Zurich *http://www.the-internet-of-things.org/prg/slides/trossen.pdf*


Trossen's observations
Adapted from slide 4 of Dirk Trossen, Information-centric Internetworking: A Few Insights, University of Cambridge, Computer Laboratory, 14 November 2010 http://www.cl.cam.ac.uk/teaching/1011/R02/slides/psirp.pptx
Fundamentals of the Internet
Reality of the Internet today
Collaboration
collaborative forwarding and routing
Commercial services provided by ISPs
Cooperation
trust among participants
Trust has eroded due to phishing, spam, worm, viruses, …
• current technology favors senders
• receivers pay the costs of unwanted traffic
Endpoint-centric services (e-mail, FTP, WWW, VoIP, …)
end-to-end principle
Do endpoints really matter?
• Often the content is more important than where you get it from (if you can trust that it really is the original content)
• Many endpoint services moving toward information retrieval via CDNs
⇒ IP with end-to-end reachability
⇒ Ossification of IP-based network architecture
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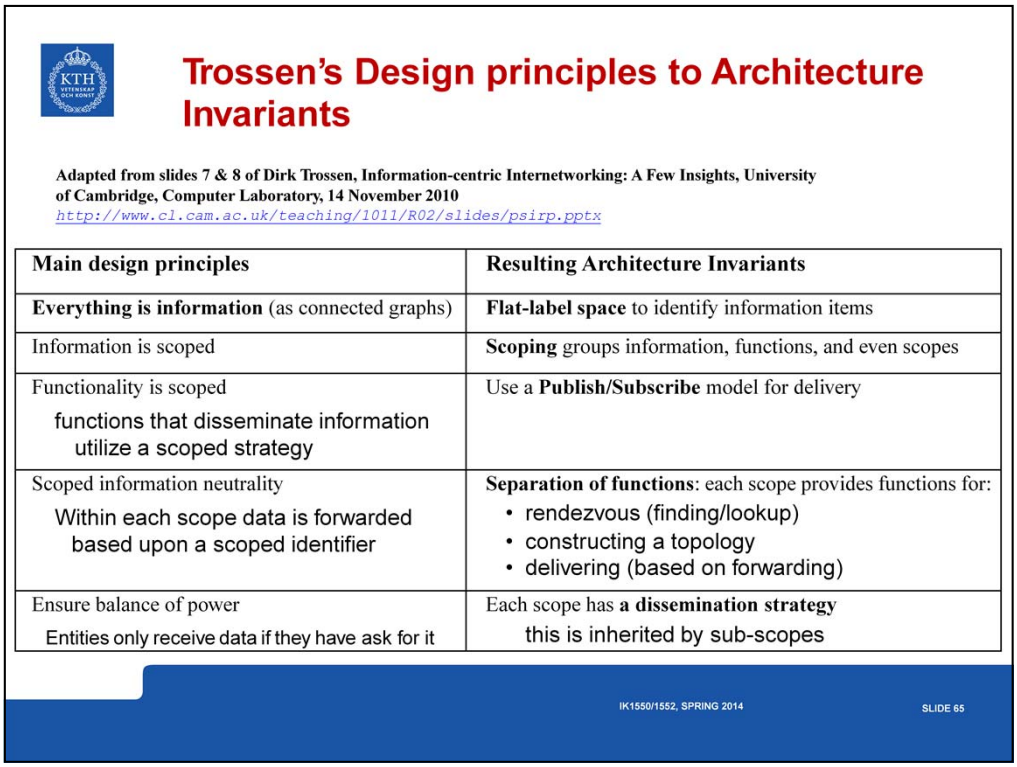

Trossen's Design principles to Architecture Invariants

Adapted from slides 7 & 8 of Dirk Trossen, Information-centric Internetworking: A Few Insights, University of Cambridge, Computer Laboratory, 14 November 2010
http://www.cl.cam.ac.uk/teaching/1011/R02/slides/psirp.pptx

Main design principles	**Resulting Architecture Invariants**
Everything is information (as connected graphs)	**Flat-label space** to identify information items
Information is scoped	**Scoping** groups information, functions, and even scopes
Functionality is scoped functions that disseminate information utilize a scoped strategy	Use a **Publish/Subscribe** model for delivery
Scoped information neutrality Within each scope data is forwarded based upon a scoped identifier	**Separation of functions**: each scope provides functions for: • rendezvous (finding/lookup) • constructing a topology • delivering (based on forwarding)
Ensure balance of power Entities only receive data if they have ask for it	Each scope has **a dissemination strategy** this is inherited by sub-scopes

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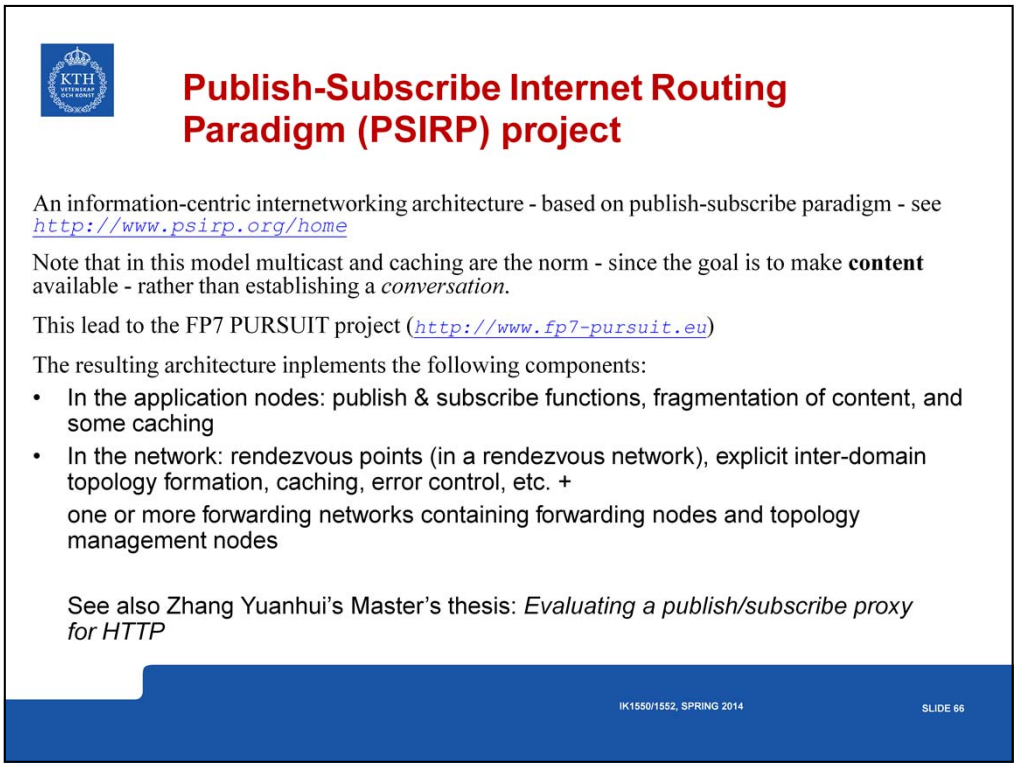
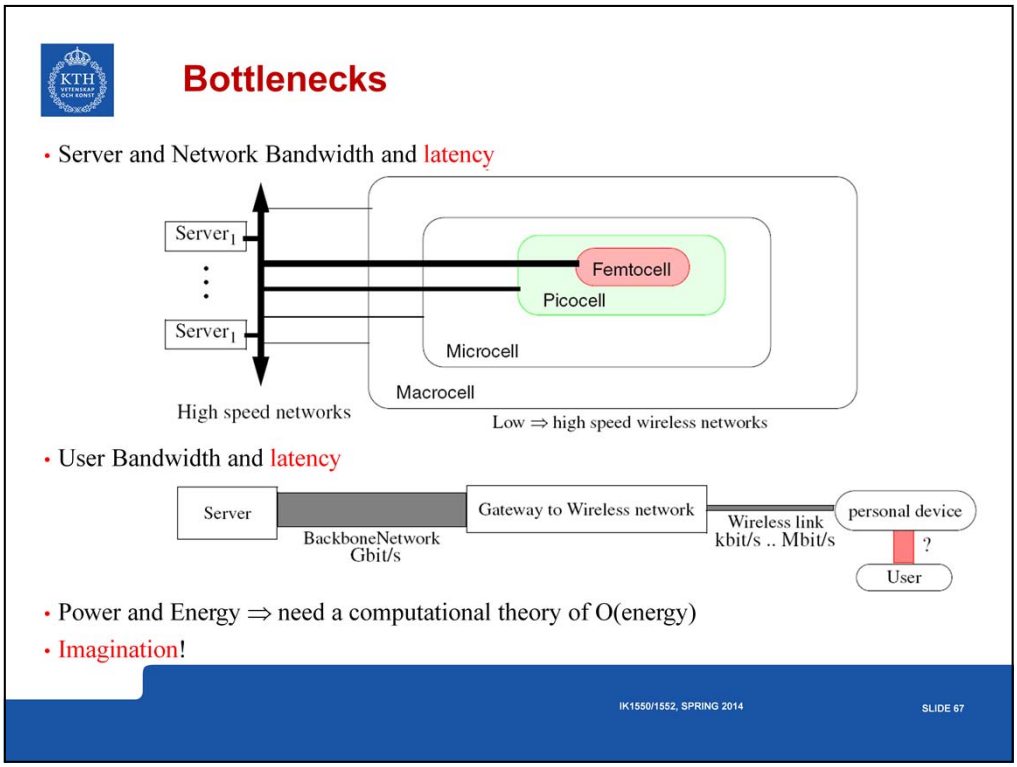


Zhang Yuanhui, Evaluating a publish/subscribe proxy for HTTP, Master's thesis, KTH Royal Institute of Technology, School of Information and Communication Technology, Stockholm, Sweden, TRITA-ICT-EX-2013:68, April 2013


Bottlenecks
• Server and Network Bandwidth and latency
Server1
Server1
Femtocell
Picocell
Microcell
Macrocell
High speed networks
Low ⇒ high speed wireless networks
• User Bandwidth and latency
Server
BackboneNetwork
Gbit/s
Gateway to Wireless network
Wireless link
kbit/s .. Mbit/s
personal device
?
User
• Power and Energy ⇒ need a computational theory of O(energy)
• Imagination!
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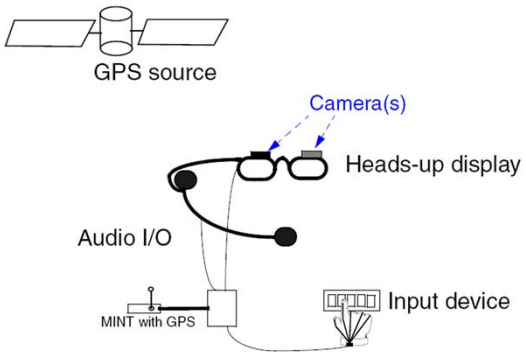
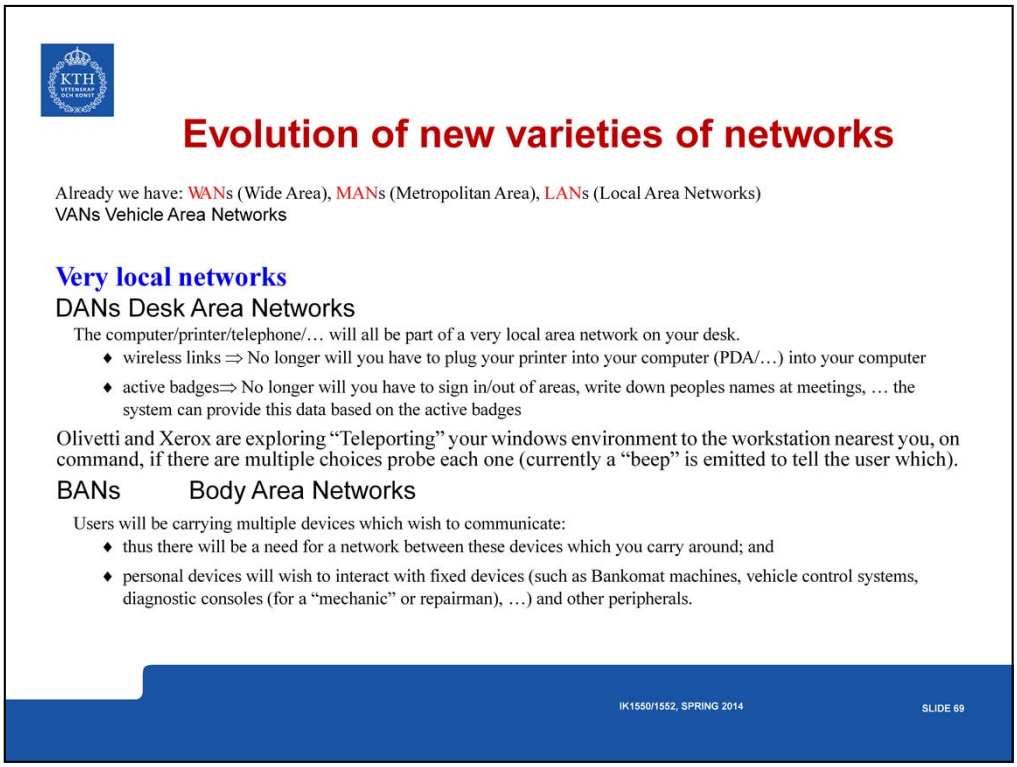
Near Future systems: Personal Portal



Vision-2, 2000 - high level of integration


Evolution of new varieties of networks
Already we have: WANs (Wide Area), MANs (Metropolitan Area), LANs (Local Area Networks)
VANs Vehicle Area Networks
Very local networks
DANs Desk Area Networks
The computer/printer/telephone/… will all be part of a very local area network on your desk.
wireless links ⇒ No longer will you have to plug your printer into your computer (PDA/…) into your computer
active badges⇒ No longer will you have to sign in/out of areas, write down peoples names at meetings, … the system can provide this data based on the active badges
Olivetti and Xerox are exploring "Teleporting" your windows environment to the workstation nearest you, on command, if there are multiple choices probe each one (currently a "beep" is emitted to tell the user which).
BANs Body Area Networks
Users will be carrying multiple devices which wish to communicate:
thus there will be a need for a network between these devices which you carry around; and
personal devices will wish to interact with fixed devices (such as Bankomat machines, vehicle control systems, diagnostic consoles (for a "mechanic" or repairman), …) and other peripherals.
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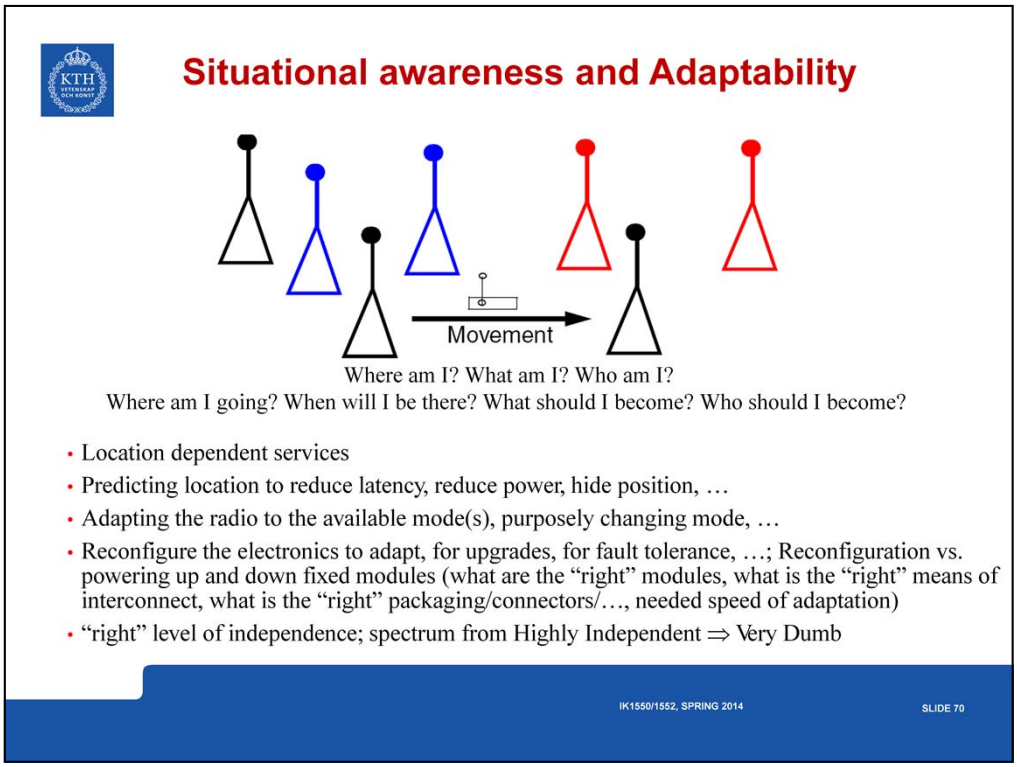
Situational awareness and Adaptability
Movement
Where am I? What am I? Who am I?
Where am I going? When will I be there? What should I become? Who should I become?
• Location dependent services
• Predicting location to reduce latency, reduce power, hide position, …
• Adapting the radio to the available mode(s), purposely changing mode, …
• Reconfigure the electronics to adapt, for upgrades, for fault tolerance, …; Reconfiguration vs. powering up and down fixed modules (what are the "right" modules, what is the "right" means of interconnect, what is the "right" packaging/connectors/…, needed speed of adaptation)
• "right" level of independence; spectrum from Highly Independent ⇒ Very Dumb
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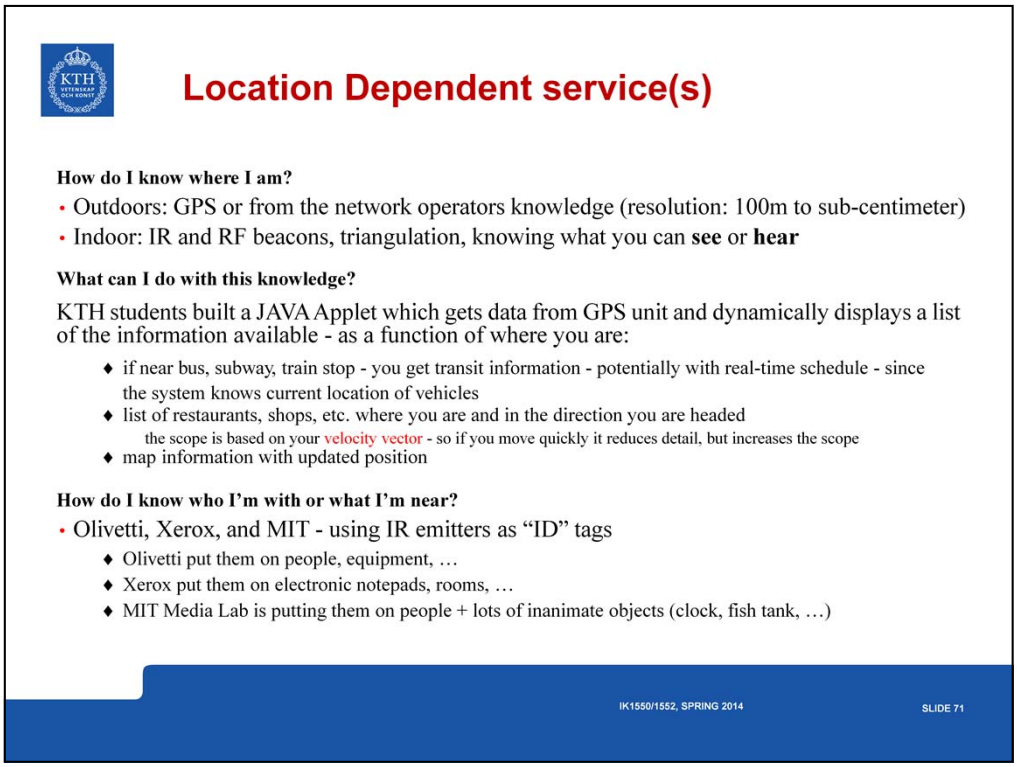
Location Dependent service(s)
How do I know where I am?
• Outdoors: GPS or from the network operators knowledge (resolution: 100m to sub-centimeter)
• Indoor: IR and RF beacons, triangulation, knowing what you can see or hear
What can I do with this knowledge?
KTH students built a JAVA Applet which gets data from GPS unit and dynamically displays a list of the information available - as a function of where you are:
♦ if near bus, subway, train stop - you get transit information - potentially with real-time schedule - since the system knows current location of vehicles
♦ list of restaurants, shops, etc. where you are and in the direction you are headed
the scope is based on your velocity vector - so if you move quickly it reduces detail, but increases the scope
♦ map information with updated position
How do I know who I'm with or what I'm near?
• Olivetti, Xerox, and MIT - using IR emitters as "ID" tags
♦ Olivetti put them on people, equipment, …
♦ Xerox put them on electronic notepads, rooms, …
♦ MIT Media Lab is putting them on people + lots of inanimate objects (clock, fish tank, …)
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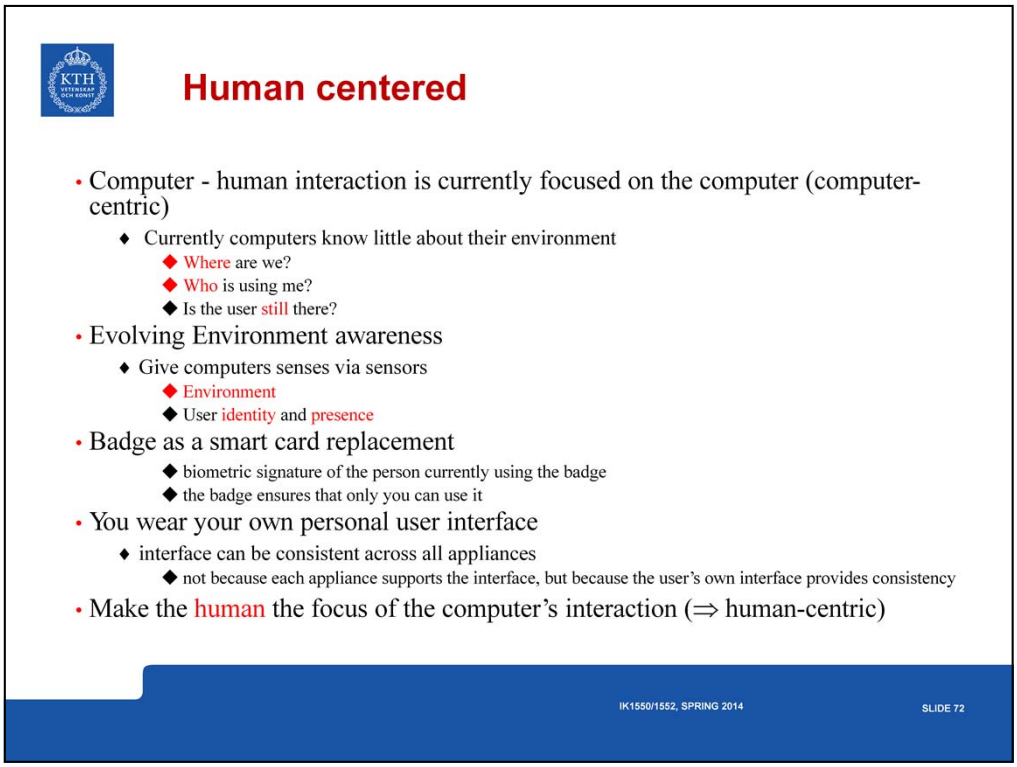
Human centered
• Computer - human interaction is currently focused on the computer (computer-centric)
♦ Currently computers know little about their environment
◆ Where are we?
◆ Who is using me?
◆ Is the user still there?
• Evolving Environment awareness
♦ Give computers senses via sensors
◆ Environment
◆ User identity and presence
• Badge as a smart card replacement
◆ biometric signature of the person currently using the badge
◆ the badge ensures that only you can use it
• You wear your own personal user interface
♦ interface can be consistent across all appliances
◆ not because each appliance supports the interface, but because the user's own interface provides consistency
• Make the human the focus of the computer's interaction (⇒ human-centric)
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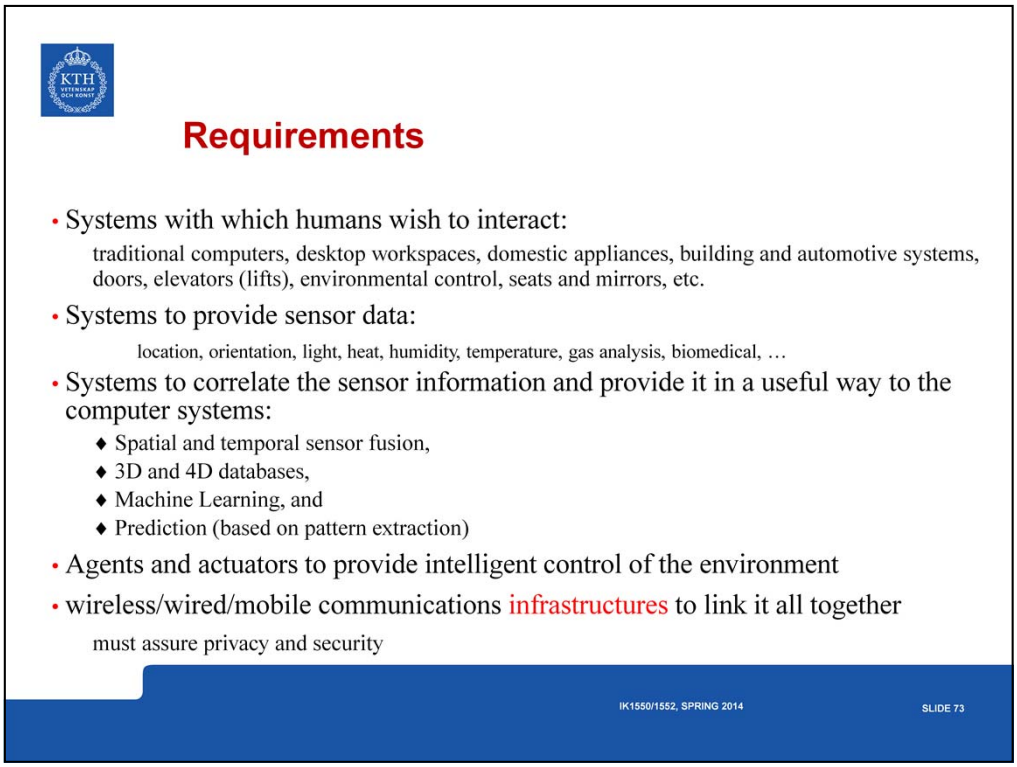
Requirements
• Systems with which humans wish to interact:
traditional computers, desktop workspaces, domestic appliances, building and automotive systems, doors, elevators (lifts), environmental control, seats and mirrors, etc.
• Systems to provide sensor data:
location, orientation, light, heat, humidity, temperature, gas analysis, biomedical, …
• Systems to correlate the sensor information and provide it in a useful way to the computer systems:
♦ Spatial and temporal sensor fusion,
♦ 3D and 4D databases,
♦ Machine Learning, and
♦ Prediction (based on pattern extraction)
• Agents and actuators to provide intelligent control of the environment
• wireless/wired/mobile communications infrastructures to link it all together
must assure privacy and security
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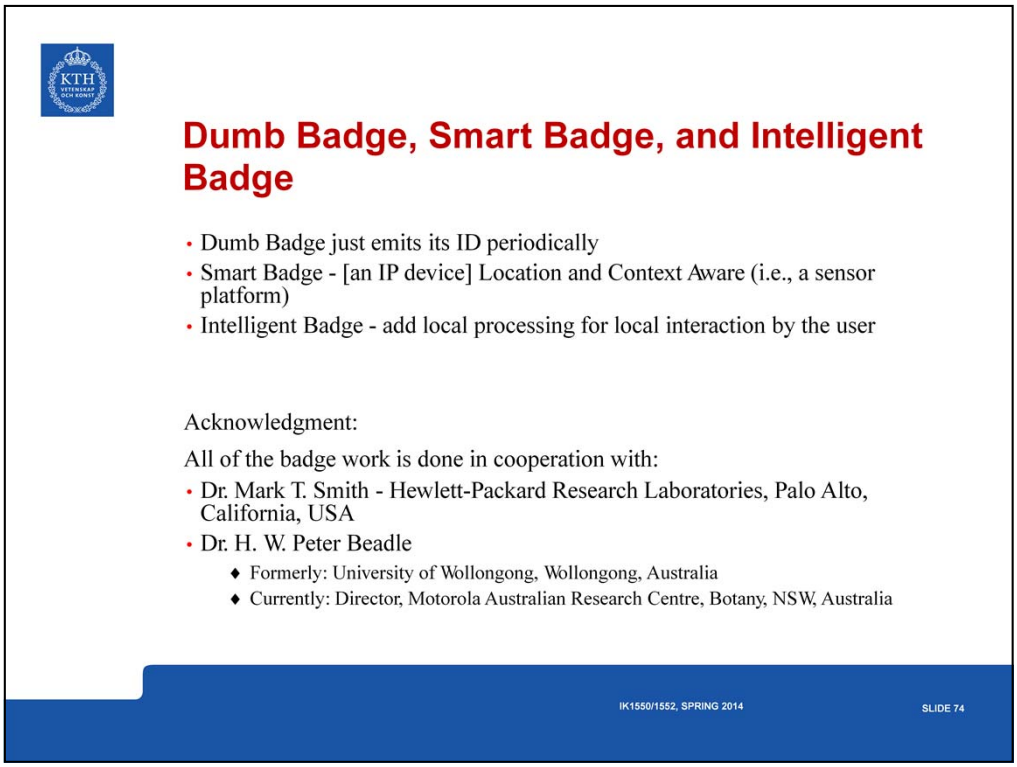
Dumb Badge, Smart Badge, and Intelligent Badge
• Dumb Badge just emits its ID periodically
• Smart Badge - [an IP device] Location and Context Aware (i.e., a sensor platform)
• Intelligent Badge - add local processing for local interaction by the user
Acknowledgment:
All of the badge work is done in cooperation with:
• Dr. Mark T. Smith - Hewlett-Packard Research Laboratories, Palo Alto, California, USA
• Dr. H. W. Peter Beadle
♦ Formerly: University of Wollongong, Wollongong, Australia
♦ Currently: Director, Motorola Australian Research Centre, Botany, NSW, Australia
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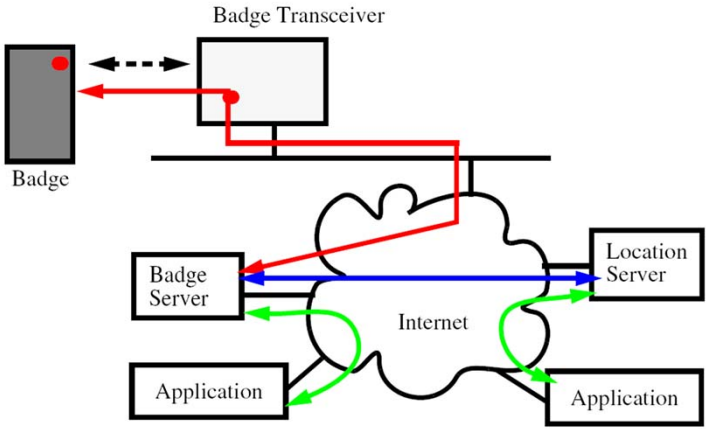
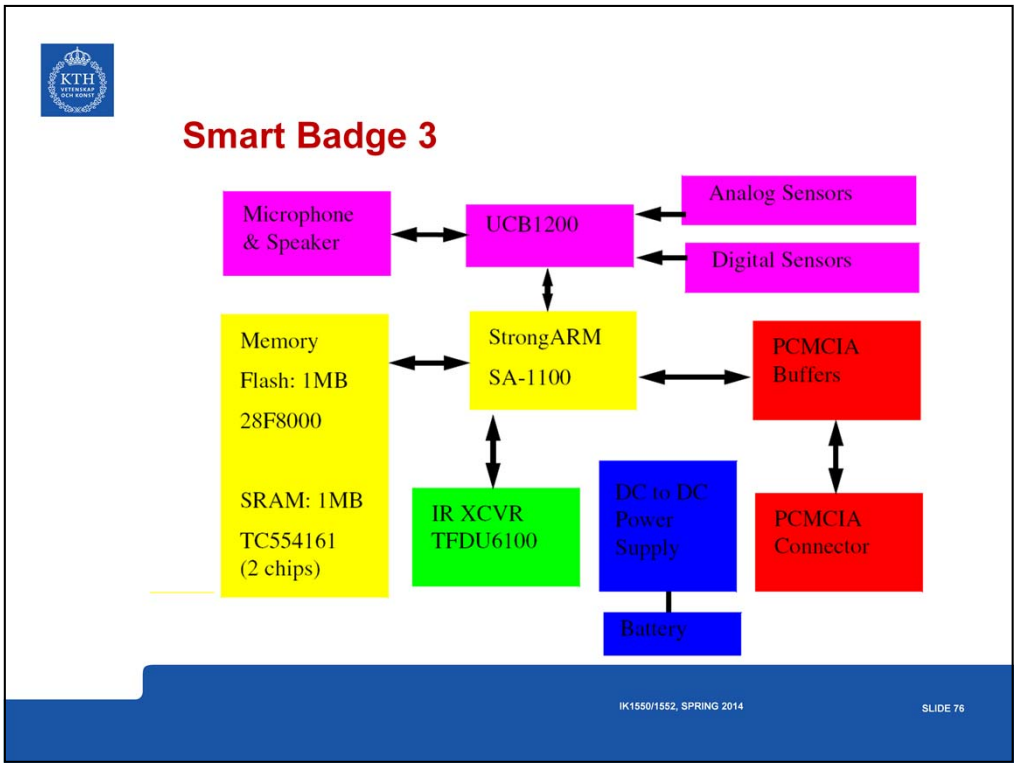
Badge Communications Model

Badges are IP devices (or should be), they communicate via network attached access points.



⇒ Banks as intermediaries (**if** they have **any** future role)


Smart Badge 3
Microphone & Speaker
UCB1200
Analog Sensors
Digital Sensors
Memory
Flash: 1MB
28F8000
SRAM: 1MB
TC554161
(2 chips)
StrongARM
SA-1100
PCMCIA Buffers
IR XCVR
TFDU6100
DC to DC Power Supply
PCMCIA Connector
Battery
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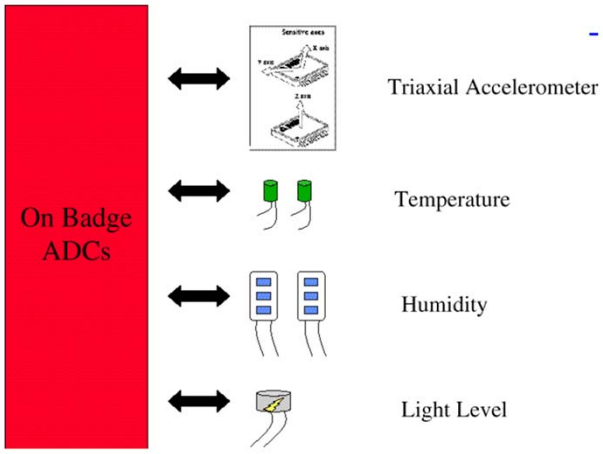
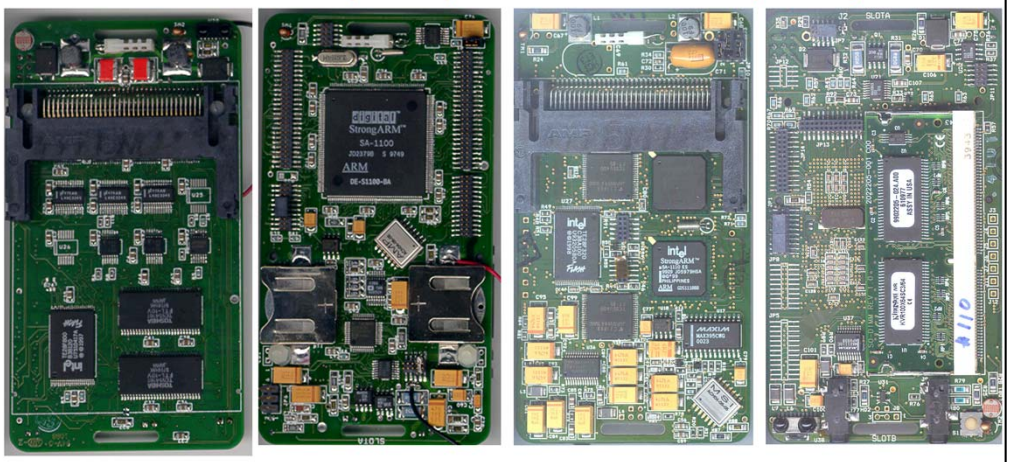
Smart Badge Sensors

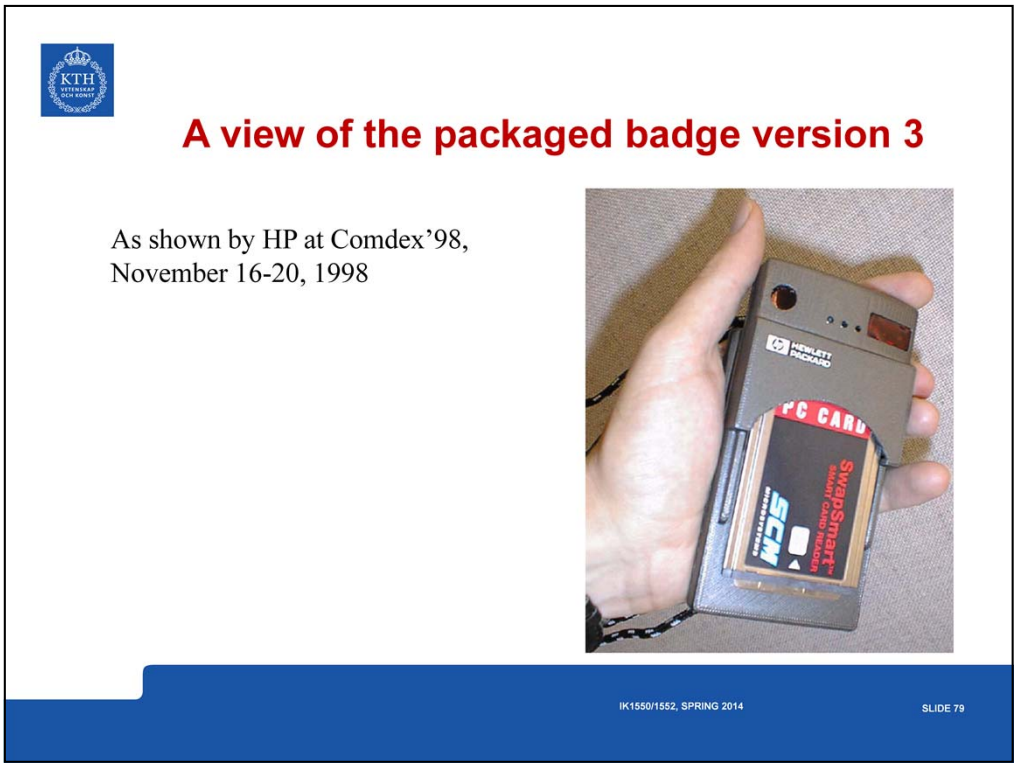


Details of the 3rd version: http://web.it.kth.se/~maguire/badge3/badge3.html

SmartBadge/BadgePad
version 3 (1997) version 4 (1999)



For details about version 4 see http://web.it.kth.se/~maguire/badge4.html


A view of the packaged badge version 3
As shown by HP at Comdex'98,
November 16-20, 1998
HEWLETT PACKARD
SwapSmart
IK1550/1552, SPRING 2014
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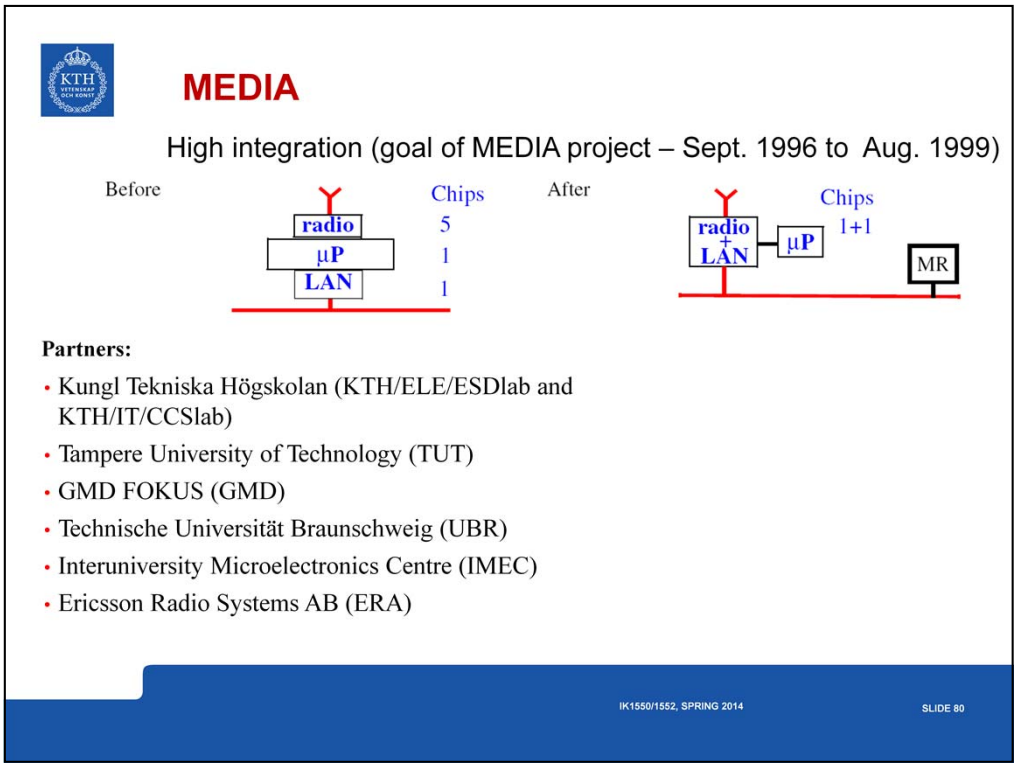
MEDIA
High integration (goal of MEDIA project – Sept. 1996 to Aug. 1999)
Before
radio
µP
LAN
Chips
5
1
1
After
radio + LAN
µP
Chips
1+1
MR
Partners:
• Kungl Tekniska Högskolan (KTH/ELE/ESDlab and KTH/IT/CCSlab)
• Tampere University of Technology (TUT)
• GMD FOKUS (GMD)
• Technische Universität Braunschweig (UBR)
• Interuniversity Microelectronics Centre (IMEC)
• Ericsson Radio Systems AB (ERA)
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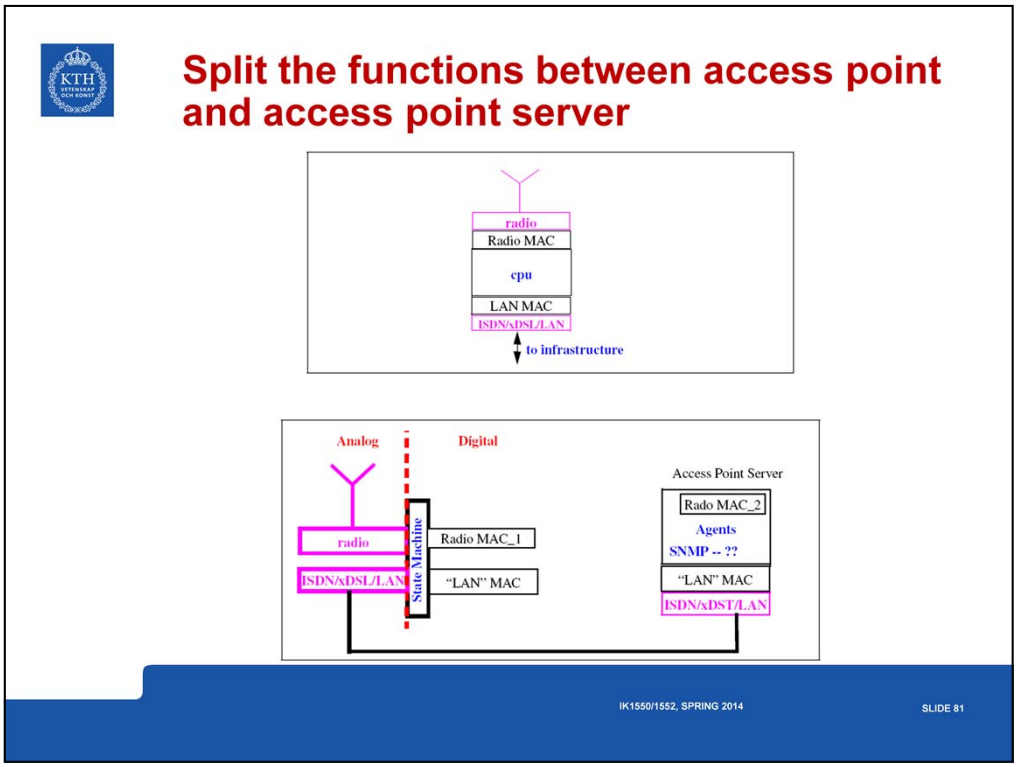
Split the functions between access point and access point server
radio
Radio MAC
cpu
LAN MAC
ISDN/xDSL/LAN
to infrastructure
Analog
Digital
radio
ISDN/xDSL/LAN
State Machine
Radio MAC_1
"LAN" MAC
Access Point Server
Rado MAC_2
Agents
SNMP -- ??
"LAN" MAC
ISDN/xDST/LAN
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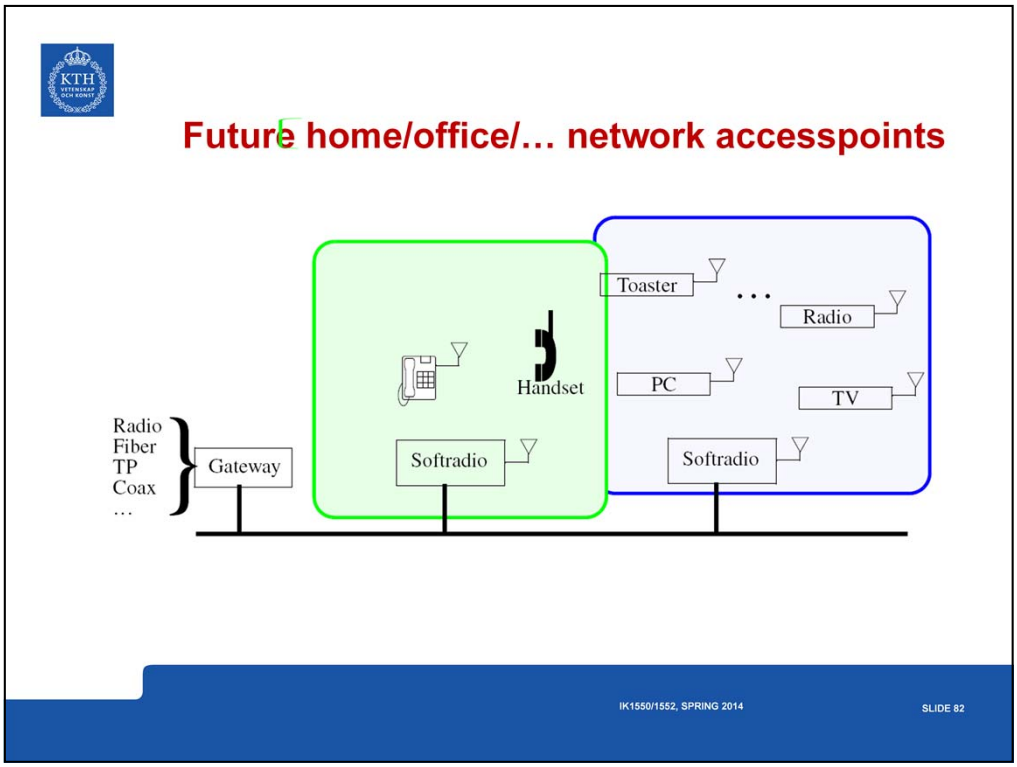
Future home/office/… network accesspoints
Toaster
Radio
PC
TV
Handset
Softradio
Softradio
Radio
Fiber
TP
Coax
…
Gateway
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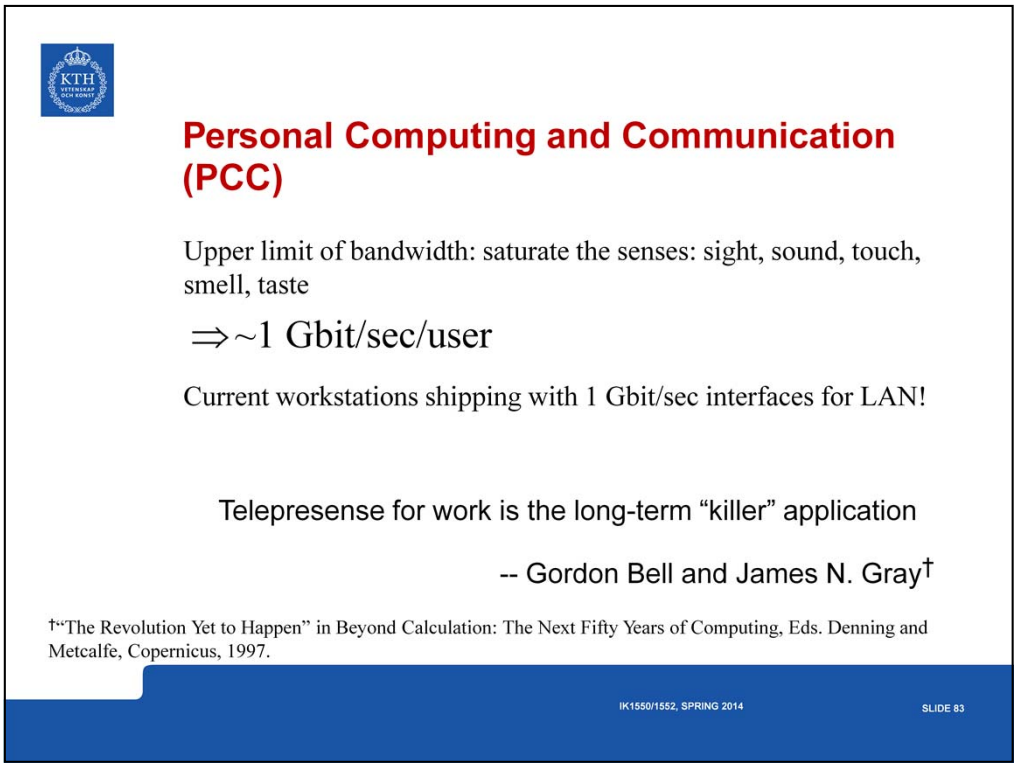
Personal Computing and Communication (PCC)
Upper limit of bandwidth: saturate the senses: sight, sound, touch, smell, taste
⇒~1 Gbit/sec/user
Current workstations shipping with 1 Gbit/sec interfaces for LAN!
Telepresense for work is the long-term "killer" application
-- Gordon Bell and James N. Gray†
†"The Revolution Yet to Happen" in Beyond Calculation: The Next Fifty Years of Computing, Eds. Denning and Metcalfe, Copernicus, 1997.
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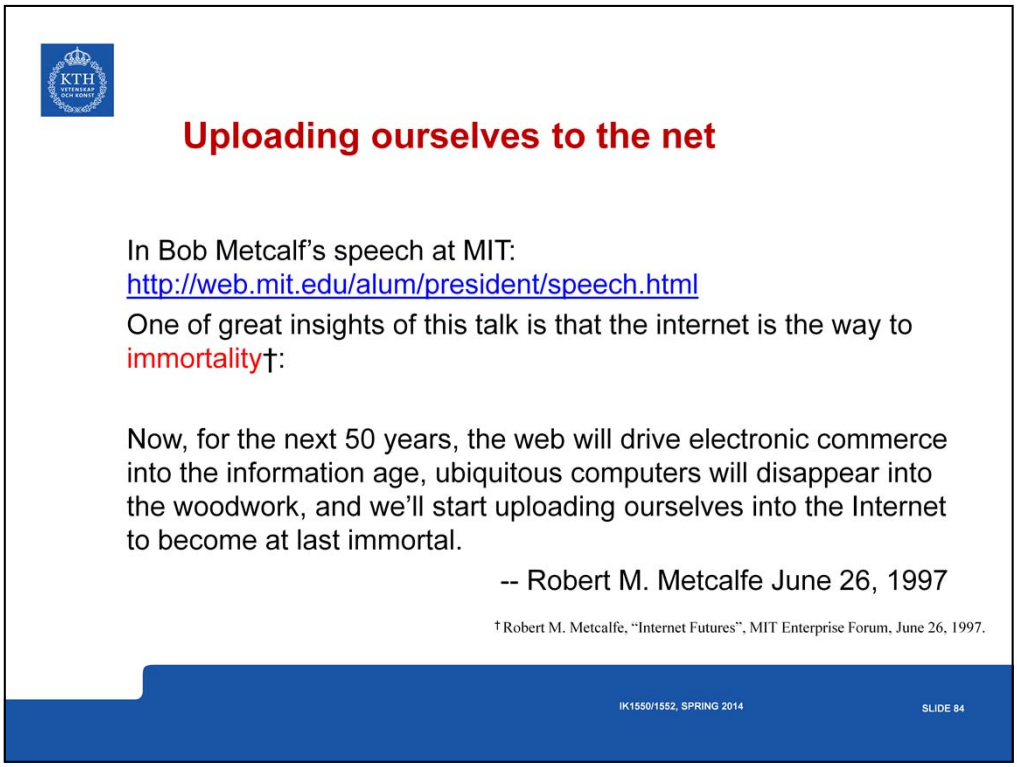
Uploading ourselves to the net
In Bob Metcalf's speech at MIT:
http://web.mit.edu/alum/president/speech.html
One of great insights of this talk is that the internet is the way to immortality†:
Now, for the next 50 years, the web will drive electronic commerce into the information age, ubiquitous computers will disappear into the woodwork, and we'll start uploading ourselves into the Internet to become at last immortal.
-- Robert M. Metcalfe June 26, 1997
† Robert M. Metcalfe, "Internet Futures", MIT Enterprise Forum, June 26, 1997.
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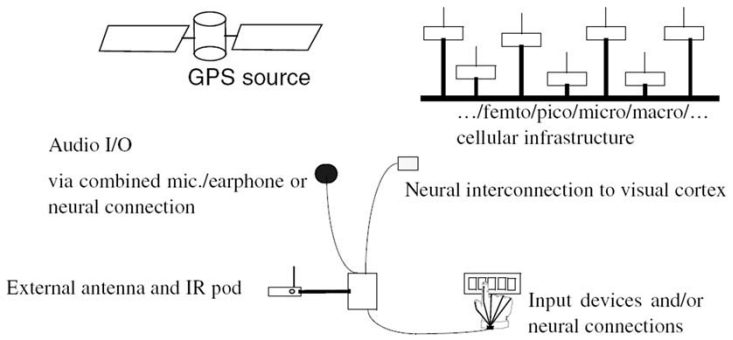
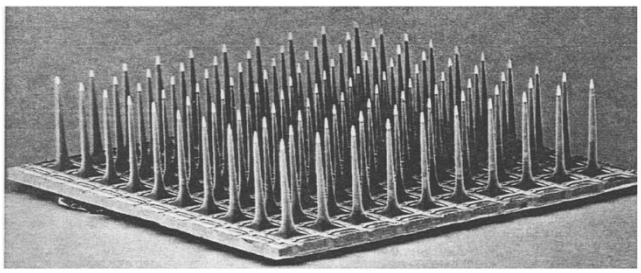
Future Systems



Vision-3, 2005-2015 - very high level of integration

Bionic Technologies, Inc.†s Intracortical Electrode Array – aka "Utah array"

Acute microelectrode assembly (10x10 array, 100 active electrodes)



10 x 10 silicon electrode array (each electrode: 1.5mm long, 0.08mm wide at base, 0.001mm tip), Built at the Univ. of Utah, by Richard A. Normann, et al.; from Scientific American, March 1994, pg. 108.

See http://www.blackrockmicro.com/content.aspx?id=78 and https://www.youtube.com/watch?v=EbOkBbtxw74

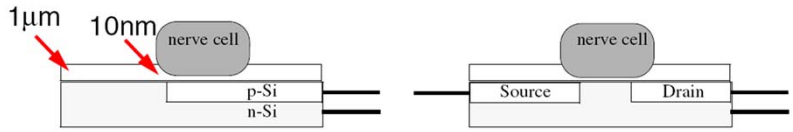
†Now: Blackrock Microsystems LLC.

Non-metalic bi-directional neural interfaces

Neurochip: Neuron silicon circuits http://www.biochem.mpg.de/en/eg/fromherz

(a) Silicon-Neuron Junction (input to the nerve)

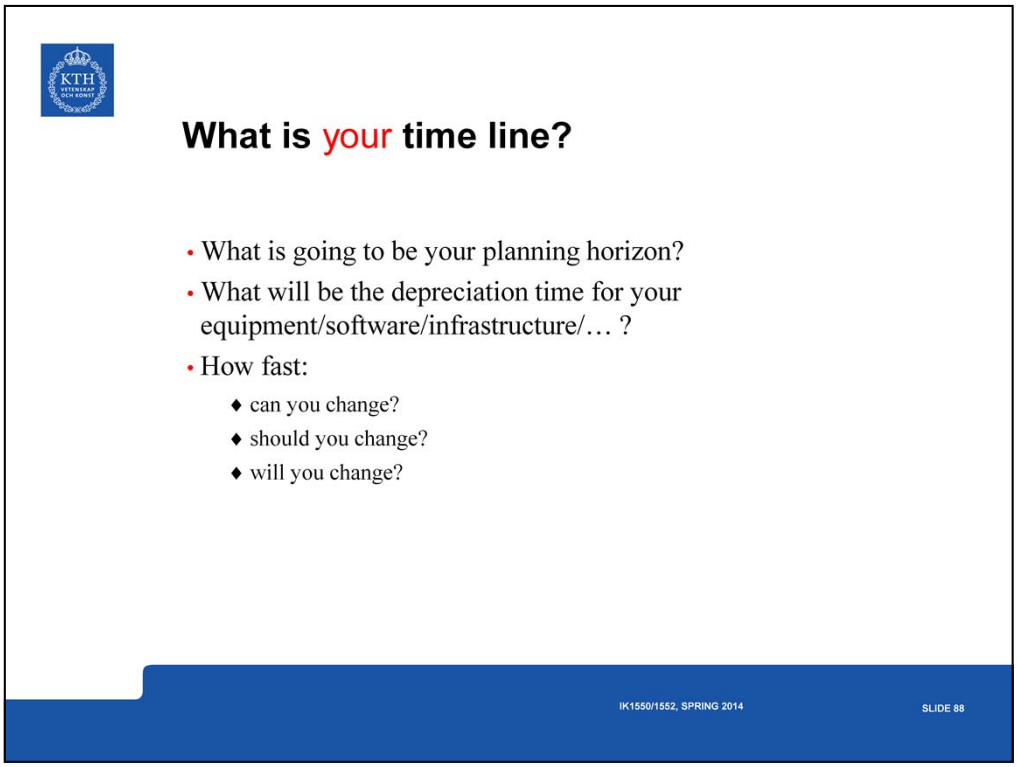
(b) Neuron transistor (output from the nerve)



(a) Capacitive coupling of data into nerve and
(b) using the charge in the nerve to control a transistor's gate for getting data out of the nerve

(a) Peter Fromherz and Alfred Stett, "Silicon-Neuron Junction: Capacitive Stimulation of an Individual Neuron on a Silicon Chip" Phys.Rev.Lett. 75 (1995) 1670-1673

(b) P.Fromherz, A.Offenhäusser, T.Vetter, and J.Weis, "A Neuron-Silicon Junction: A Retzius-Cell of the Leech on an Insulated-Gate Field-Effect Transistor" Science 252 (1991) 1290-1293.


What is your time line?
• What is going to be your planning horizon?
• What will be the depreciation time for your equipment/software/infrastructure/… ?
• How fast:
♦ can you change?
♦ should you change?
♦ will you change?
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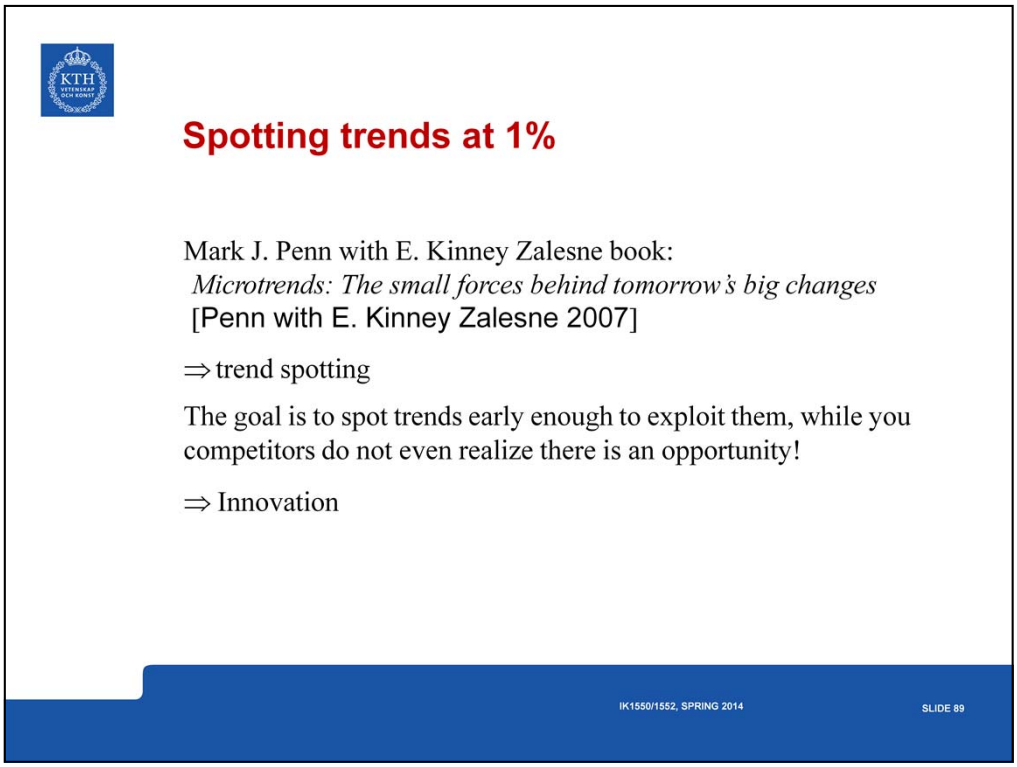
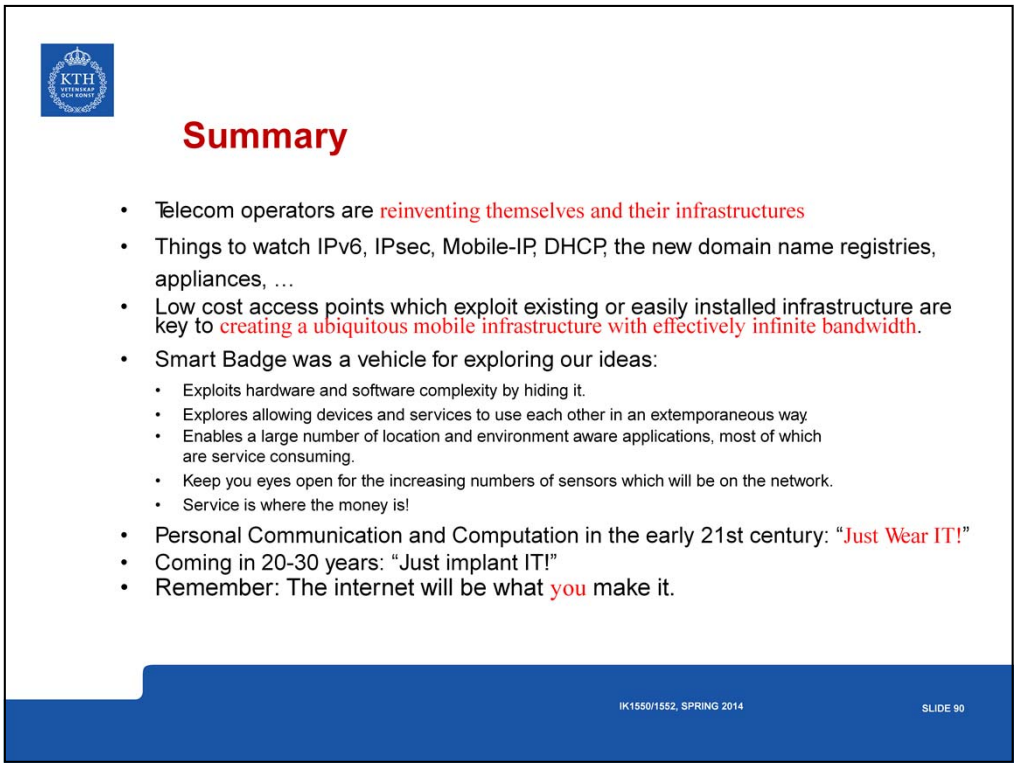


Mark J. Penn with E. Kinney Zalesne, Microtrends: The small forces behind tomorrow's big changes, Twelve (The Hachette Book Group), NY, NY, 2007, ISBN 978-0-446-69976-1


Summary
Telecom operators are reinventing themselves and their infrastructures
Things to watch IPv6, IPsec, Mobile-IP, DHCP, the new domain name registries, appliances, …
Low cost access points which exploit existing or easily installed infrastructure are key to creating a ubiquitous mobile infrastructure with effectively infinite bandwidth.
Smart Badge was a vehicle for exploring our ideas:
Exploits hardware and software complexity by hiding it.
Explores allowing devices and services to use each other in an extemporaneous way.
Enables a large number of location and environment aware applications, most of which are service consuming.
Keep you eyes open for the increasing numbers of sensors which will be on the network.
Service is where the money is!
Personal Communication and Computation in the early 21st century: "Just Wear IT!"
Coming in 20-30 years: "Just implant IT!"
Remember: The internet will be what you make it.
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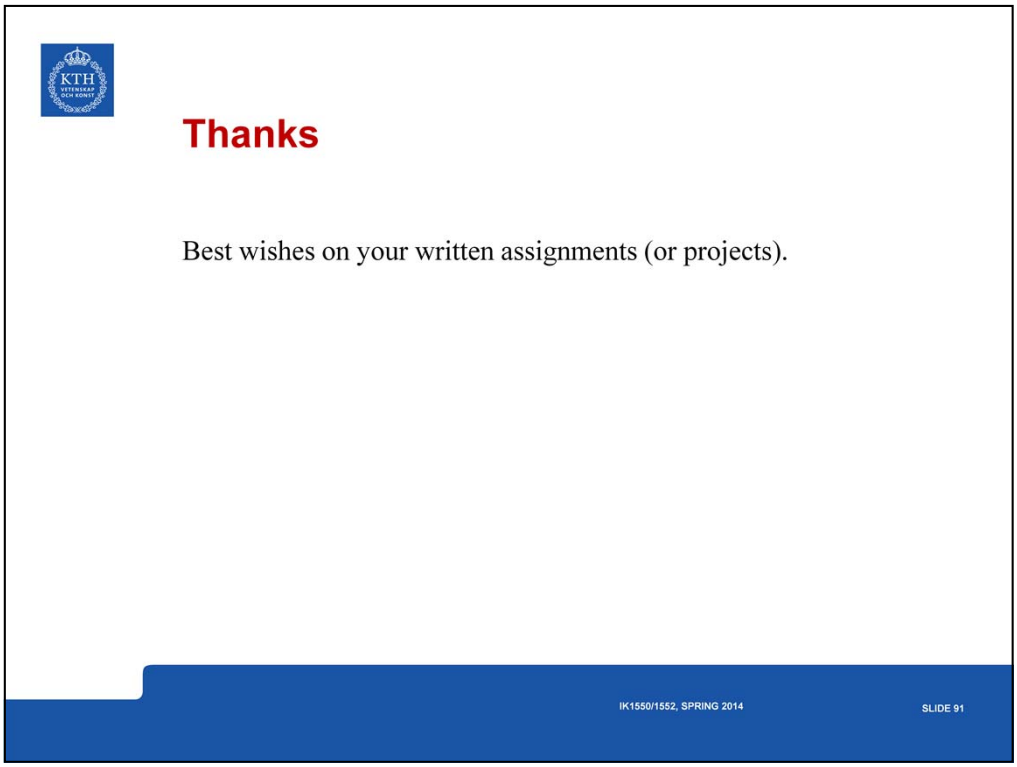
Thanks
Best wishes on your written assignments (or projects).
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¿Questions?
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