The prospects of self-aware networks

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Where innovation starts

Advances in communication networks:
The human switch

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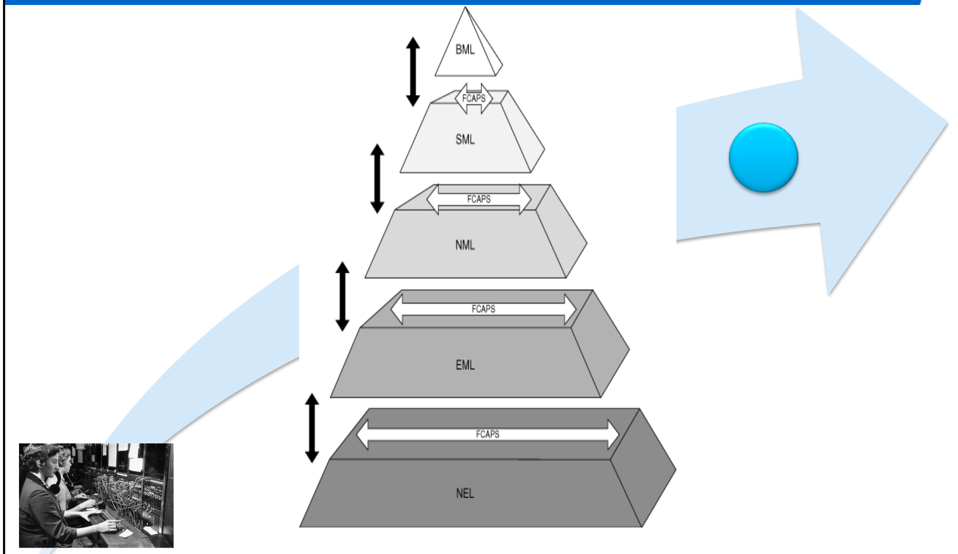
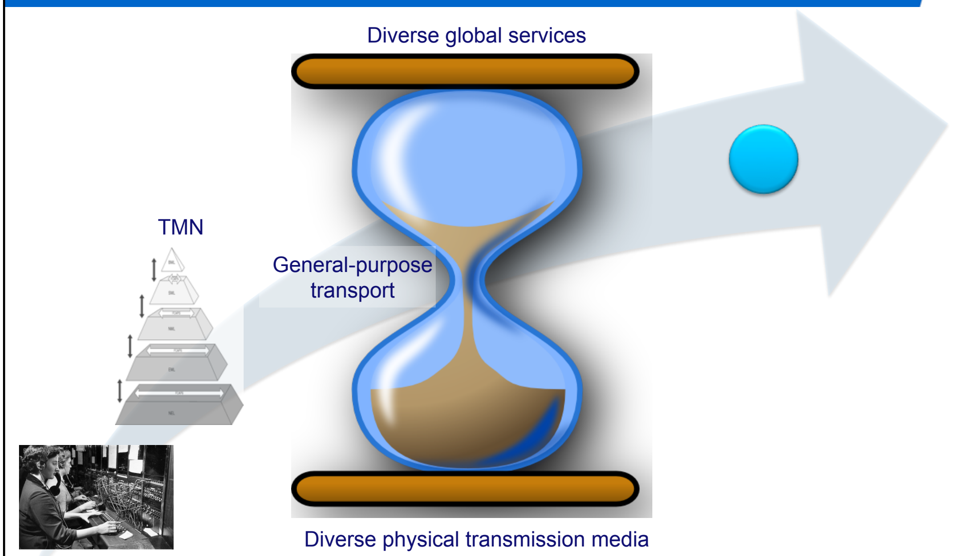
Advances in communication networks:
The perfectly engineered Telecommunications Management Network



Human switch

Advances in communication networks:
A perfectly simple Net

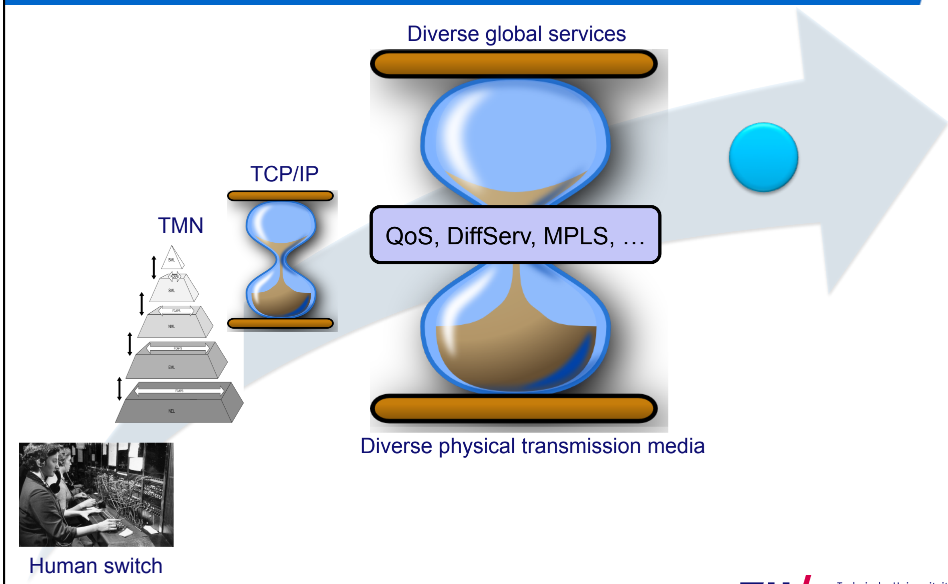
Diverse global services



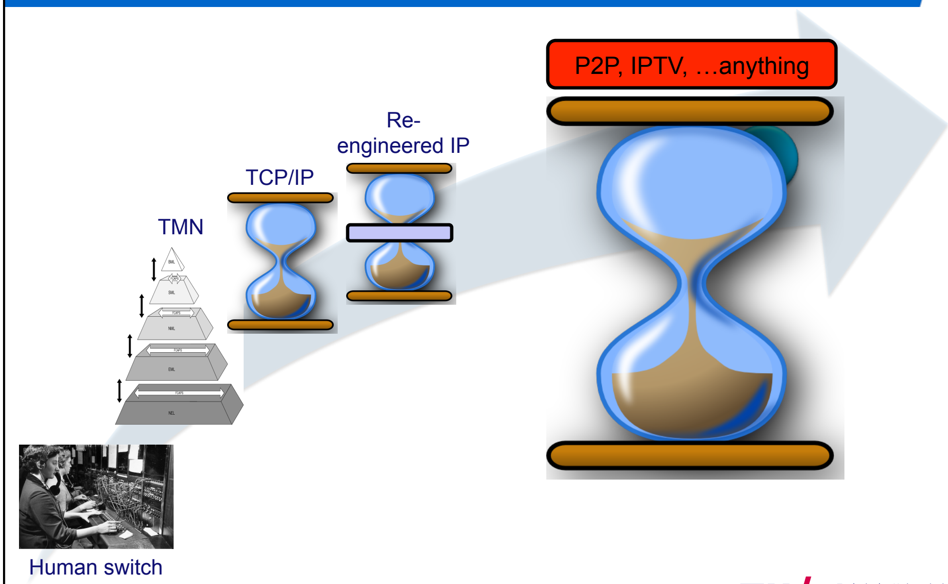
Human switch

Diverse physical transmission media

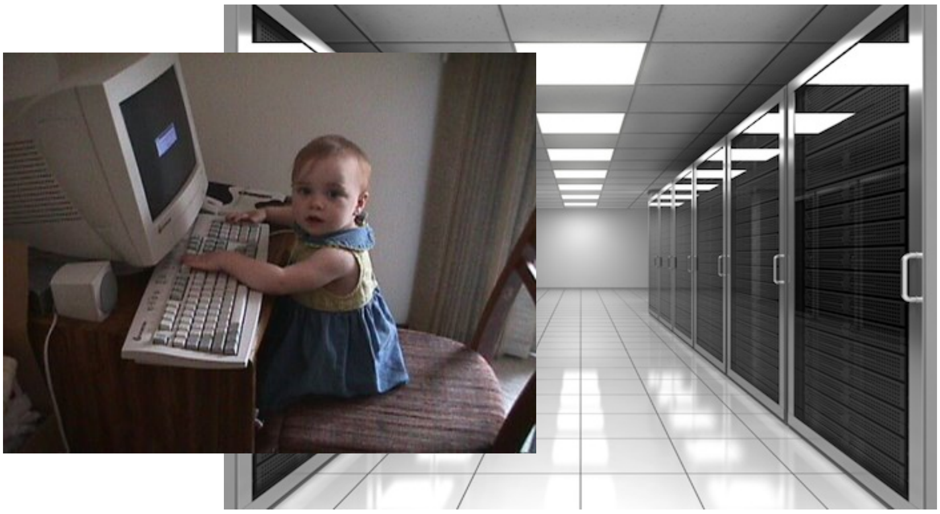
Advances in communication networks:
The (unsuccessful) re-engineered IP



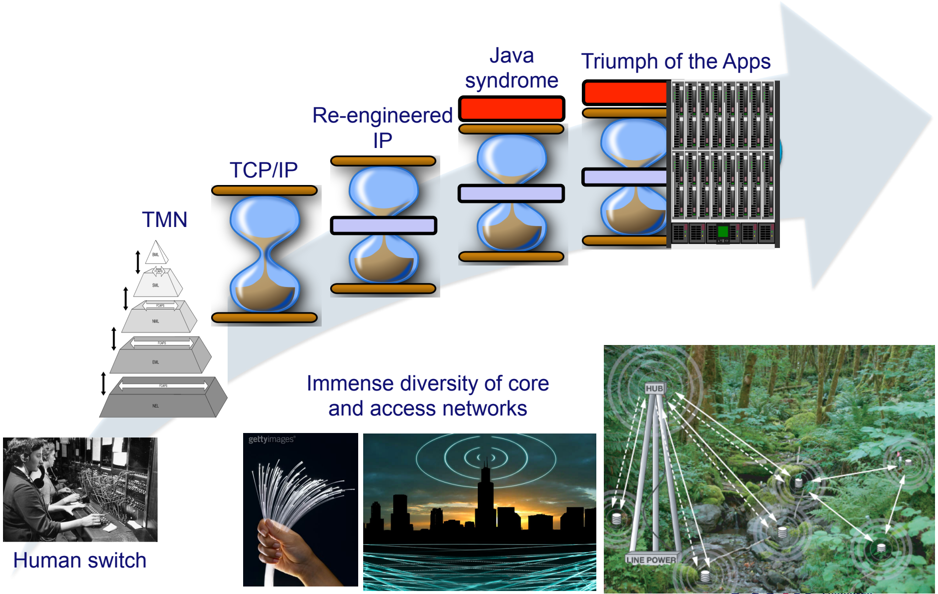
Advances in communication networks:
The Java syndrome



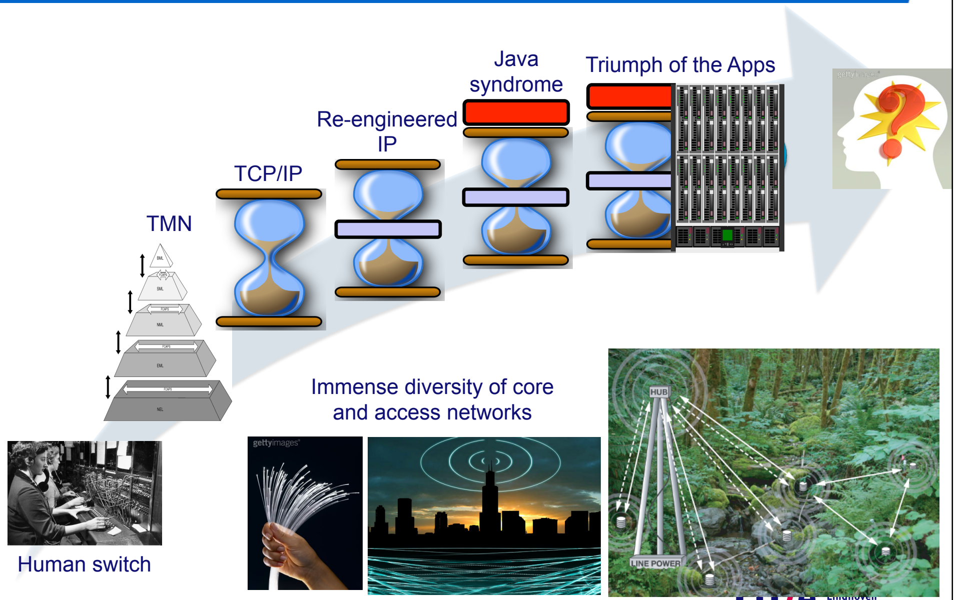
Advances in communication networks:
Everything in the cloud



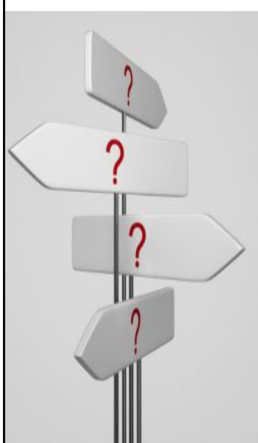
Advances in communication networks:
Triumph of the *Apps* and “near”-ubiquitous connectivity



Advances in communication networks:
Next ????



Multi-dimensional evolution



- Any application on any terminal
- Any application in the Cloud
- Communic. is spontaneous, on-demand, erratic and opportunistic
- Real-time services over best-effort Net

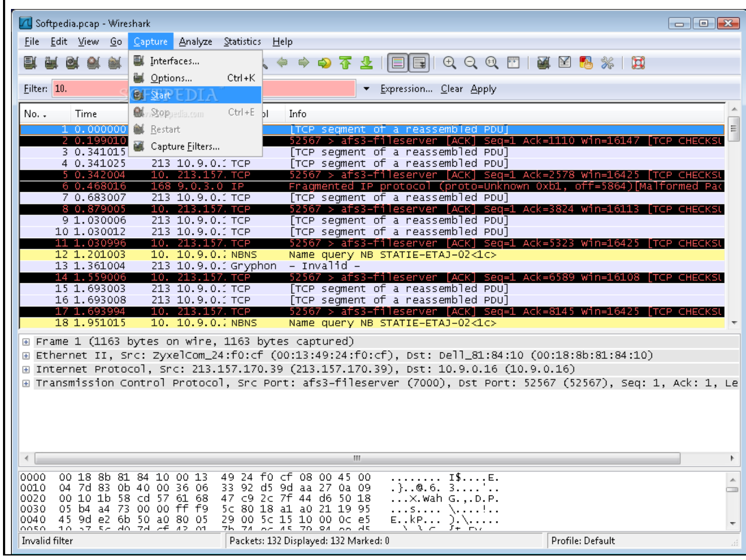
Immediate scenarios to deal with

- Massive routing networks (anything can route)
- Ultra-complex contextual combinations (terminals, apps, content, preferences…)
- Huge range of dynamics (anything can change)
- Ubiquity beyond the managed infrastructure

… these translate into unavoidable research riddles …

1) Heisenberg's indetermination principle hits the network

➔ How can we monitor these massive, ultra-dynamic networks?



- Passive probes
- Active probes
- Polling
- Event based

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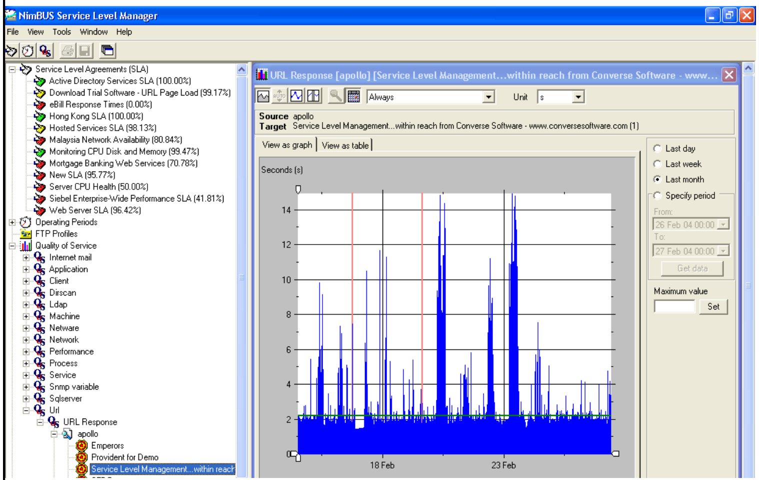

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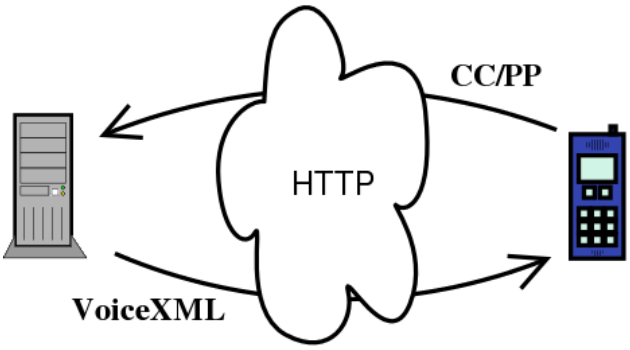
"I don't have a big screen, I'd prefer voice interaction"



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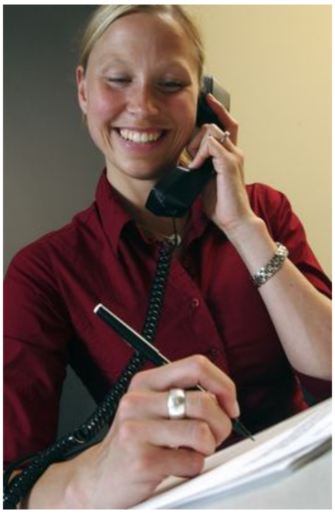

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- Offline QoE

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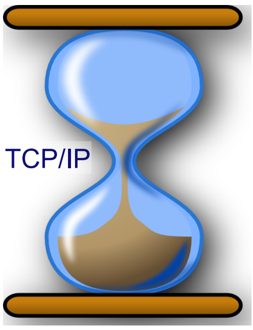


- Passive probes
- Active probes
- Polling
- Event based
- SLA Monitoring
- Terminal capab
- Offline QoE
- No Monitoring

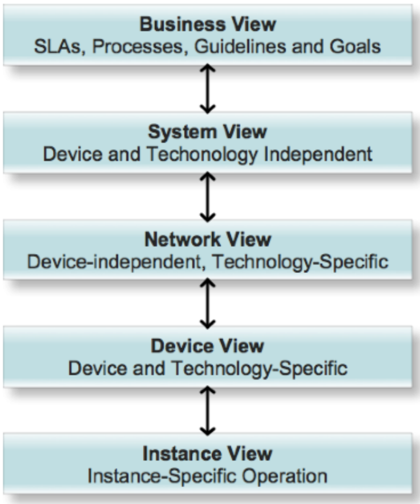
Perhaps we shouldn't try to monitor in the conventional way.
Time to look at new monitoring paradigms

… these translate into unavoidable research riddles …

2) The possibility of human intervention onto networked system becomes very limited

➔ How can we translate high-level business goals and orchestration policies onto the network?

Policy-based management is still reflecting the conventional management vision: we need to have solved the monitoring problem first



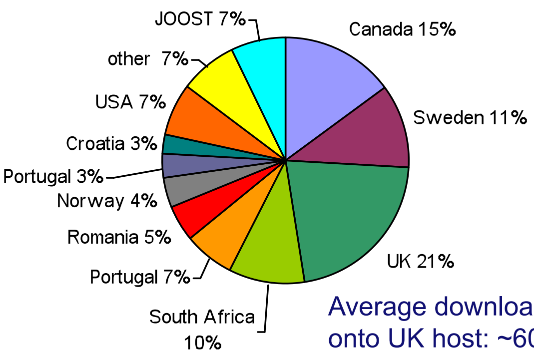
The policy continuum.
Source: Prof. P. Demeester, IBBT-U Gent

… these translate into unavoidable research riddles …

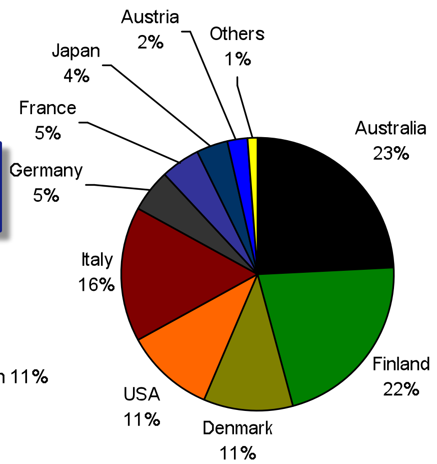
3) Self-management is probably the only way to go forward

➔ Can we really expect the network to stabilize and survive?

The relentless clash between overlay and underlay networks



Average download onto UK host: ~600 Kbps



Average upload from UK host: ~60 Kbps

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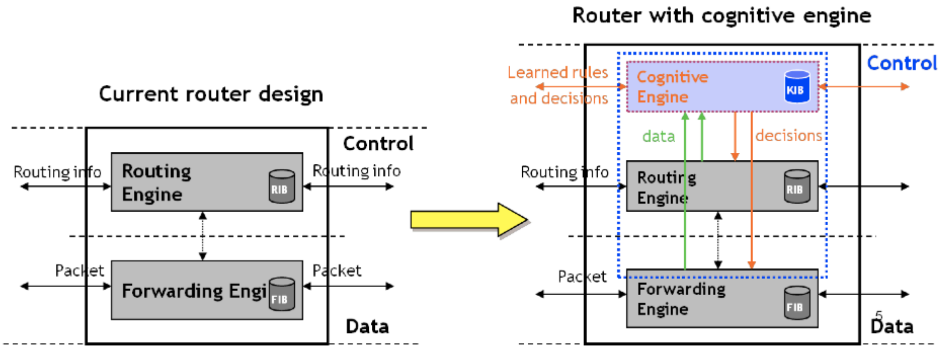
4) The network must make sense of complex context and respond adaptively: autonomic networks and autonomic management

➔ Will distributed ML and distributed data mining work for autonomic networks?



A cognitive routing system according to FP7 ECODE (Experimental Cognitive Distributed Engine)

Substantial skepticism in the NM community about AI:
How can we know whether the system is doing what is supposed to do?
What do we do if things go wrong?

… these translate into unavoidable research riddles …

5) The network must learn how to deliver quality of experience (QoE).

➔ The networks of today cannot even manage QoS

QoS researchers might be aiming at the wrong target

- **QoS processes do not consider the users' perception of services**
  - **The provision of QoS conditions does not guarantee a satisfied user**
- **The outcome of QoS processes is quite often**
  - **The over-provisioning of network resources**
  - **A lack of knowledge regarding the user's satisfaction**
- **QoS management is predominantly**
  - **open-loop**
  - **off-line**

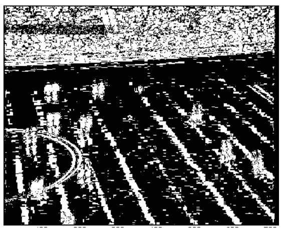
Before we see how network might handle QoE
let's see how well humans understand QoE

Objective measurements show a clear difference between different types of video

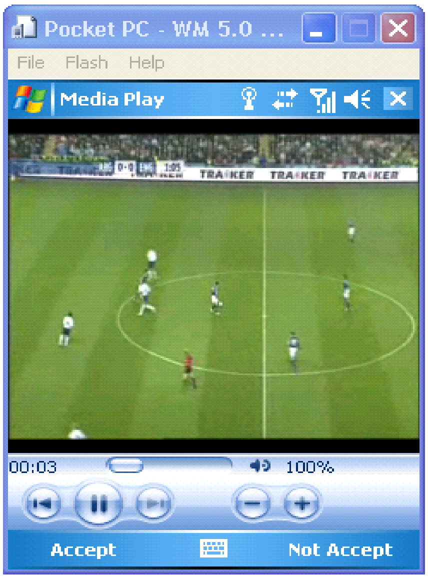
News clip | Sport clip

Original Clips

Difference in Temporal Motion



But if we want to capture a real set of contextual variables (terminal, network, people category, etc) we need subjective tests



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What is the acceptability threshold of these two "degrading" videos?

Segment	Time (seconds)	Video Encoding Bitrates (kbps)	Audio Encoding Bitrates (kbps)	Frame Rate (FPS)	Image Size (Pixels)
1	1- 5	285	32	20	320×240
2	6-10	224	32	15	320×240
3	11-15	128	32	10	320×240
4	16-20	96	32	10	320×240
5	21-25	64	32	6	320×240
6	26-30	32	32	6	320×240
7	31-35	21	32	6	320×240
8	36-40	16	32	6	320×240

- **Every five seconds we degrade the video**
- **We asked people to indicate WHEN the video becomes unacceptably bad**
- **We repeat for 11 different videos, 3 different terminals to assess the influence of more variables (but in reality there are many more)**

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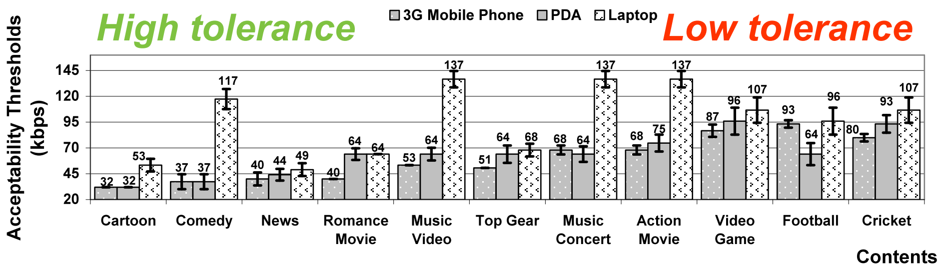
What is the acceptability threshold of the following two “degrading” videos? – “News”

What is the acceptability threshold of the following two “degrading” videos? – “Football”

What is the acceptability threshold of the following two "degrading" videos? - results



One quality ➔ different perceptions

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A bit of *discriminant* Analysis on the subjective responses

	Content types	Standardized Coefficients for the predictors: Encoding bitrate	Standardized Coefficients for the predictors: Frame rate
This content is less sensitive to frame rate	News	1.430	-0.449
	Romance movie	1.430	-0.449
	Cartoon	1.189	-0.196
	Comedy	1.362	-0.376
This content is more sensitive to frame rate	Music video	0.153	0.851
	Action movie	-0.938	1.871
	Music concert	-0.924	1.854
	Cricket	-0.325	1.306
	Football	-0.267	1.255

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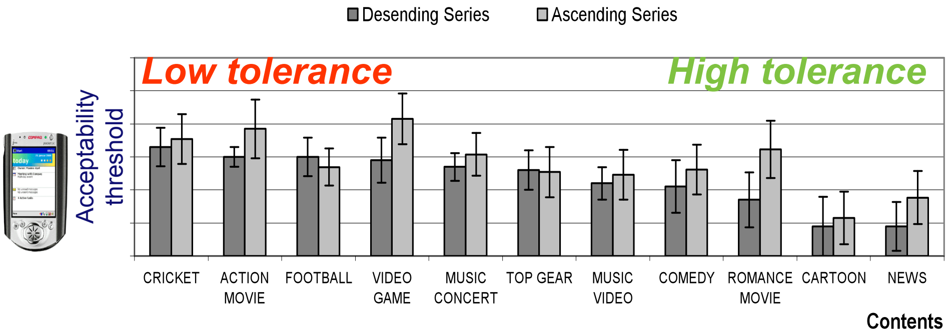
Tricks of the brain



One quality ➔ different perceptions

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Which of the following two videos has better quality? 1) The "pedestrian area" video

Source: K. Seshadrinathan et al. "Study of subjective and objective quality assessment of video". IEEE Trans. Image Processing, Vol.29(6). June 2010. (Full image data base available online: http://live.ece.utexas.edu/)

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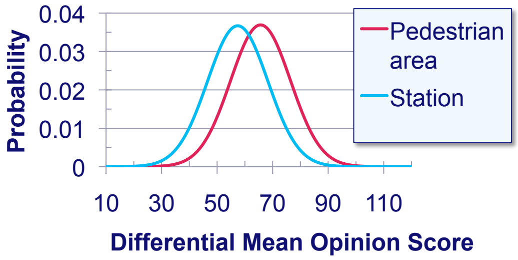
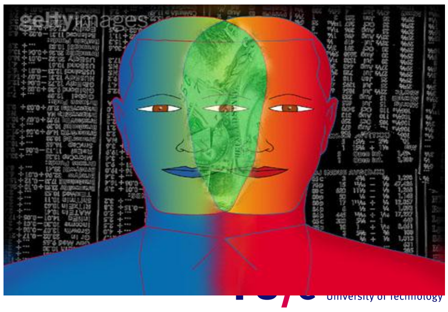
Which of the following two videos has better quality?
2) The "station" video

Source: K. Seshadrinathan et al. "Study of subjective and objective quality assessment of video". IEEE Trans. Image Processing, Vol.29(6). June 2010. (Full image data base available online: http://live.ece.utexas.edu/)

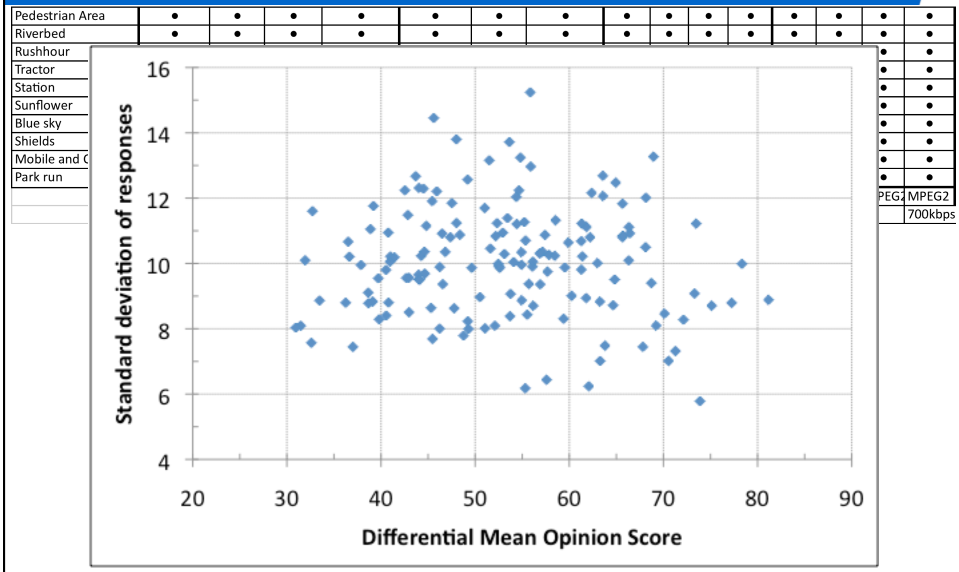
Both videos are encoded exactly in the same way but the "pedestrian" one is "perceived" as worse



- **On average the "pedestrian" video was perceived worse compared to "unimpaired" reference**
- **But the overlapping Gaussians indicate that many subjects actually had an opposite perception of quality**
- **It's all about human perception, but even humans cannot agree**



Subjective test on 150 impaired videos show a huge variation of perceived QoE



Analysis by V. Menkovski (TU/e) based on data accessible at http://live.ece.utexas.edu/

So far we have established that we, the humans, don’t have a good grasp of QoE perception

Perhaps we should look at the QoE-delivery issue from new perspectives

We are not good at judging QoE but if we are given the right level of QoE we can recognize it

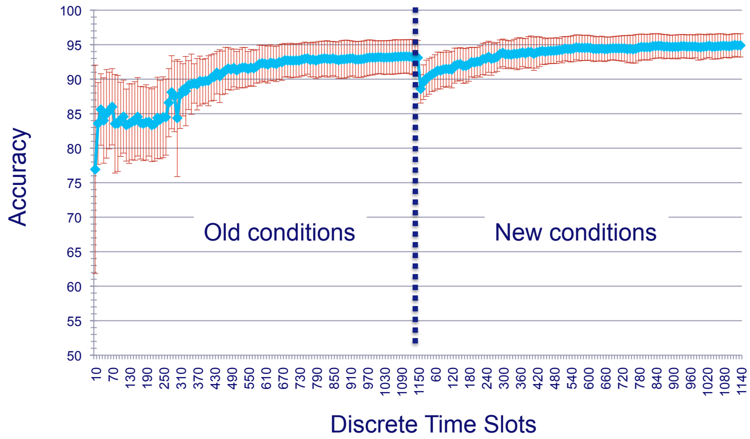
Perhaps a machine can learn what a “good” QoE is and how to deliver it

I believe that that machine is “the network”

Networks are in the best position to make clever correlations

- Every terminal / sensor is a network element
- Most nodes are able to sense at least their immediate neighborhood and also their environment (integration with sensors)
- There are tools to gather
  - session-level information
  - terminal-level information
  - user patterns
- Most nodes (except the simplest sensors) are able run simple ML algorithms

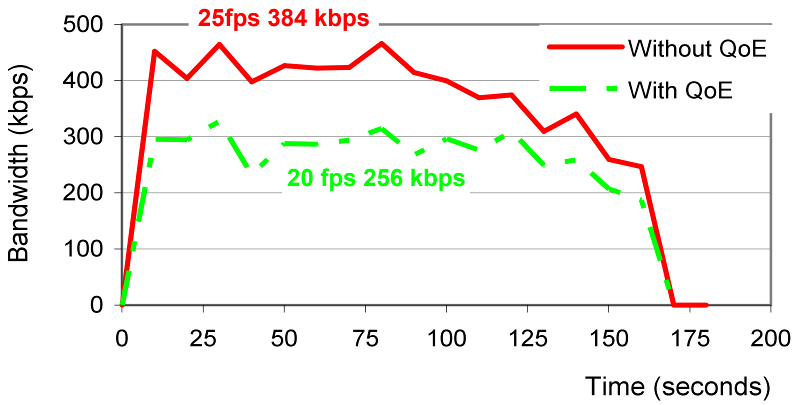
Networks can easily build accurate / self-learning QoS-to-QoE mapping predictions



Accuracy vs. number of introduced datapoints for the OzaBag HoeffdingOptionNB Adaptive Tree

We want to minimize resource consumption but be sure that QoE is unaffected

Action movie on mobile phone



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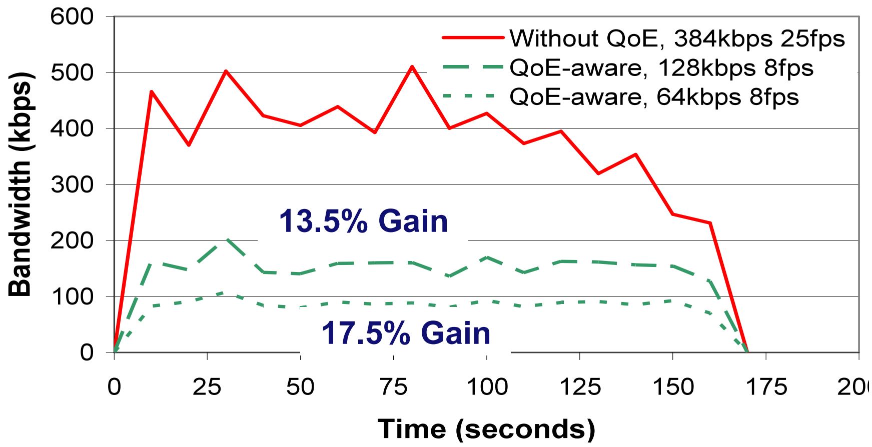
News clip on mobile phone



One day networks will …

- Make sense of what happens around them
- Understand and manage the QoE perceived by the end users
- Adapt to whatever happens without generating instability

and fill the gap between "automatic" and "autonomic" behavior

Good prospect for research jobs

There is still a lot to explore. *Autonomic self-awareness* requires:

- Means to gather subjective QoE data automatically
- Effective "feature" monitoring techniques
- To understand how to apply distributed ML to networks
- Network "actuators" (formerly QoS mechanisms)
- Evidence about stability, reliability, optimality, …
- Develop high-level management and orchestration tools (manage / influence the autonomics)
- Business and economic models
- Regulatory obligations
- … and much more

The ultimate switch… quite a few decades ago. The "switching & routing" paradigm has not changed that much

TNO Offices – Delft, The Netherlands

Thank you !