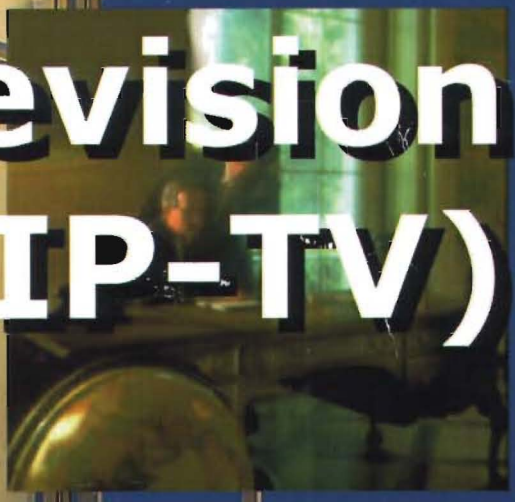
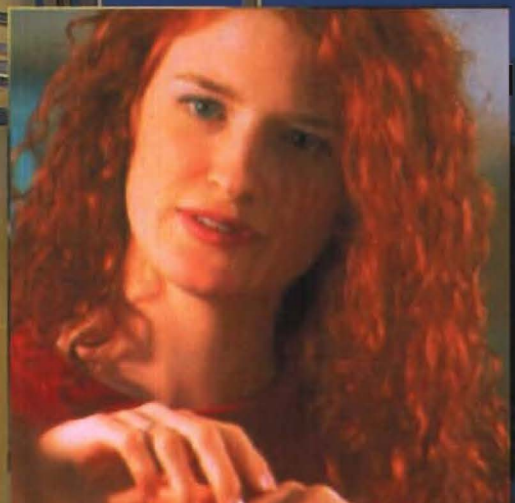
# WIC midwintermeeting on IP-television (IP-TV)

Proceedings 2007

# WIC Midwintermeeting on

# IP-Television (IP-TV)





IEEE Benelux Chapters on Consumer Electronics and Information Theory

# WIC Midwintermeeting on IP-Television (IP-TV)

Peter H. N. de With and Goran Petrovic (eds.)

Proceedings of a one-day workshop organized by the

*Werkgemeenschap voor Informatie en Communicatietheorie and IEEE Benelux Chapters on Consumer Electronics and Information Theory*

in conjunction with the

*Electrical Engineering Department of the Technische Universiteit Eindhoven*

January 19th, 2007

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WIC

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Subject headings: digital television / IP networks / image coding / visual communication.

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Earlier releases in this series:

- Proceedings Workshop on "Embedded Video Streaming Technology (MPEG-4) and the Internet", IEEE Benelux Chapter on Consumer Electronics, ISBN 90-386-0991-4, P.H.N. de With (Ed.), Technische Universiteit Eindhoven, The Netherlands, December 2001 (155 pages).
- Proceedings Workshop on "The Design of Multimedia Architectures", IEEE Benelux Chapter on Consumer Electronics, ISBN 90-386-0822-5, P.H.N. de With (Ed.), Technische Universiteit Eindhoven, The Netherlands, December 2003 (136 pages).
- Proceedings Workshop on "Resource Management for Media Processing in Networked Embedded Systems", IEEE Benelux Chapter on Consumer Electronics, ISBN 90-386-0544-7, R.J. Bril and R.Verhoeven (Eds.), Technische Universiteit Eindhoven, The Netherlands, March 2005 (142 pages).
- Proceedings Workshop on "Content Generation and Coding for 3D-Television", IEEE Benelux Chapter on Consumer Electronics, P.H.N. de With, C. Varekamp, D. Farin, Y. Morvan (Eds.), ISBN 90-386-2062-4, The Netherlands, June 2006 (CD-ROM).

# Preface

The IEEE Chapter on Consumer Electronics in the Benelux was founded in the late nineties to support events that are related to applications of Consumer Electronics, and is part of the international IEEE CE Society. The CE domain is growing yearly, due to the continuous advances in technology in the area of computing, communication and storage.

The first workshop of the Benelux CE Section was devoted to multimedia video coding for Internet applications. The MPEG video compression standards have been a phenomenal success for the recording and digital distribution of video signals. From these standards, MPEG-2 is most widely applied (e.g. DVD) and MPEG-4 is studied for e.g. portable applications of video systems. The widely accepted use of communication in computer networks is gradually becoming part of the consumer electronics area, leading to communicating consumer video over the Internet. This was the theme of the first workshop.

The second workshop of the Benelux CE Section was devoted to the design of multimedia architectures, motivated by the ever increasing density of transistors in a chip. This development poses system designers with the challenge to deal with very complex and divers architectures inside a single system. Given this growing complexity, many CE manufacturers outsource the design of subsystems. The system design owner should subsequently solve the problem of smooth integration and operation of the various subsystems. This complexity control problem occurs both in software and hardware design.

Media processing is often characterized by highly fluctuating, content dependent, resource requirements. Combined with their real-time constraints, media processing puts high demands on resource management in networked embedded systems. This is especially true for consumer systems that provide high-quality media, which have a low tolerance for artifacts and quality fluctuations. The above considerations have led to the theme of the third workshop, which was organized by the Benelux CE Section in conjunction with the Mathematics and Computer Science Department of the Technische Universiteit Eindhoven.

The fourth workshop was on 3D-Television and was developed in close cooperation with Philips Research. In 3D-TV, the creation of depth signals and correct 3D signals is of crucial importance for substantiating the transmission of such signals and a good 3D reconstruction. This workshop discussed various techniques to create such signals in a sound way and also how such signals should be coded for transmission.

This fifth workshop is primary lead by the "Werkgemeenschap for Information and Communication Theory" (WIC) which regularly organizes so-called midwintermeetings of a tutorial nature in conjunction with the IEEE Chapter of Information Theory. The IEEE CE Chapter has joined this event, since this years' theme on IP-TV is so close to the above-given list of events on media coding.

The first lecture, given by Dr. Ralph Schaefer of the Heinrich Hertz Institute of Berlin, explains the key video coding standard for digital TV applications which is MPEG AVC or H.264 compression. This standard offers the best compression for broadcast TV signals at the moment and is therefore the primary candidate for IP-TV systems. Dr. Schaefer and his colleague Dr. Thomas Wiegand of the same department have played a leading role in chairing the H.264 standardization and validating the standard.

We are happy that Mr. Keith Baker of Philips Consumer Electronics will address the market developments and discuss prospects of IP-TV. Mr. Baker is innovation manager at Philips Applied Technologies where he is regularly involved in spotting strategic innovations and the design of first-of-a-kind TV systems. There are currently several strategic reports on IP-TV available and the considerations made in recent reports are certainly addressed.

We are happy to also have speakers from the real TV broadcasting industry. Mr. Werner Ramaekers of the Flemish Radio and TV Broadcasting Corporation (VRT) is the third speaker of the workshop. He will address the practice of modern broadcasting as it is now in Belgium and he will address the challenges that IP-TV poses to existing TV broadcasting.

We are honored that Prof. Gunnar Karlsson of the Royal Institute KTH from Stockholm, Sweden, has accepted as a fourth speaker for presenting the networking aspects of IP-TV systems. Broadcasting TV over the Internet is a complicated matter for many reasons. He will address the IP, that is the Internet Protocol and the usefulness of the protocol and the Internet for Video streaming and TV applications.

Dr. Chris Lefrere presents the final lecture of this workshop. He is with the Belgian company Telenet, who are leading in establishing interactive TV applications in the market and having access to the viewing behavior of the TV viewers, thus the customers. Dr. Lefrere will address iDTV aspects in his presentation. Unfortunately, his presentation could not be made available for printing (on his request), which explains the empty spot in these proceedings.

The IEEE Benelux Chapters on Consumer Electronics and Information Theory and the Electrical Engineering faculty of the Technische Universiteit Eindhoven (TU/e) are pleased to offer this workshop and the enclosed topics to a wide audience. They gratefully acknowledge the VCA group of the Signal Processing Systems (SPS) dept. of the TU/e for their support, and the stimulating help of Prof. Peter Schelkens and Dr. Frans Willems.

These proceedings contain a mixture of slide copies addressing the themes of the individual lectures. This simple approach was chosen to give maximum flexibility to the authors with minimum effort, thereby allowing the input of the latest material.

Peter H.N. de With

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Professor Video Coding and Architectures,
Electronics Engineering Faculty,
Technische Universiteit Eindhoven,
The Netherlands

Goran Petrovic

Ph.D. student,
Electrical Engineering Department,
Technische Universiteit Eindhoven,
The Netherlands

## Program of "WIC Midwintermeeting on IP-Television (IP-TV)"

One-day workshop at the Technische Universiteit Eindhoven (TU/e), The Netherlands, on January 19th, 2007. Organized by the "Werkgemeenschap voor Informatie en Communicatietheorie" and IEEE Benelux Chapters on Consumer Electronics and Information Theory.

### Organization committee

Prof.dr. Peter H.N. de With (TU/e, LogicaCMG)
Prof.dr. Peter Schelkens (VUB, Brussels, Belgium)
M.Sc. Goran Petrovic (TU/e), and
Dr.ir. Frans M.J. Willems (TU/e).

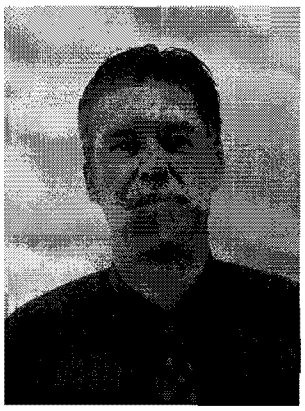
## Workshop Program

| | |
|---|---|
| 09:30 – 09:55 hrs | Registration and coffee |
| 10:00 – 10:10 hrs | Opening Midwintermeeting, Prof.dr. Peter H.N. de With (TU/e) |
| 10:10 – 11:00 hrs | Dr. Ralf Schaefer (Heinrich Hertz Institute, Berlin, Germany)<br>"H.264 Video Coding standard overview and its suitability for IP-TV" |
| Break | |
| 11:30 – 12:20 hrs | Ir. Keith Baker (Philips Applied Technol., Eindhoven, The Netherlands)<br>"Can't Pay Won't Pay will drives at Home IP Media Distribution" |
| Lunch | |
| 13:40 – 14:30 hrs | Ir. Werner Ramaekers (Flemish Radio- and Television Network - VRT, Brussels, Belgium)<br>"IP-TV: Challenges for a broadcast company" |
| 14:30 – 15:20 hrs | Prof. dr. Gunnar Karlsson (Royal Institute of Technology - KTH, Stockholm, Sweden)<br>"The IP in IP-TV: the Networking Aspects" |
| Break | |
| 15:45 – 16:35 hrs | Dr. Chris Lefrere (Telenet, Belgium)<br>"Under the hood of iDTV technical aspects" |
| 16:35 – 16:40 hrs | Closing by WIC chairman, Dr. Jos H. Weber (TU Delft) |

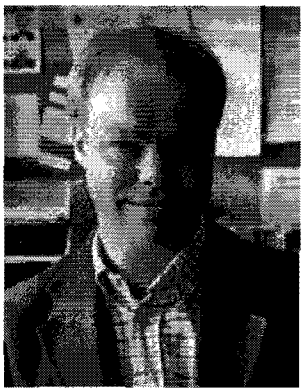
## Contributors

**Ralf Schäfer** received his Dipl.-Ing. and Dr.-Ing. degrees both in electrical engineering from the Technical University of Berlin in 1977 and 1984 respectively. In October 1977 he joined the Heinrich-Hertz-Institut (HHI) in Berlin. From this time he worked in various fields of signal processing and image coding and he was leader of several research projects. Since 1989 he is head of the Image Processing Department. In the department he is responsible for about 50 researchers and technicians, about 40 students and about 30 R&D projects funded by the German Government (BMBF, BMWi), by the German Science Foundation (DFG), by the European Commission and by industries. He was chairman of several national and international projects, currently he is coordinating the German project DXB on mobile TV systems. Ralf Schäfer is co-founder of the companies 2SK Media Technologies and MikroM GmbH. He is member of the Steering Committees of the Picture Coding Symposium (PCS) and the Packet Video Workshop (PV) as well as of the German "Society for Information Technology" (ITG), where he is chairman of experts committee "Digital Coding" (FA 3.2). Furthermore he is member of the German „Society for Television and Motion Picture Technology" (FKTG), where he belongs to the URTEL Award Committee. In 1986 he received the paper award of the ITG and in 2000 the Richard Theile Medal of the FKTG.

**Keith Baker** is Open Innovation manager for Philips Applied Technologies in Eindhoven, project leader for a large number of Eureka projects under the MEDEA+ and ITEA programmes. He received his B.Sc. and M.Sc. from University of Essex in UK. Also went to the same school as Ali-G, but Keith completed his education at this now famous educational establishment in Staines. He invites you to Google "Torque Kills Baker" and consider the consequences of future media landscape were "smart narcotics" can be created using nanotechnology.



**Werner Ramaekers** has obtained a Master in telecommunication engineering from the Belgian Royal Military Academy, Brussels, in 1991 and a Master in mechatronics engineering from the Katholieke Universiteit Leuven, in 1997. His research interests include software architectures for internet applications and technologies for building social software applications. He is also interested in Rich Internet Applications for media over IP-networks. From 1991 until 2000 he was an Officer in the Belgian Military responsible for automated testing software and later on the introduction of internet technologies in the logistics domain. He was an independent software architect from 2000 until 2004 with a strong background in the use of open-source technologies for internet applications. He joined VRT in 2004 as software architect in the IT department and currently leads the research cluster on internet technologies for media since November 2006. The research work he performs and guides takes place in close collaboration with the IBBT (Institute for BroadBand Technologies) in Gent.



**Gunnar Karlsson** received his Ph.D. in electrical engineering from Columbia University (1989), New York, and the M.Sc. in electrical engineering from Chalmers University of Technology in Gothenburg, Sweden (1983). He is Professor since 1998 in the School of Electrical Engineering of KTH, the Royal Institute of Technology in Stockholm Sweden. He has previously worked as Research Staff Member for IBM Zurich Research Laboratory from 1989 to 1992, and as Senior Researcher at the Swedish Institute of Computer Science (SICS) from 1992 to 1998. He has been Visiting Professor at ETH Zurich in 2005-2006, at EPFL in 1996-1997, and at the Helsinki University of Technology in 1997. His current research relates to quality of service for the Internet and wireless LAN developments. Prof. Karlsson is senior member of IEEE and member of ACM and serves on the editorial boards of IEEE Journal on Selected Areas in Communication and Elsevier Computer Networks. He is program co-chair of the 5th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt) and guest co-editor of a special issue on delay and disruption tolerant wireless communication for the IEEE Journal on Selected Areas in Communication.

Biography of **Chris Lefrere** was not available for printing.

# H.264 Video Coding standard overview and its suitability for IP-TV

**Dr. Ralf Schaefer**

**Heinrich Hertz Institute, Berlin, Germany**

# H.264 Video Coding Standard Overview and its Suitability for IP-TV


**Ralf Schäfer**

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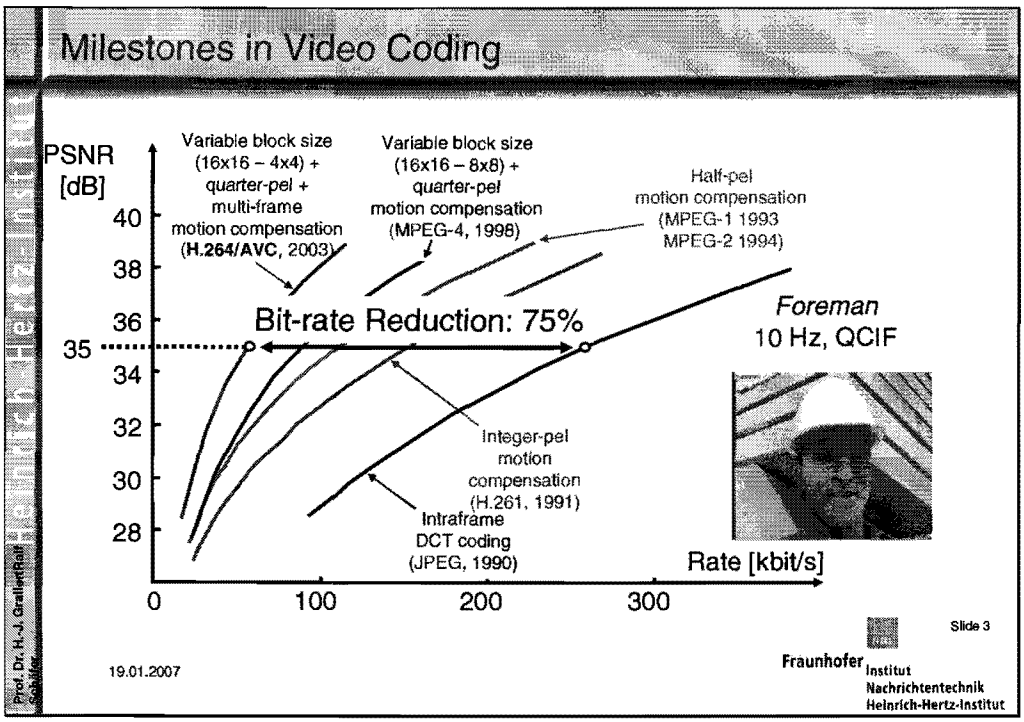
http://ip.hhi.de




## Outline

- Introduction
- Standardisation: History, Objectives, and Applications
- H.264/AVC overview
- New or improved coding tools
  - Motion Compensated Prediction
  - Intra Prediction
  - Prediction Error Coding
  - Deblocking Filter
  - Entropy Coding
- Profiles and Levels
- System layer
- Scalable extension – SVC
- H.265 – an outlook
- Conclusions


Milestones in Video Coding
PSNR [dB]
40
38
36
35
34
32
30
28
0
100
200
300
Rate [kbit/s]
Variable block size (16x16 – 4x4) + quarter-pel + multi-frame motion compensation (H.264/AVC, 2003)
Variable block size (16x16 – 8x8) + quarter-pel motion compensation (MPEG-4, 1998)
Half-pel motion compensation (MPEG-1 1993 MPEG-2 1994)
Bit-rate Reduction: 75%
Foreman
10 Hz, QCIF
Integer-pel motion compensation (H.261, 1991)
Intraframe DCT coding (JPEG, 1990)
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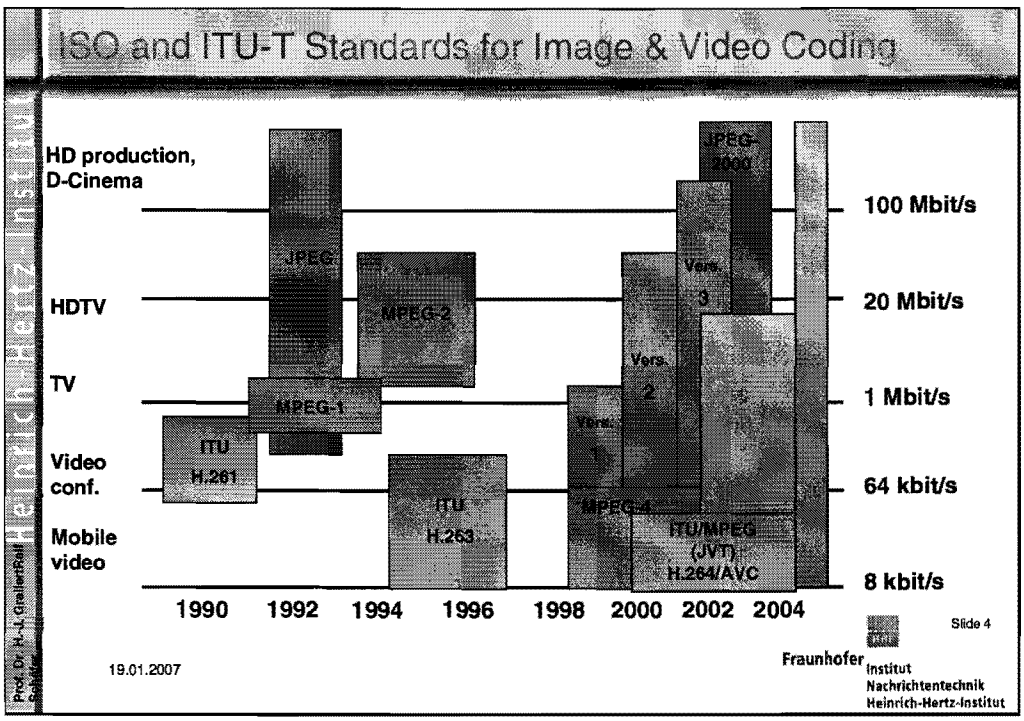
ISO and ITU-T Standards for Image & Video Coding
HD production, D-Cinema
HDTV
TV
Video conf.
Mobile video
100 Mbit/s
20 Mbit/s
1 Mbit/s
64 kbit/s
8 kbit/s
JPEG
MPEG-2
MPEG-1
ITU H.261
ITU H.263
MPEG-4
Vers. 2
Vers. 3
JPEG-2000
ITU/MPEG (JVT) H.264/AVC
1990
1992
1994
1996
1998
2000
2002
2004
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## Goals of H.264 Standardization

- **Improved Coding Efficiency**
  - Average bit rate reduction of 50% given fixed fidelity compared to any other standard
  - Complexity vs. coding efficiency scalability
- **Improved Network Friendliness**
  - Issues examined in H.263 and MPEG-4 are further improved
  - Anticipate error-prone transport over mobile networks and the wired and wireless Internet
- **Simple syntax specification**
  - Targeting simple and clean solutions
  - Avoiding any excessive quantity of optional features or profile configurations



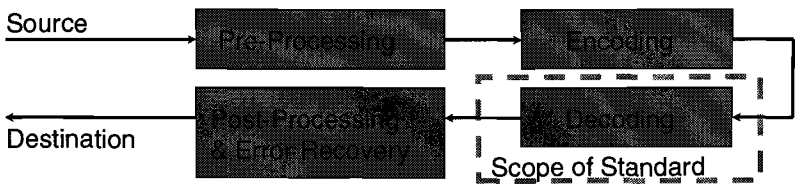
## Relationship to Other Standards

- **Identical specifications have been approved in both ITU-T / VCEG and ISO/IEC / MPEG**
- **In ITU-T / VCEG this is a new & separate standard**
  - ITU-T Recommendation H.264
  - ITU-T Systems (H.32x) will be modified to support it
- **In ISO/IEC / MPEG this is a new "part" in the MPEG-4 suite**
  - Separate codec design from prior MPEG-4 visual
  - New part 10 called "Advanced Video Coding" (AVC – similar to "AAC" position in MPEG-2 as separate codec)
  - MPEG-4 Systems / File Format has been modified to support it
  - **H.222.0 | MPEG-2 Systems also modified to support it**
- **IETF has specified RTP payload packetization**

## The Scope of Picture and Video Coding Standardization

**Only Restrictions on the *Bitstream, Syntax,* and *Decoder* are standardized:**

- Permits optimization beyond the obvious
- Permits complexity reduction for implementability
- Provides *no* guarantees of quality

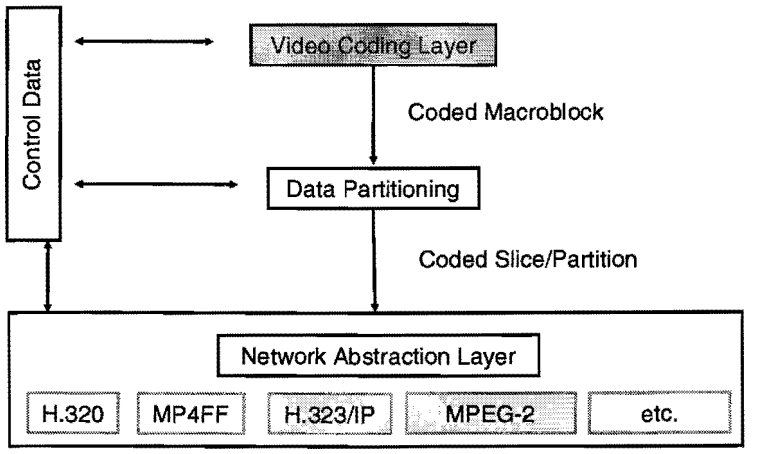





## Profiles & Levels Concepts

- **Many standards contain different configurations of capabilities – often based in "profiles" & "levels"**
  - A profile is usually a set of algorithmic features
  - A level is usually a degree of capability (e.g. resolution or speed of decoding)
- **H.264/AVC has four profiles**
  - Baseline (lower capability plus error resilience, e.g., videoconferencing, mobile video)
  - Main (high compression quality, e.g., broadcast)
  - Extended (added features for efficient streaming)
  - High Profiles

## H.264/AVC Layer Structure



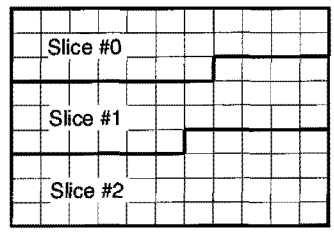


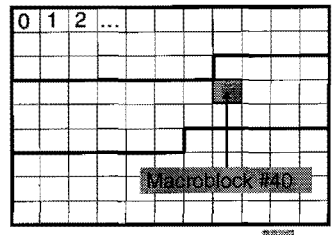

## Common Elements with other Standards

- Macroblocks: 16x16 luma + 2 x 8x8 chroma samples
- Input: Association of luma and chroma and conventional sub-sampling of chroma (4:2:0)
- Block motion displacement
- Motion vectors over picture boundaries
- Variable block-size motion
- Block transforms
- Scalar quantization
- I, P, and B coding types

## Partitioning of the Picture

- **Slices:**
  - A picture is split into 1 or several slices
  - Slices are self-contained
  - Slices are a sequence of macroblocks
- **Macroblocks:**
  - Basic syntax & processing unit
  - Contains 16x16 luma samples and 2 x 8x8 chroma samples
  - Macroblocks within a slice depend on each other
  - Macroblocks can be further partitioned




Prof. Dr. H.-J. Grallert/Ralf Schäfer

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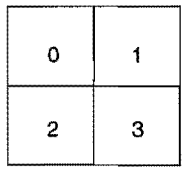
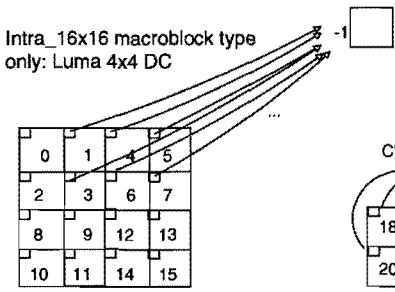
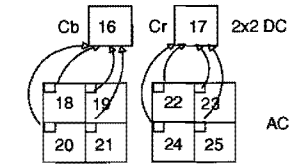
## Scanning of a Macroblock




Coded Block Pattern for Luma in 8x8 block order: signals which of the 8x8 blocks contains at least one 4x4 block with non-zero transform coefficients




Luma 4x4 block order for 4x4 intra prediction and 4x4 residual coding




Chroma 4x4 block order for 4x4 *residual coding*, shown as 16-25, and intra 4x4 prediction, shown as 18-21 and 22-25

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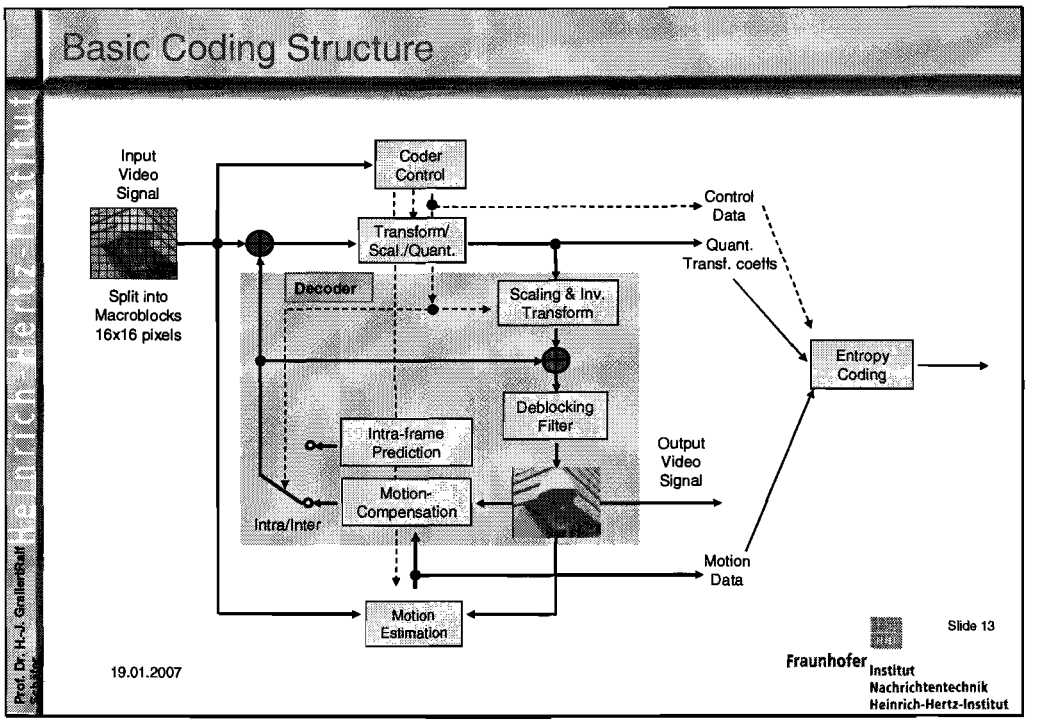
Basic Coding Structure
Input Video Signal
Split into Macroblocks 16x16 pixels
Coder Control
Control Data
Transform/ Scal./Quant.
Quant. Transf. coeffs
Decoder
Scaling & Inv. Transform
Entropy Coding
Deblocking Filter
Intra-frame Prediction
Output Video Signal
Motion-Compensation
Intra/Inter
Motion Data
Motion Estimation
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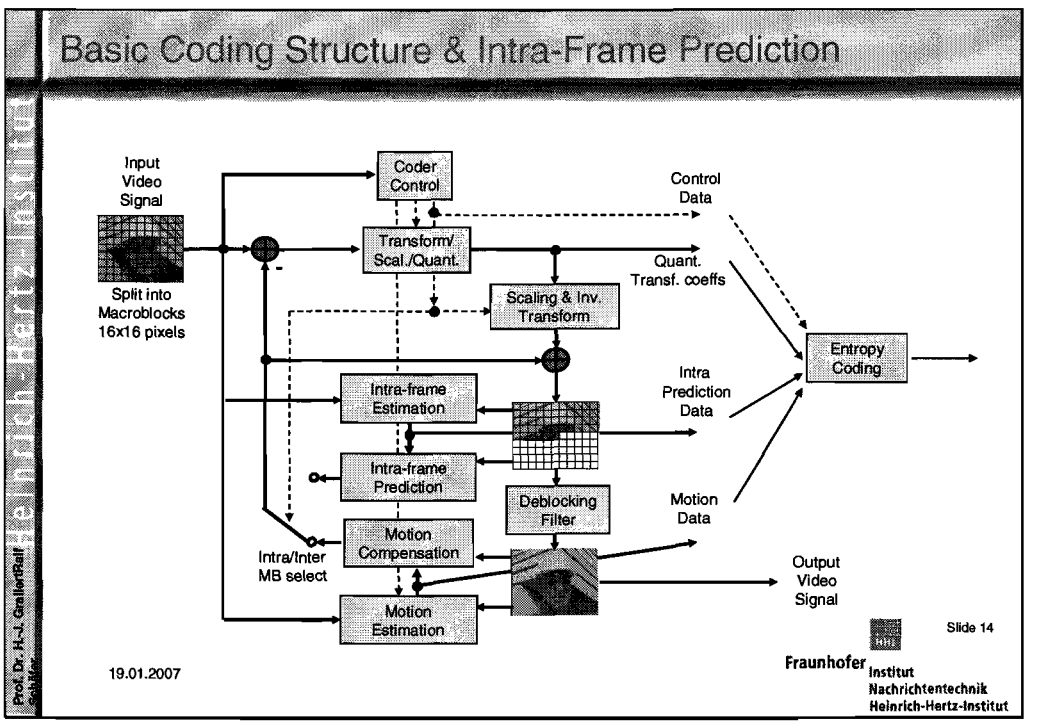
Basic Coding Structure & Intra-Frame Prediction
Input Video Signal
Split into Macroblocks 16x16 pixels
Coder Control
Control Data
Transform/ Scal./Quant.
Quant. Transf. coeffs
Scaling & Inv. Transform
Entropy Coding
Intra-frame Estimation
Intra Prediction Data
Intra-frame Prediction
Deblocking Filter
Motion Data
Motion Compensation
Intra/Inter MB select
Output Video Signal
Motion Estimation
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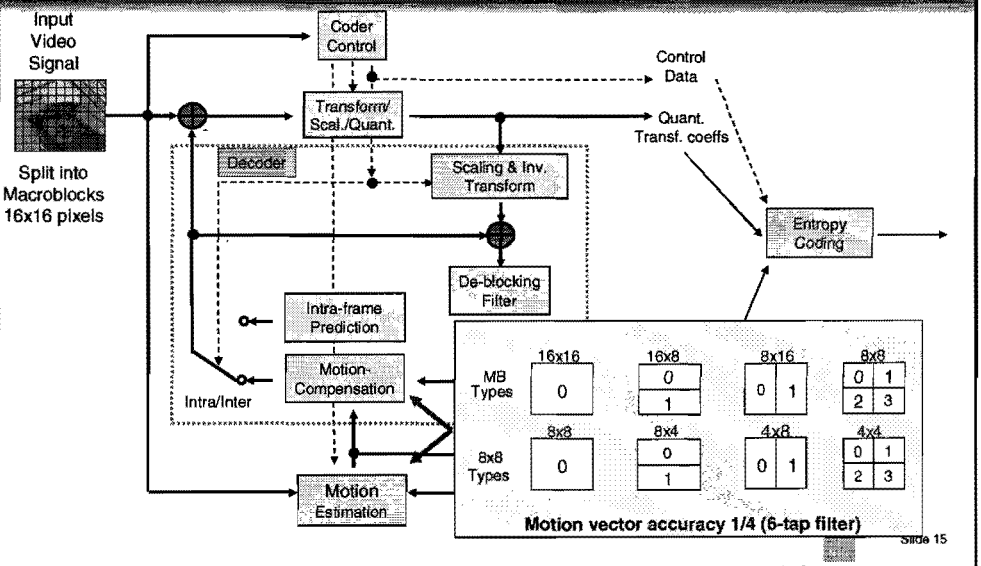
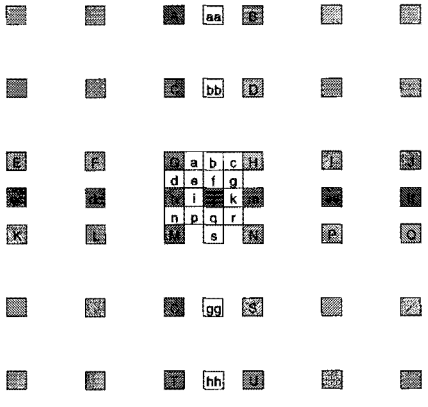
## Motion Compensation Accuracy



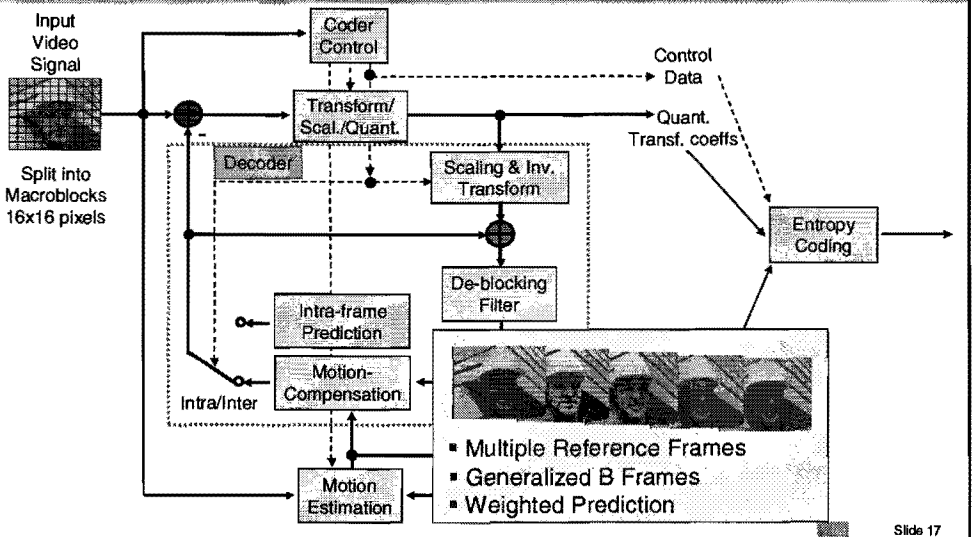



## Quarter Sample Luma Interpolation

- Half sample positions are obtained by applying a 6-tap filter with tap values: (1, -5, 20, 20, -5, 1)
- Quarter sample positions are obtained by averaging samples at integer and half sample positions

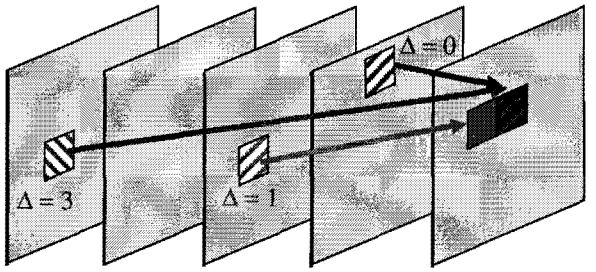


## Multiple Reference Frames






## Multiple Reference Frames and Generalized Bi-Predictive Frames




4 Prior Decoded Pictures as Reference

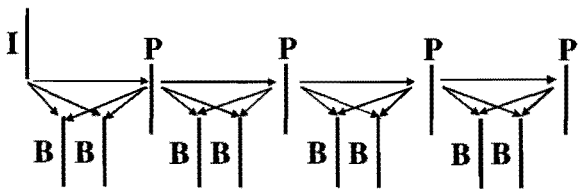
Current Picture

1. Extend motion vector by reference picture index Δ
2. Provide reference pictures at decoder side
3. In case of bi-predictive pictures: decode 2 sets of motion parameters

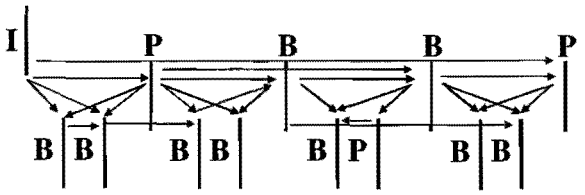
*Can jointly exploit scene cuts, aliasing, uncovered background and other effects with one approach*

## New Types of Temporal Referencing

- Known dependencies (MPEG-1, MPEG-2, etc.)




- New types of dependencies:
  - Referencing order and display order are decoupled
  - Referencing ability and picture type are decoupled



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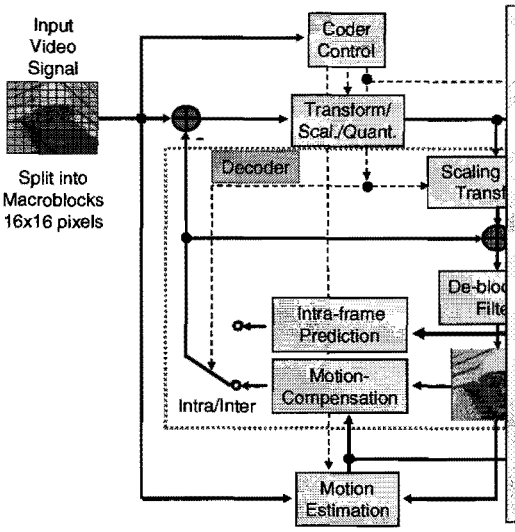
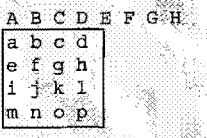
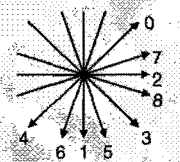
## Intra Prediction




- Directional spatial prediction (9 types for luma, 1 chroma)




- e.g., Mode 3: diagonal down/right prediction a, f, k, p are predicted by (A + 2Q + I + 2) >> 2

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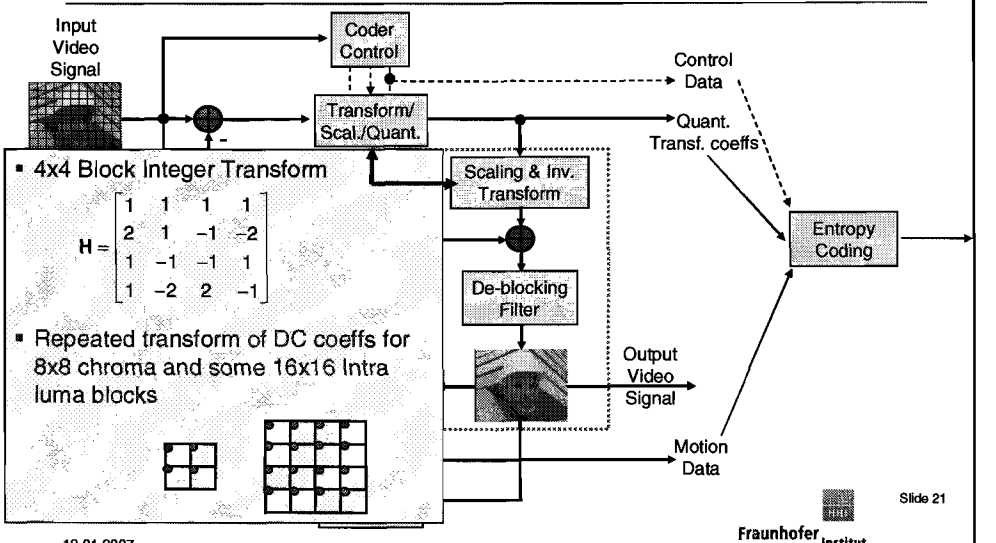
## Transform Coding






## Quantization of Transform Coefficients

- Logarithmic step size control
- Smaller step size for chroma (per H.263 Annex T)
- Extended range of step sizes
- Can change to any step size at macroblock level
- Quantization reconstruction is one multiply, one add, one shift

## Deblocking Filter

- Improves subjective visual *and* objective quality of the decoded picture
- Significantly superior to post filtering
- Filtering affects the edges of the 4x4 block structure
- Highly content adaptive filtering procedure mainly removes blocking artifacts and does not unnecessarily blur the visual content
  - On slice level, the global filtering strength can be adjusted to the individual characteristics of the video sequence
  - On edge level, filtering strength is made dependent on inter/intra, motion, and coded residuals
  - On sample level, quantizer dependent thresholds can turn off filtering for every individual sample
  - Specially strong filter for macroblocks with very flat characteristics almost removes "tiling artifacts"



## Deblocking: Subjective Result for Intra

Highly compressed first decoded intra picture
at a data rate of 0.28 bit/sample

1) Without Filter

2) with H264/AVC Deblocking

## Deblocking: Subjective Result for Inter

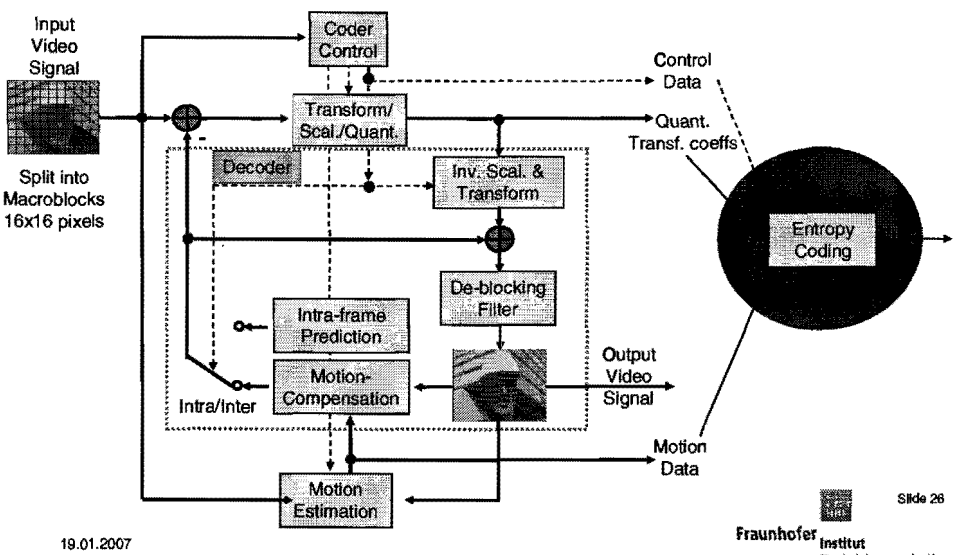
Highly compressed decoded inter picture

1) Without Filter

2) with H264/AVC Deblocking



## Entropy Coding



## Variable Length Coding

- Exp-Golomb code is used universally for almost all symbols except for transform coefficients
- Context adaptive VLCs for coding of transform coefficients
  - No end-of-block, but number of coefficients is decoded
  - Coefficients are scanned backwards
  - Contexts are built dependent on transform coefficients



## Context Adaptive VLC (CAVLC)

- Transform coefficients are coded with the following elements:
  - Number of non-zero coefficients
  - Levels and signs for all non-zero coefficients
  - Total number of zeros before last non-zero coefficient
  - Run before each non-zero coefficient

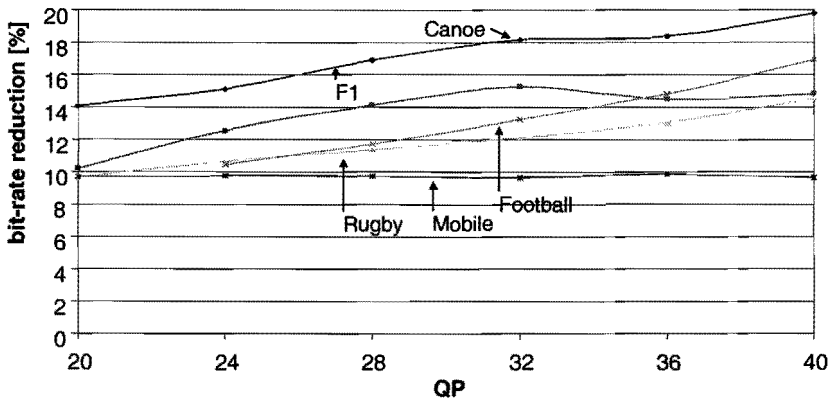
## Context-based Adaptive Binary Arithmetic Coding (CABAC)

- Usage of adaptive probability models for most symbols
- Exploiting symbol correlations by using contexts
- Restriction to binary arithmetic coding
  - Simple and fast adaptation mechanism
  - Fast binary arithmetic codec based on table look-ups and shifts only



## Bit-Rate Savings for CABAC

**Average Bit-Rate Savings CABAC vs. VLC/CAVLC for SD interlace sequences**



## Summary of Profiles

**Four profiles:**

- Baseline
- Extended
- Main
- High



## Baseline Profile

- **Baseline** (Videoconferencing & Wireless)
  - I and P picture types (not B)
  - In-loop deblocking filter
  - 1/4-sample motion compensation
  - Tree-structured motion segmentation down to 4x4 block size
  - VLC-based entropy coding (No CABAC)
  - Some enhanced error resilience features
    - Flexible macroblock ordering
    - Arbitrary slice ordering
    - Redundant slices

## Main Profile

**Main** Profile (esp. Broadcast/Entertainment)

- All Baseline features except enhanced error resilience features
- B pictures
- CABAC
- Adaptive block-size transforms
- MB-level frame/field switching
- Adaptive weighting for B and P picture prediction
- **Note**: Main is not exactly a superset of Baseline



## Extended Profile

**Extended Profile** (Streaming)

- All Baseline features
- B pictures
- More error resilience: Data partitioning
- SP/SI switching pictures
- **Note**: Extended Profile is a superset of Baseline

## High Profiles

- **The High profile (HP):**

  Supporting 8-bit video with 4:2:0 sampling, addressing high-end consumer use and other applications using high-resolution video without a need for extended chroma formats or extended sample accuracy.

- **The High 10 profile (Hi10P):**

  Supporting 4:2:0 video with up to 10 bits of representation accuracy per sample.

- **The High 4:2:2 profile (H422P):**

  Supporting up to 4:2:2 chroma sampling and up to 10 bits per sample.

- **The High 4:4:4 profile (H444P):**

  Supporting up to 4:4:4 chroma sampling, up to 14 bits per sample, and additionally supporting efficient lossless region coding.

- **3 additional Intra only Profiles for High 10, High 4:2:2 and High 4:4:4**



## New Coding Tools in High Profiles

**New coding tools are:**

- **Support of an adaptive block-size for the residual spatial frequency transform**

  4x4 or 8x8 transform

- **Support of encoder-specified perceptual-based quantization scaling matrices**

  Either default or user defined matrix

- **Support of efficient lossless representation of specific regions in video content**

  Bypass transform and quantization and use prediction and entropy coding only

## H.264/AVC Levels (1)

| Level No. | Max macro-block proces-sing rate (MB/s) | Max frame size (MBs) | Max decoded picture buffer size | Max video bit rate (kbit/s) | Vertical MV component range MaxVmvR (luma frame samples) | Typical picture size (depen-ding on frame rate) |
|---|---|---|---|---|---|---|
| 1 | 1 485 | 99 | 148.5 | 64 | [-64,+63.75] | SQCIF |
| 1b | 1 485 | 99 | 148.5 | 128 | [-64,+63.75] | SQCIF |
| 1.1 | 3 000 | 396 | 337.5 | 192 | [-128,+127.75] | QCIF |
| 1.2 | 6 000 | 396 | 891.0 | 384 | [-128,+127.75] | QCIF |
| 1.3 | 11 880 | 396 | 891.0 | 768 | [-128,+127.75] | QCIF |
| 2 | 11 880 | 396 | 891.0 | 2 000 | [-128,+127.75] | CIF |
| 2.1 | 19 800 | 792 | 1 782.0 | 4 000 | [-256,+255.75] | CIF |
| 2.2 | 20 250 | 1 620 | 3 037.5 | 4 000 | [-256,+255.75] | 4CIF |



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## H.264/AVC Levels (2)

| Level No. | Max macroblock processing (MB/s) | Max frame size (MBs) | Max decoded picture buffer size | Max video bit rate (kbit/s) | Vertical MV component range (luma frame samples) | Typical picture size (Depen-ding on frame rate) |
|---|---|---|---|---|---|---|
| 3 | 40 500 | 1 620 | 3 037.5 | 10 000 | [-256,+255.75] | SD |
| 3.1 | 108 000 | 3 600 | 6 750.0 | 14 000 | [-512,+511.75] | 720 p |
| 3.2 | 216 000 | 5 120 | 7 680.0 | 20 000 | [-512,+511.75] | SXGA |
| 4 | 245 760 | 8 192 | 12 288.0 | 20 000 | [-512,+511.75] | 1080 I |
| 4.1 | 245 760 | 8 192 | 12 288.0 | 50 000 | [-512,+511.75] | 1080 I |
| 4.2/Lo | 491 520 | 8 192 | 12 288.0 | 50 000 | [-512,+511.75] | 2k |
| 4.2/Hi | 522 240 | 8 704 | 13 056.0 | 50 000 | [-512,+511.75] | 2k |
| 5 | 589 824 | 22 080 | 41 400.0 | 135 000 | [-512,+511.75] | 16VGA |
| 5.1 | 983 040 | 36 864 | 69 120.0 | 240 000 | [-512,+511.75] | 4k |



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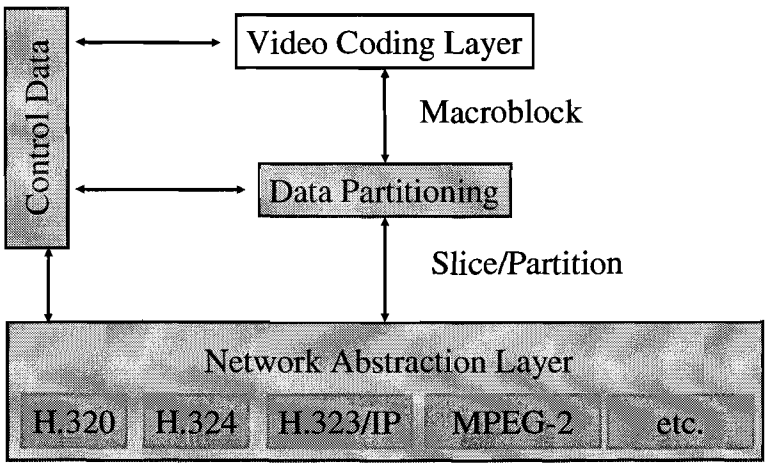
## Networks and Applications

- Broadcast over cable, satellite, DSL, terrestrial, etc.
- Interactive or serial storage on optical and magnetic devices, DVD, etc.
- Conversational services over ISDN, Ethernet, LAN, DSL Wireless Networks, modems, etc. or a mixture of several.
- Video-on-demand or multimedia streaming services over ISDN, DSL Ethernet, LAN, Wireless Networks, etc.
- Multimedia Messaging Services (MMS) over ISDN, DSL, Ethernet, LAN, Wireless Network, etc.
- New applications over existing and future networks!

How to handle this variety of applications and networks?



## H.264/AVC Layer Structure



## Network Abstraction Layer

**Mapping of H.264/AVC video to transport layers like**

- RTP/IP for any kind of real-time wireline and wireless Internet services (conversational and streaming)
- File formats, e.g. ISO MP4 for storage and MMS
- H.32X for wireline and wireless conversational services
- MPEG-2 systems for broadcasting services, etc.

Outside the scope the H.264/AVC standardization, but awareness!

**Provision of appropriate mechanisms and interfaces**

- Provide mapping to network and to facilitate gateway design
- Key Concepts: Parameter Sets, Network Abstraction Layer (NAL) Units, NAL unit and byte-stream formats

Completely within the scope of H.264/AVC standardization



## Network Abstraction Layer (NAL) Units

**Constraints:**

- Many relevant networks are packet switched networks
- Mapping packets to streams is easier than vice versa
- Undetected bit-errors practically do not exist on the application layer

**Architecture:** NAL units as the transport entity

- NAL units may be mapped into a bit stream...
- ... or forwarded directly by a packet network
- NAL units are self-contained (independently decodable)
- The decoding process assumes NAL units in decoding order
- The integrity of NAL units is signaled by the correct size (conveyed externally) and the *forbidden_bit* set to 0.

## NAL Unit Format and Types

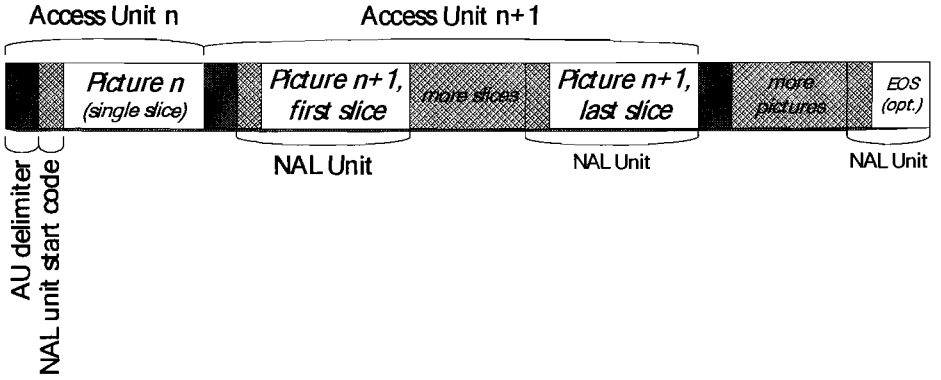

**NAL unit header**: 1 byte consisting of

- forbidden_bit (1 bit): may be used to signal that a NAL unit is corrupt (useful e.g. for decoders capable to handle bit errors)
- nal_storage_idc (2 bit): signals relative importance, and if the picture is stored in the reference picture buffer
- nal_unit_type (5 bit): signals 1 of 10 different NAL unit types
  - Coded slice (regular VCL data),
  - Coded data partition A, B, C (DPA, DPB, DPC),
  - Instantaneous decoder refresh (IDR),
  - Supplemental enhancement information (SEI),
  - Sequence and picture parameter set (SPS, PPS),
  - Picture delimiter (PD) and filler data (FD).

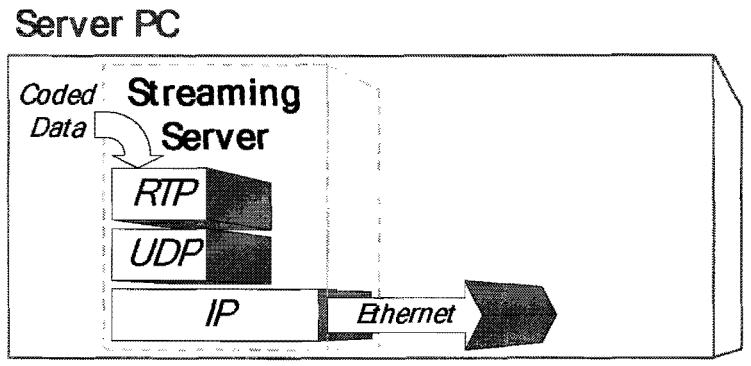
**NAL unit payload**: an emulation prevented sequence of bytes.



## NAL Unit Structure



## Protocol Stack for IP Based Transmission

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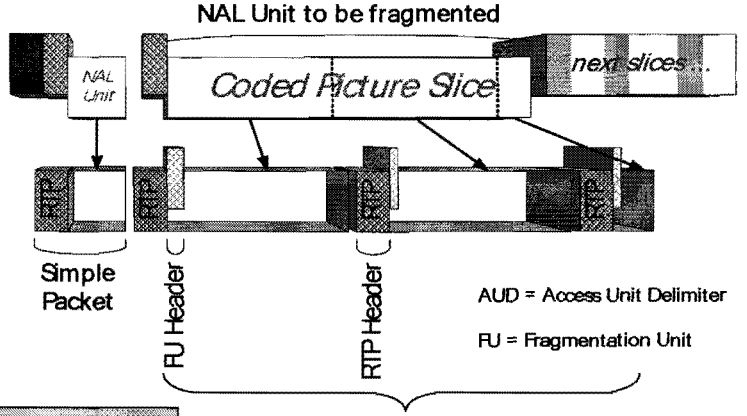
## NAL -> RTP




AUD are not needed in the RTP packets

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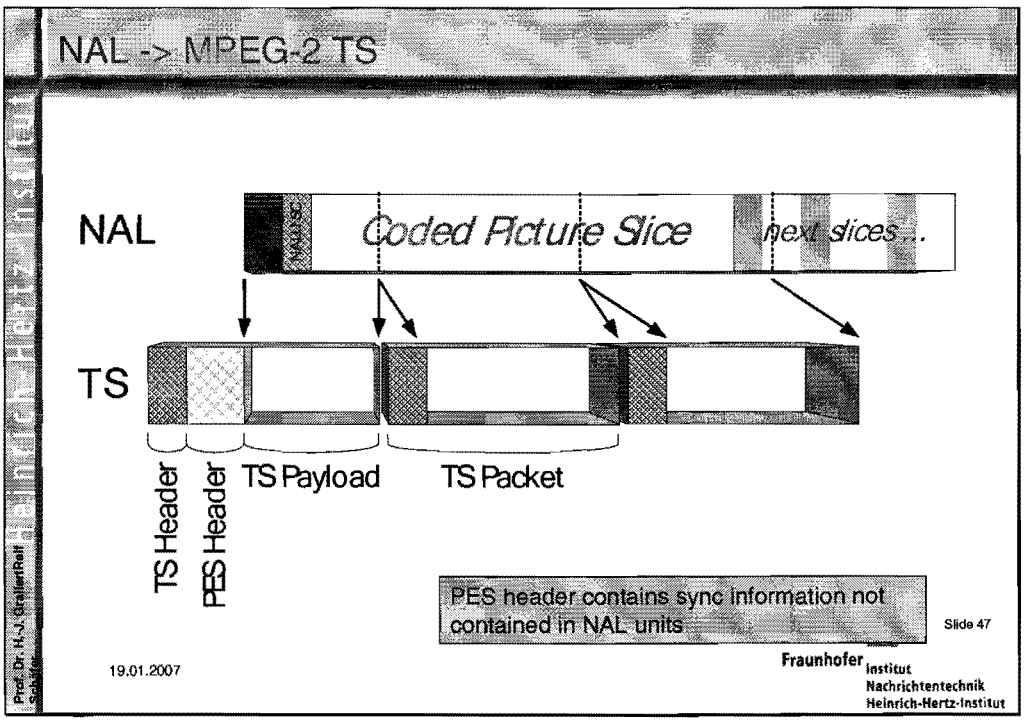
NAL -> MPEG-2 TS
NAL
Coded Picture Slice
next slices ...
TS
TS Header
PES Header
TS Payload
TS Packet
PES header contains sync information not contained in NAL units
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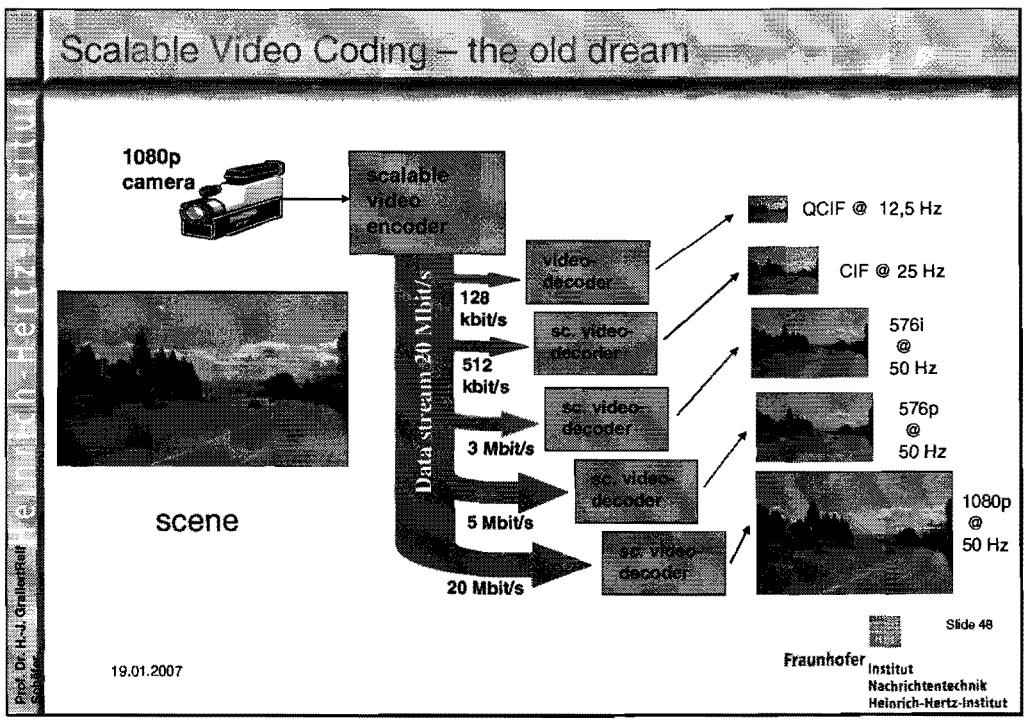
Scalable Video Coding – the old dream
1080p camera
scalable video encoder
Data stream 20 Mbit/s
128 kbit/s
512 kbit/s
3 Mbit/s
5 Mbit/s
20 Mbit/s
video-decoder
sc. video-decoder
sc. video-decoder
sc. video-decoder
sc. video-decoder
QCIF @ 12,5 Hz
CIF @ 25 Hz
576i @ 50 Hz
576p @ 50 Hz
1080p @ 50 Hz
scene
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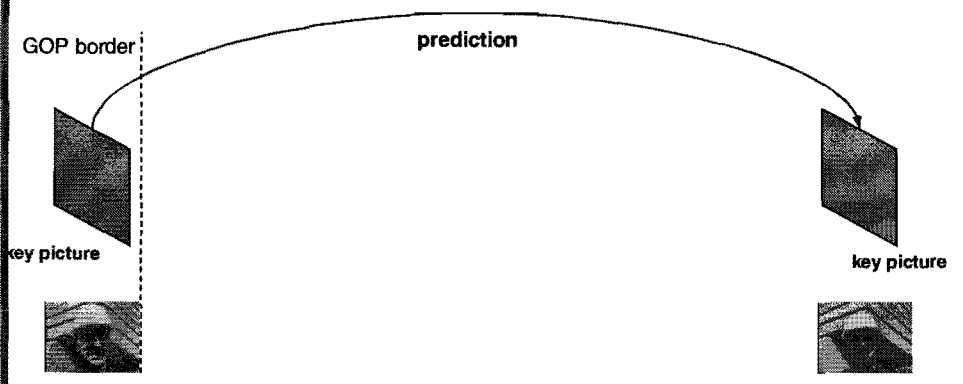
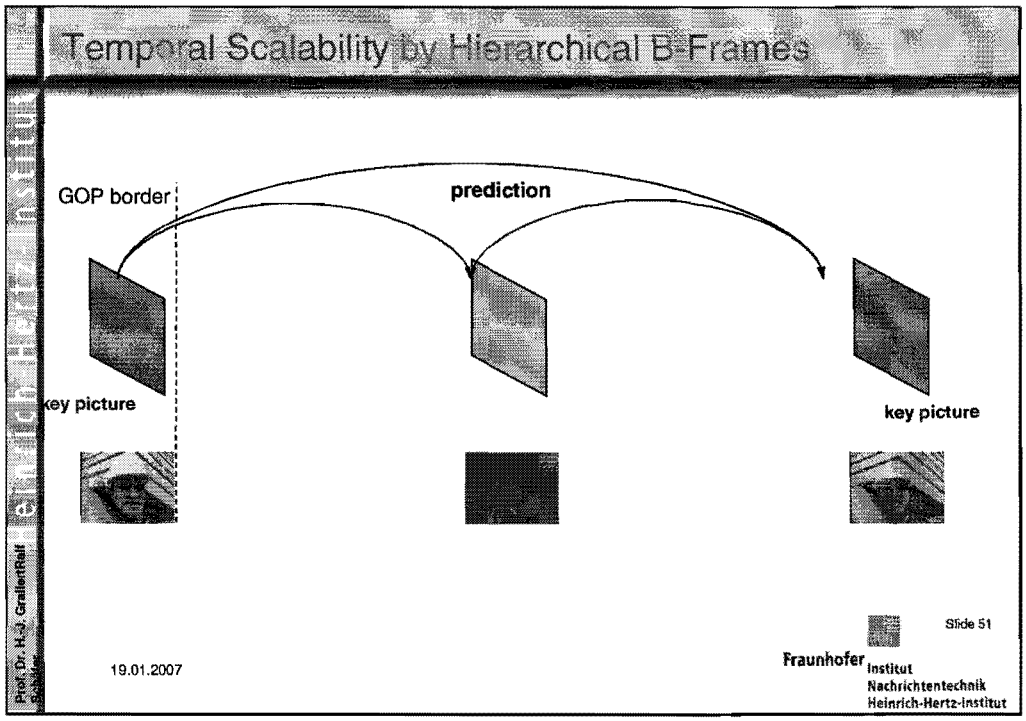
## Benefits of Scalable Video Coding & Current Status

- **Facing the scenario of heterogeneous media delivery:**
  - Different users
  - Different needs
  - Different displays
  - Different links
- **Flexible source coding, i.e. scalability is needed**
  - Simple adaptation to different bit-rates, frame rates or spatial resolutions of the video content on a bit-stream level
- **Realization of a fully scalable video coding scheme as an extension of H.264/AVC**
  - HHI proposed an SVC scheme, which incorporates the concept of Temporal, Spatial and SNR Scalability into the H.264/AVC framework.
  - This approach outperformes all competing approaches, which used spatial wavelets, by far.
  - HHI's proposal has been selected as basis for MPEG-4 SVC



## Temporal Scalability by Hierarchical B-Frames




Temporal Scalability by Hierarchical B-Frames
GOP border
prediction
key picture
key picture
Prof. Dr. H.-J. Grallert/Ralf Schäfer
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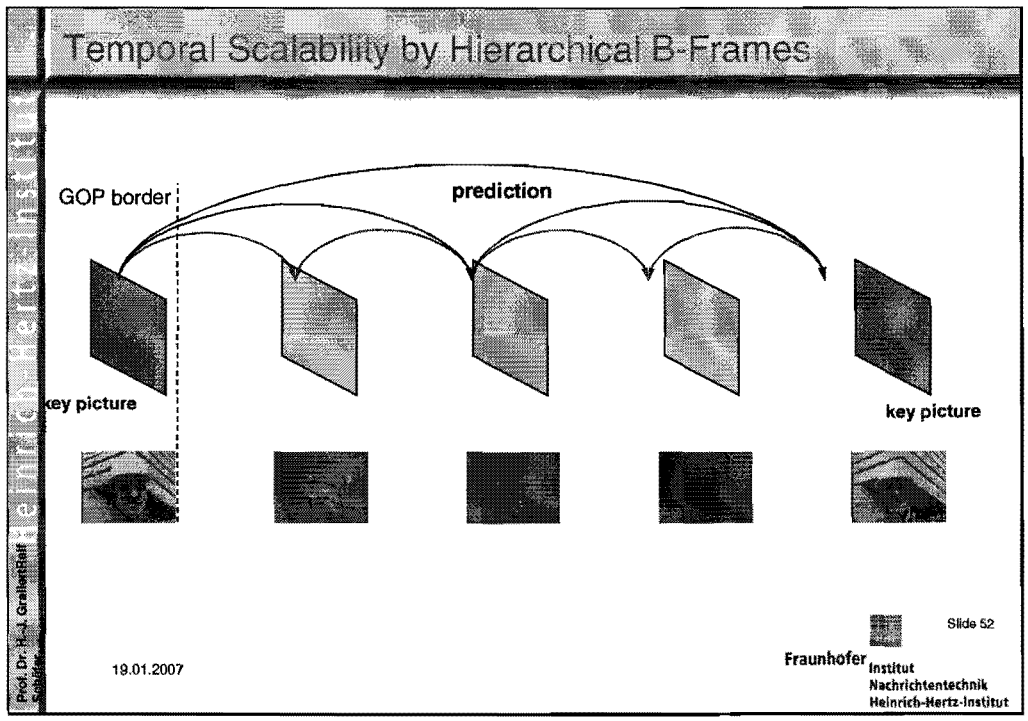
Temporal Scalability by Hierarchical B-Frames
GOP border
prediction
key picture
key picture
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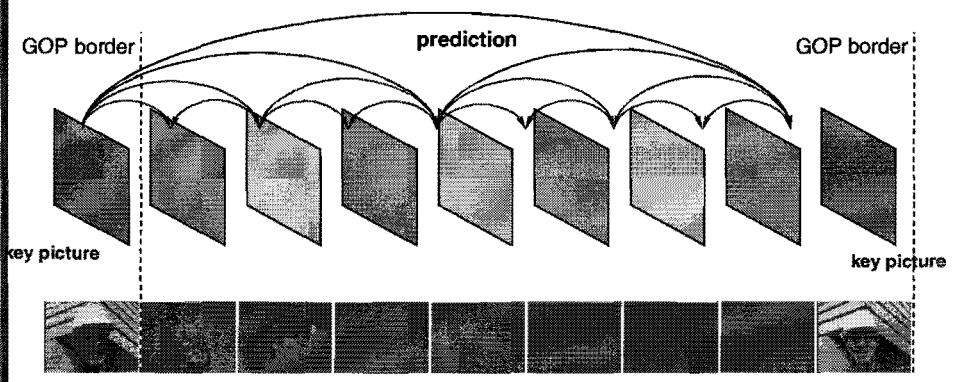
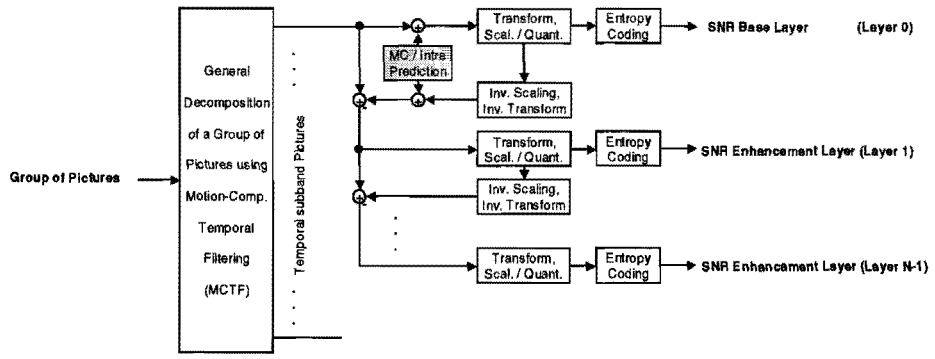
## Temporal Scalability by Hierarchical B-Frames



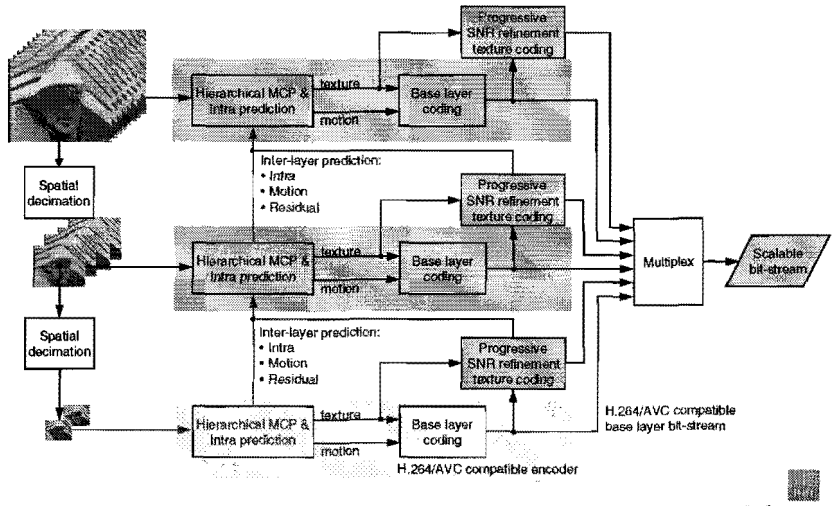

**Hierarchical B-frames are also a very efficient coding tool for H.264/AVC!**



## SNR scalability



## Spatial and SNR scalability

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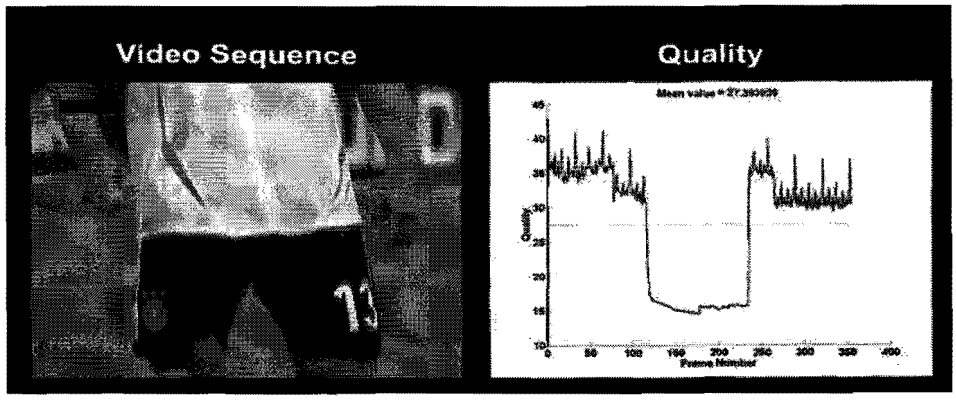
## Single Layer Streaming

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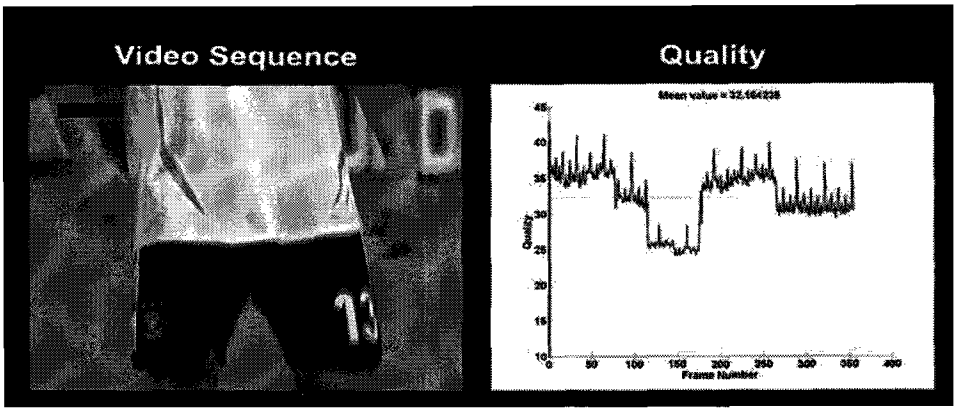
## SVC Streaming with UEP



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## Better Compression?

After the development of MPEG-2 some serious people said:

**"It will not be possible to improve coding efficiency further, so let's stop R&D in video coding!"**

Ten years later we have H.264/AVC and everybody wants it!

- ❑ Can we improve codings efficiency further, how could it work?
- ❑ Do we really need it?



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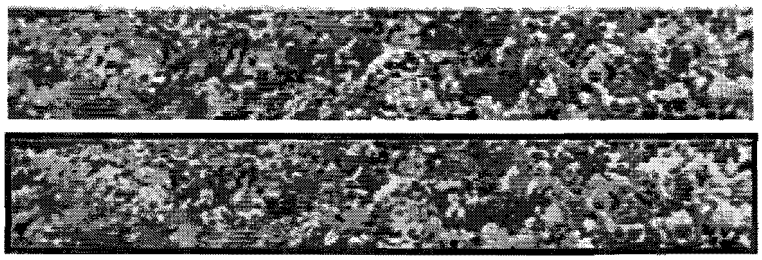
## Better Compression – How Could it Work?

One example:

- Textures with large amount of visible details are difficult to code e.g., grass, sand, clouds, water ...
- Viewer often does not perceive large differences between different versions of grass, sand, clouds, water ... -> image synthesis at the decoder



Where is the original texture ?

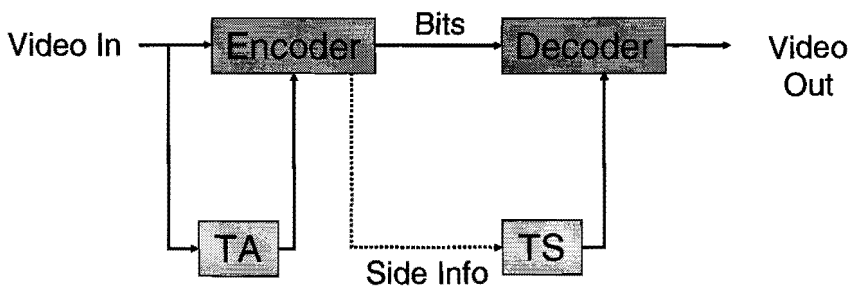






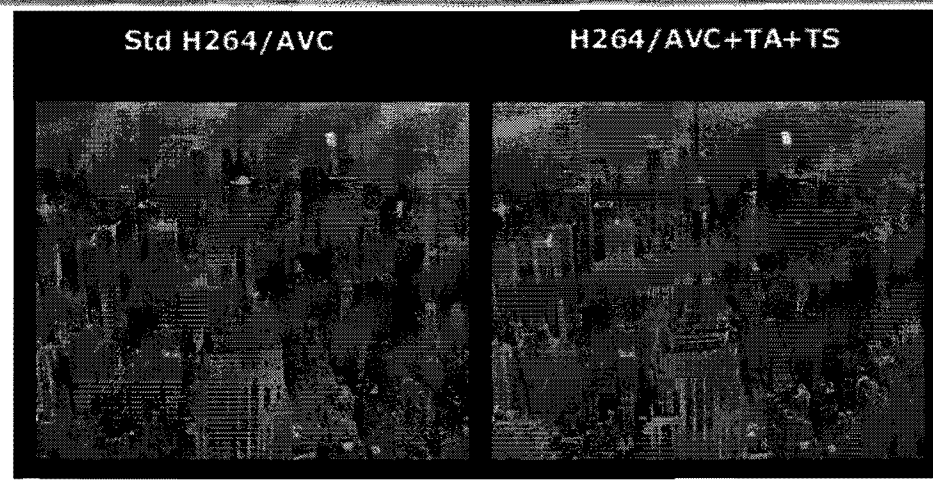


## Video coding with Texture Analysis and Synthesis




Video coding using a
texture analyzer (TA) and a texture synthesizer (TS)

## Performance of TA + TS




Bit-rate savings: 35%



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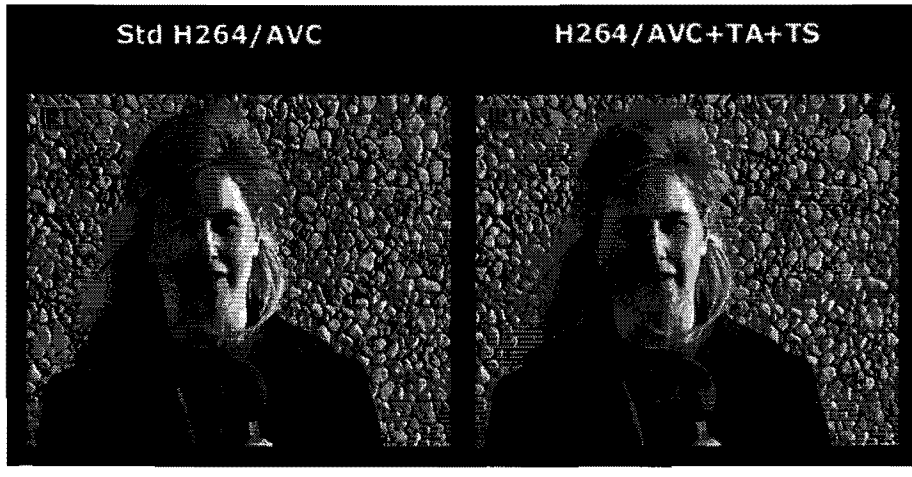
## Performance of TA + TS




Bit-rate savings: 23%



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## Better Compression – Do We Need it?

- (Video) Information is exploding – there is a need to transmit and store more and more data
- Existing analogue archives (films, records, libraries, etc.) will be digitized (Google, Quaero, Theseus, etc.) and enormous amount of data will be made available to the public
- Wireless transmission will become more and more important but spectrum will remain a scarce resource, in spite of spatial multiplexing (MIMO)
- Resolution of video will further increase: Multi-view video, Free Viewpoint Video, 3D-video, holographic representations etc.

**H.265 is on its way and it will provide another compression gain of 2 within 5 years!**

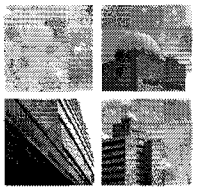


## Conclusions

- H.264/AVC is the most efficient and standardized video coding scheme
- By introducing new or improved coding tools, the coding efficiency could be increased by a factor 2-3 compared to MPEG-2 although H.265/AVC relies on traditional hybrid coding
- Competing schemes like VC1 or FLASH are subsets of H.264/AVC providing less coding tools (e.g. hierarchical B-frames) and are therefore less efficient (and less complex)
- Complexity is not an issue for IP-TV as STBs use HW decoder chips, therefore video quality should have priority.
- Even SW decoding of H.264/AVC @ HD resolution is possible today.
- There are mechanisms (NAL) available to embed H.264/AVC video streams into RTP or MPEG2-TS, which is necessary for IP-TV services.
- SVC is an interesting option for IPTV in the future, as it provides graceful degradation (and QoS) and is especially suitable for redistribution of video over unreliable home networks.
- The next step in video coding (i.e. H.265) is on its way, and it seems to be possible to obtain another factor of 2 in compression efficiency.

# Thank you

We put science into action



Prof. Dr.-Ing. H.-J. Grallert
Schulz

19.01.2007

Slide 65

Fraunhofer Institut
Nachrichtentechnik
Heinrich-Hertz-Institut

# Can't Pay Won't Pay will drives at Home IP Media Distribution

**Ir. Keith Baker**

**Philips Applied Technologies, Eindhoven, The Netherlands**

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# Can't Pay Won't Pay

Author: Keith Baker
Division: Applied Technologies Eindhoven

Date: Jan. 2007



## Overview

Where can IP-TV get Into the market?

Who will pay for it?

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## Definition

- ADSL : Common form of broadband connection in retail, but asymmetric
- Bittorrent : Social protocol on internet used for video files transfer
- DOCIS : Cable Modem standard
- FTTH : Fibre To The Home
  e.g. Nuenen Net
- iMP : a broadband service the BBC are developing that allows you to use the internet to download and watch programmes
- Non-Linear TV
  On-demand video services
- Peering : Virtual zero costs access to bandwidth for ISPs and other bulk users: e.g. BBC only pays 0.1 cents per MB/s per year
- P2P : File sharing network that using broadband internet
- TV without Frontier
  Legal Framework for European broadcasting.
- VOD : Video on Demand



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## Media was (and still is) important

- Media still has impact
  - –Not 1930's with the "War of World" radio broadcast
  - –Population are hardened and very very cynical
- Look at major Industries such as Sport
  - –Position of the monopoly is most important:
    - Sky and the English Football Monopoly
    - Plan used of DVB technology by News Corp
- Political influence is still important at EU level
  - –"TV without Frontiers"
  - –Non-linear content : Battle EU v Nations State

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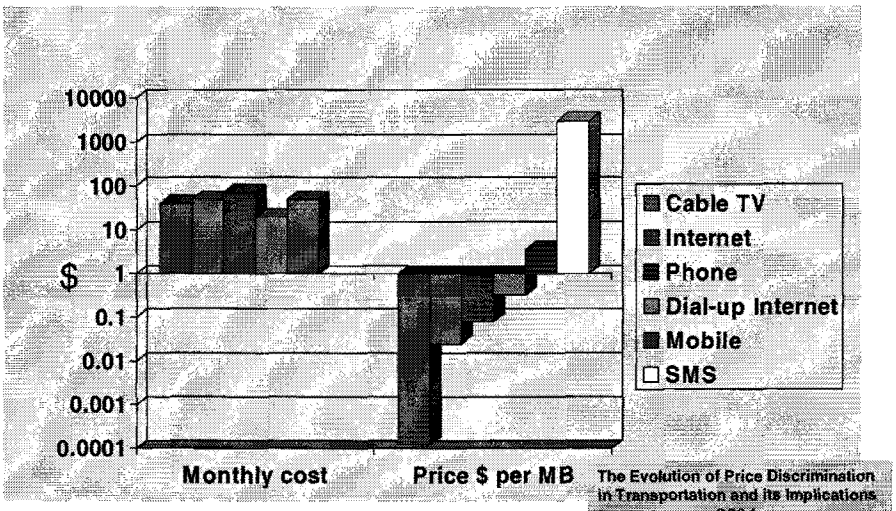
## Content is Not King : *ANDREW ODLYZKO*




The Evolution of Price Discrimination in Transportation and its Implications for the Internet, 2004



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## Television
## Roadblocks - The biggest challenges

1. New media rights issues: access, trade terms, contracts and exploitation
2. Collective management of rights (collecting societies)
3. Inconsistent application of broadcast and telecoms regulation to new media TV distribution in some countries
4. Unwillingness to damage existing revenue streams holding back new media exploitation

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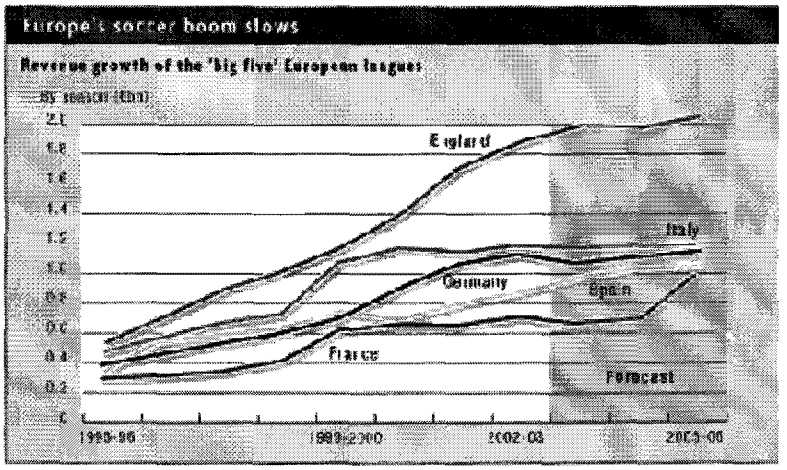
## What do people actually pay for: Football



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## EU interest and position

- Pan European Network : As DVB-S should have
  –Direct communication with the Voters
- Problems of IP-TV seen a Right issue
- I don't agree, but the Media disaggregation process is important to understand for future.

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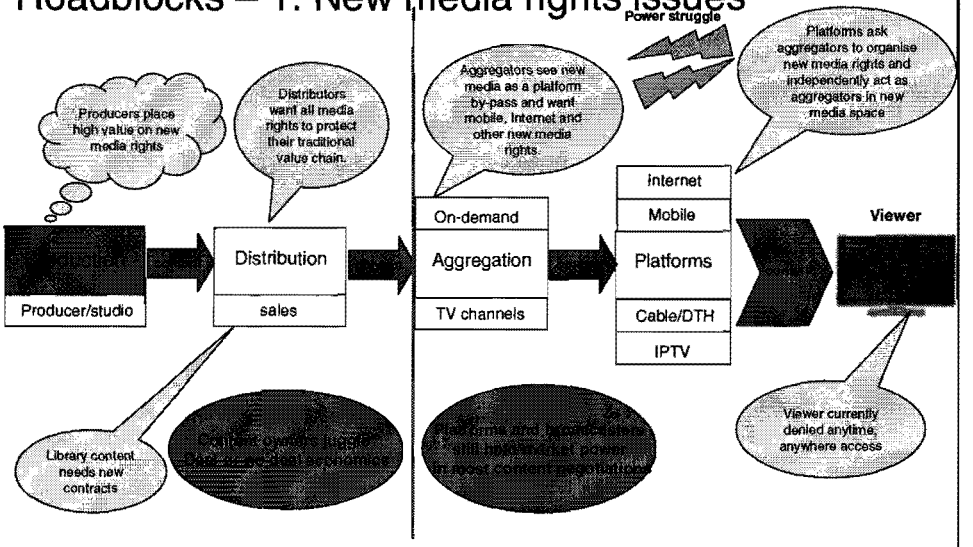
# Television
# Roadblocks – 1. New media rights issues



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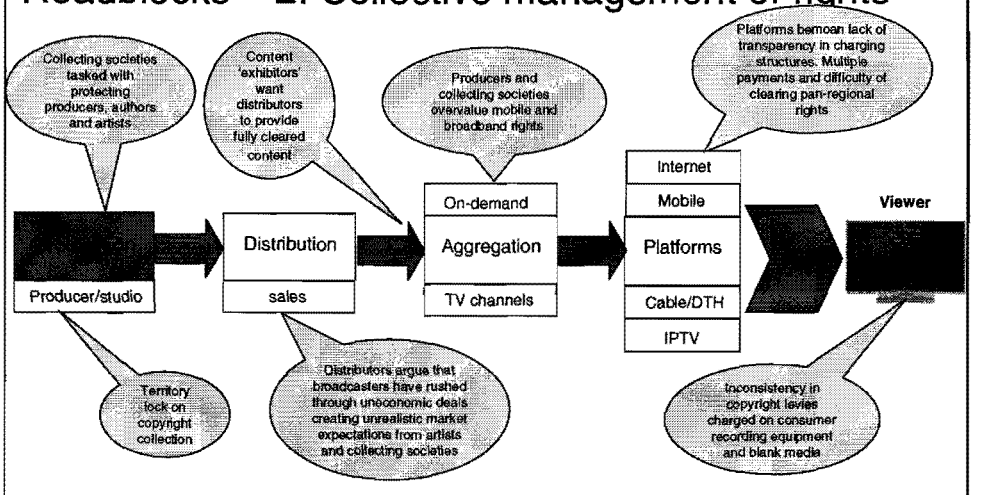
# Television
# Roadblocks – 2. Collective management of rights



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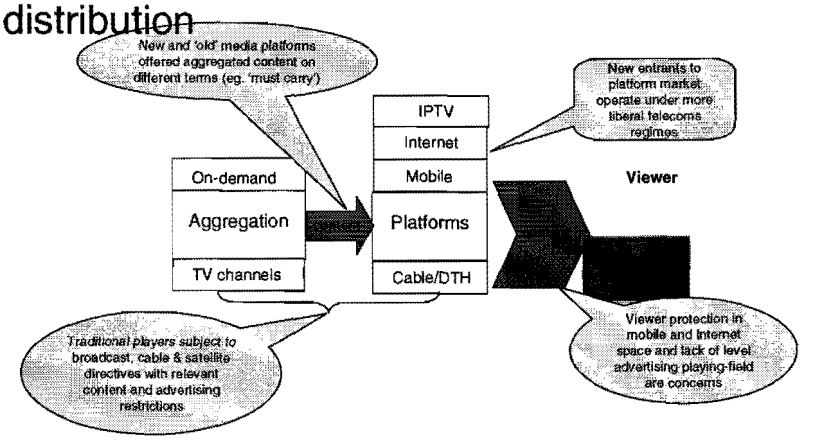
# Television
# Roadblocks – 3. Regulation of new media TV distribution



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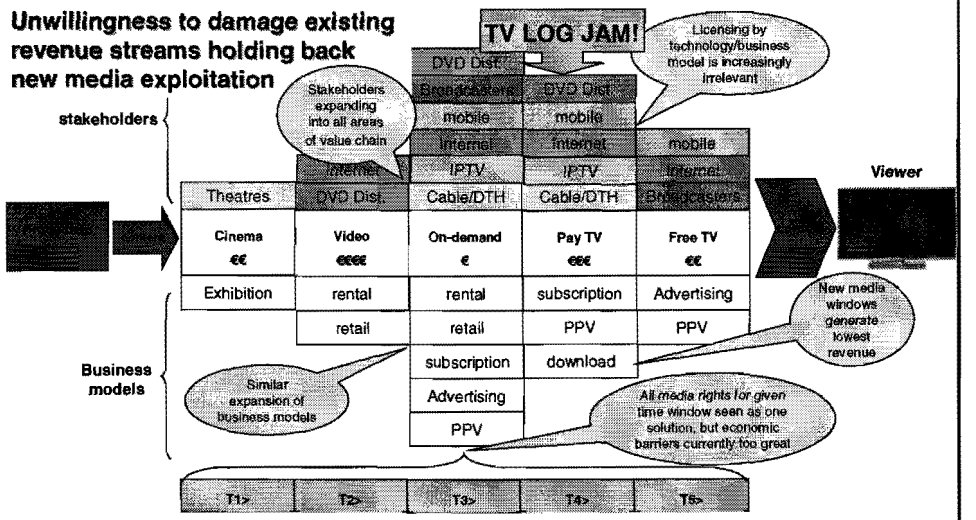
# Television
# Roadblocks – 4. Reluctance to license

**Unwillingness to damage existing revenue streams holding back new media exploitation**



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## Market Driven IP-TV

- IP-TV is old wine in new bottles
  - –Consumer reaction in Netherlands to IP-TV
    - least accepted of digital TV technologies
  - –Major IPTV project are delayed Swisscom IPTV Flagship
  - –Fastweb IP-TV network owners has sold out to create a P2P network



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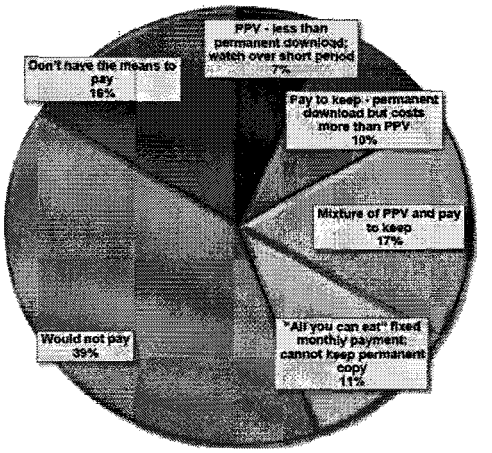
## Can't Pay Won't Pay for VOD : P2P

- P2P network use Internet friendly protocols for the virtual zero cost distribution of large files.
- Disputed P2P networks such as Bittorrent are already by over 600,000 users Europe to receive US HDTV content: e.g. 24, Battlestar-Galactica, Enterprise, Desperate Housewives. etc.
- Bittorrent protocol in inherently scalable: could be used any infinite number of users; provide they are social minded, and have internet bandwidth to share

**Figure 37: How would you prefer to pay for audiovisual content (e.g. music, TV programmes, movies) you stream or download from the internet to your computer?**
Base: All respondents

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## Who wants IP-TV to Work

- European Union
- Telco for a Triple Play
- The rest don't care or don't wish it!

**Figure 31: How often, if at all, do you do the following?**
Base: All respondents

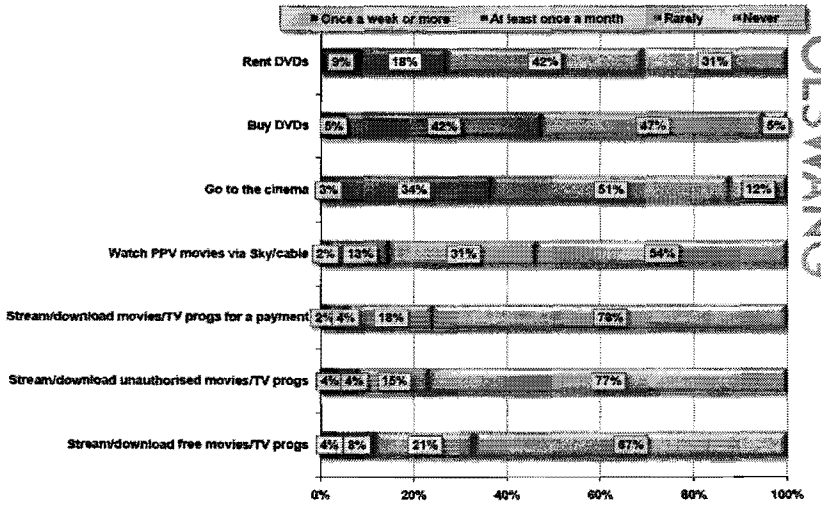


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**Figure 33: How much each month (on top of anything you are already paying your digital TV provider) would you be prepared to pay in total to watch streamed/downloaded TV programmes and movies on your PC?**
Base: All respondents

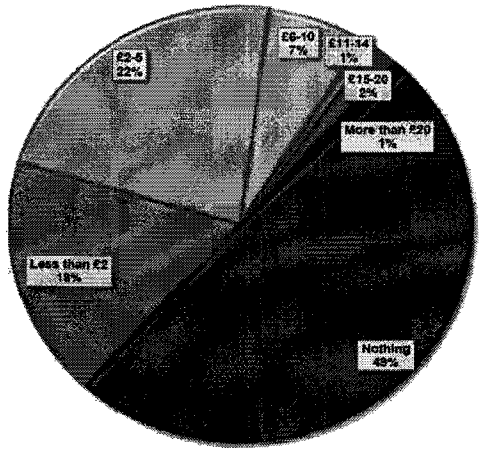


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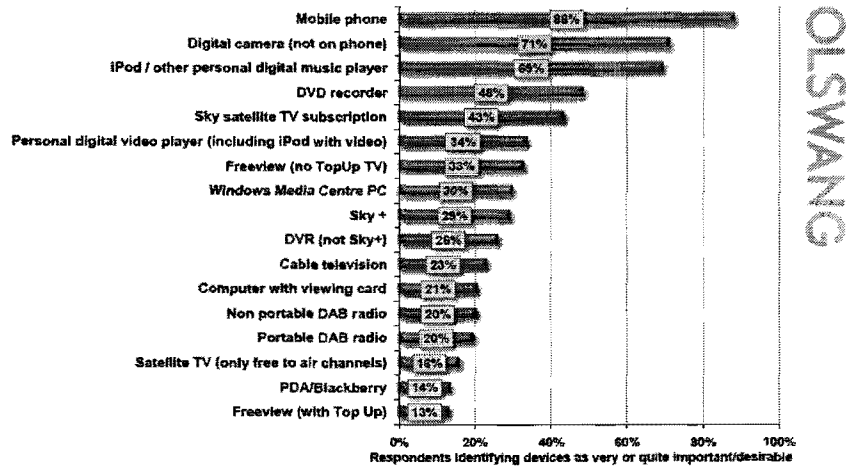
**Figure 2: Please indicate how important or desirable each of the following devices is to you**
Base: All respondents



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## Social Issues

- Openness to Media : Participation (Another slide)
  - –Youtube
  - –Blindness to "unlawful" use of Copyrighted media
- Multi-Task
  - –Multi-screened room
- PVR and Advertising
  - –Needs creativity
- Viewing information
  - –IPTV specific problem
  - –Turn very nasty if distributors think they own customer information: see RFID

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**Figure 36: Which one of the following best describes your attitude to streaming/downloading full-length TV programmes or full-length movies over the internet?**
Base: All respondents

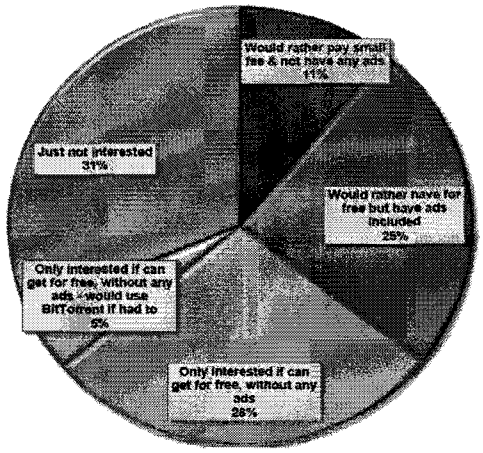


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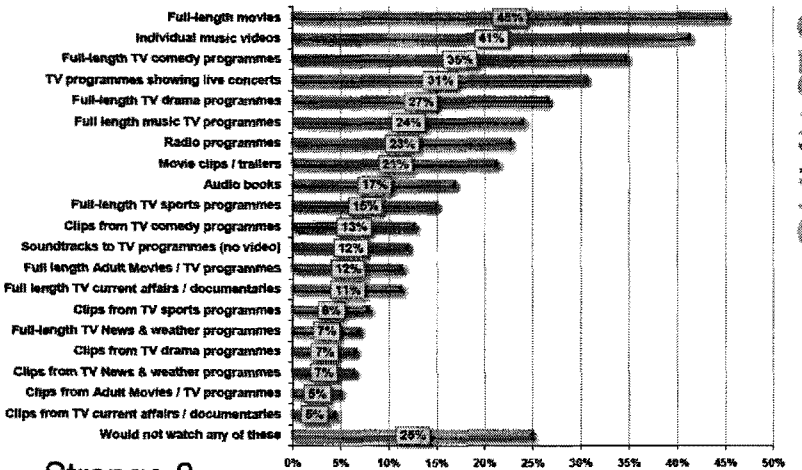
**Figure 34: Which of the following would you want to download/stream over the internet, to watch or listen to on your PC when you were at home?**
Base: All respondents




Strange ?

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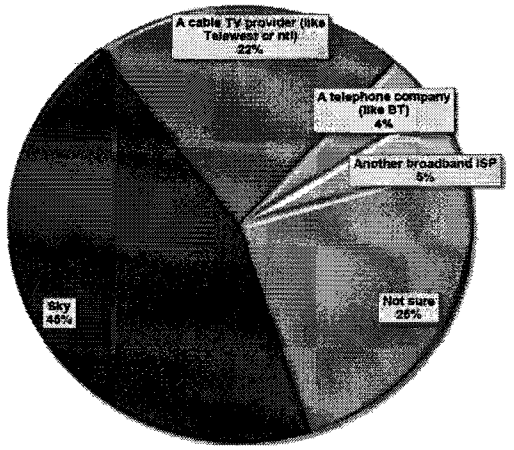
**Figure 25: Which one of the following providers would you be most likely to subscribe to for a "Video on Demand" service?**
Base: All interested in video on demand service

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## Generation Gap : < 19 year old : broadband hit the families

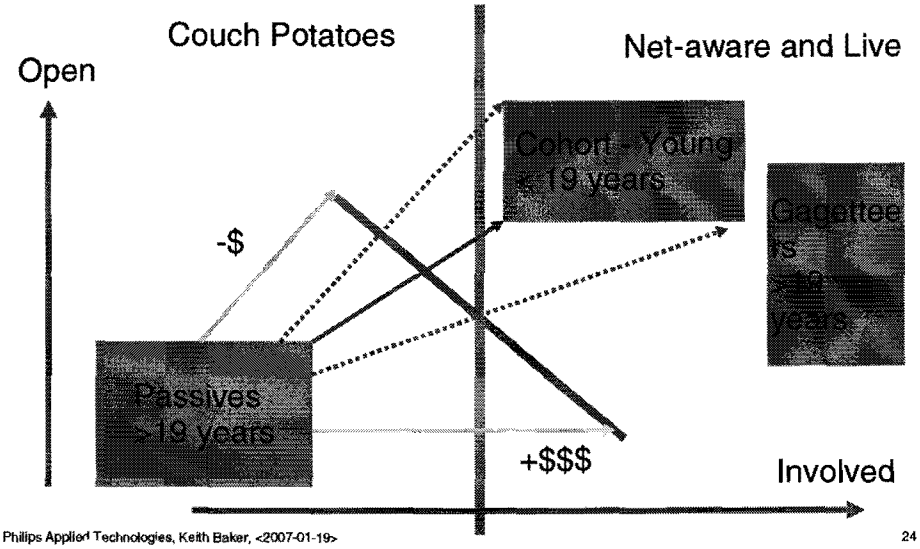

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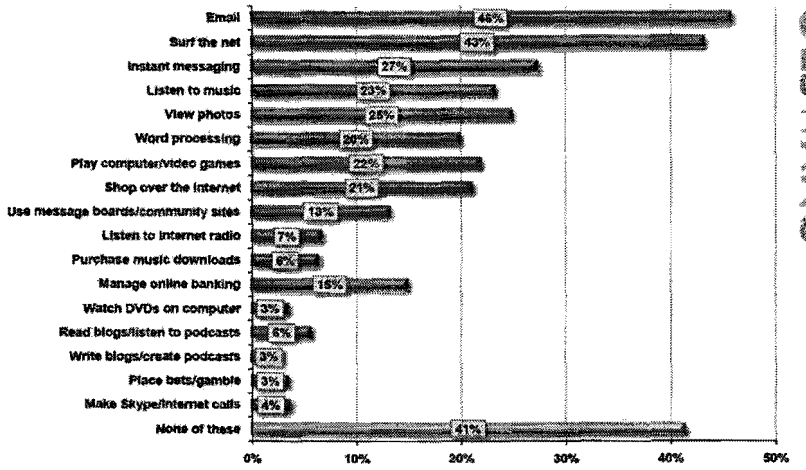
**Figure 30: When you are watching television at home on your normal television set, do you also do any of these activities at the same time?**
Base: All respondents

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# If IP-TV can't make it Alone then Team-up

- Game platforms
  - –XBOX360
  - –PS3
- PC : ISV Google and Yahoo
  - –Maybe unavoidable
- Disaggregation by Retailers : Wal-mart
  - – E-Bay : Skype and Joost (was TVP)
- Traditional Media : Hollywood
  - – DVD download or BD-Live

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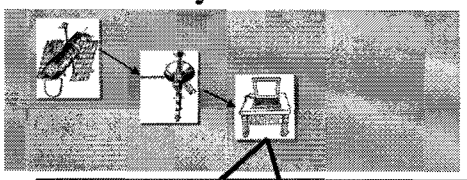
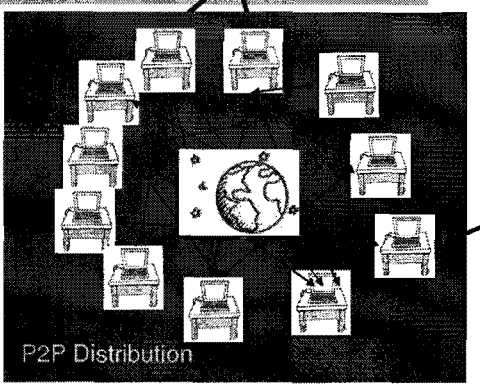
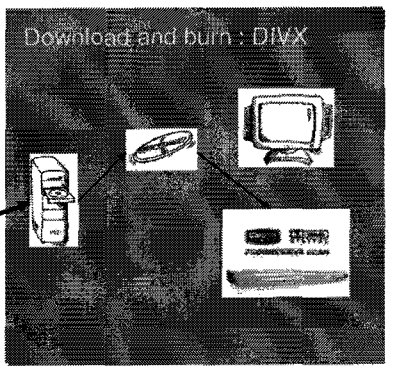
## Pirate Bay : P2P : Bittorrent Technology





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## Broadcasters and P2P

- UK Broadcasters see P2P as better than broadcast
  - –Instant PVR technology on home network
  - –Better quality than Broadcast
    - 16:9: Progressive and MPEG4 quality with VBR
      - –e.g. as good or better then DVD
    - HDTV distribution proven from US pirate networks
  - –Zero cost distribution :
    - no infra-structure
    - no codec costs from Real/Microsoft/MPEG4-AVC
    - no spectrum costs or fight with mobile operators
- BBC and now Sky active with Kontiki
  - –BBC called iMP player
  - –Sky in discussion
- Must have high "National" broadband penetration

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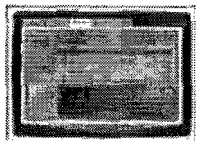
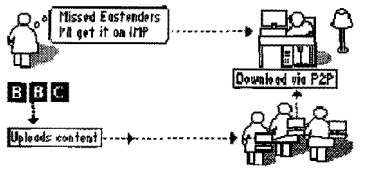
# BBC iMP player : Mis-fired P2P network

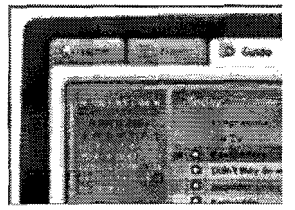
## Microsoft DRM






BBC iMP

Based on
Kontiki's OMN



Killed by Flag-ship Channel owners



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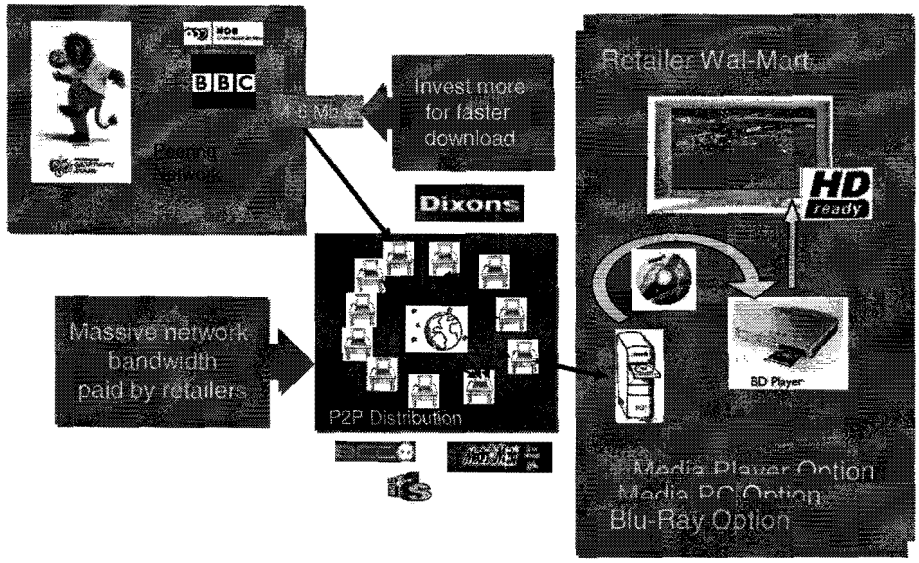
# Create a HDTV P2P Network for Wal-Mart



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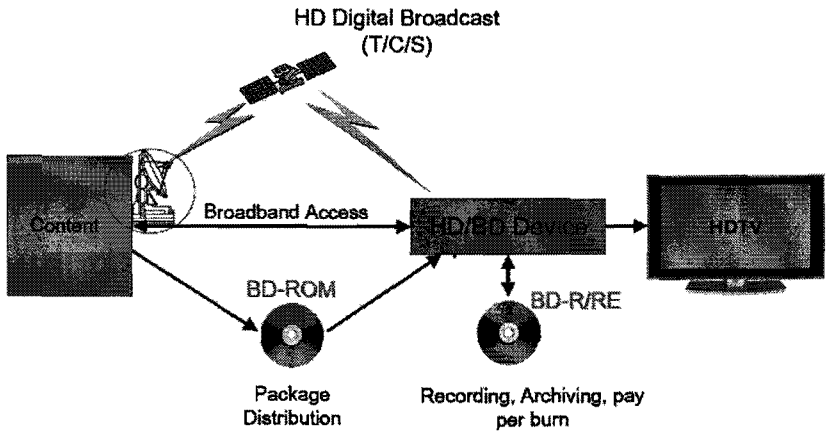
## Many options based on BD Eco-system + P2P



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## Taming of P2P happening fast in 2006

- Bittorrent accepted by some Studios
- E-bay Skype launch : The Venice Project
- Fastweb Owner move to BabelGum
- Many of the P2P technology vendors doing deals

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## Vision of Future

- Packaging of Content for Multi-Display Home Viewing
- Maxima Report
- Minority report and BD Technology : BD-Live



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## IP-TV Future

- If you can beat join them
- There are many options?

# IP-TV: Challenges for a broadcast company

**Ir. Werner Ramaekers**

**Flemish Radio- and Television Network - VRT, Brussels, Belgium**

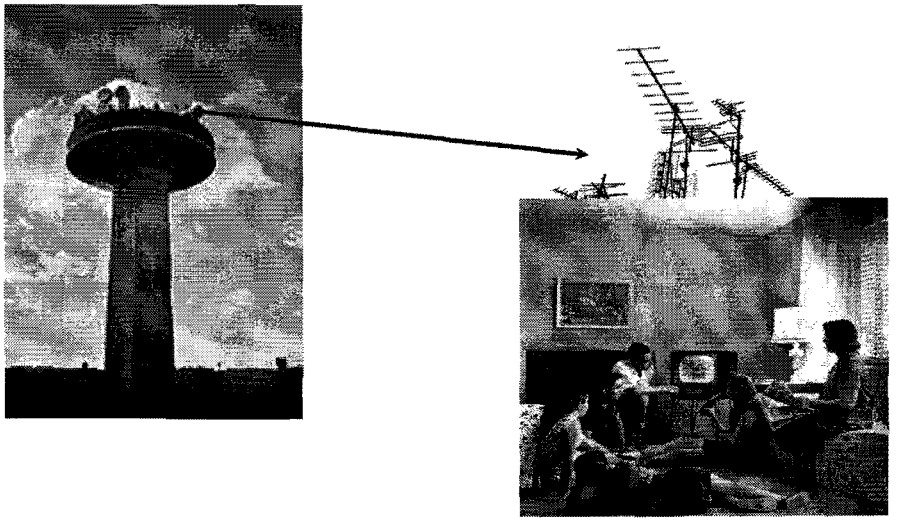
# IP-TV
## Challenges for a public broadcaster

ir. Werner Ramaekers

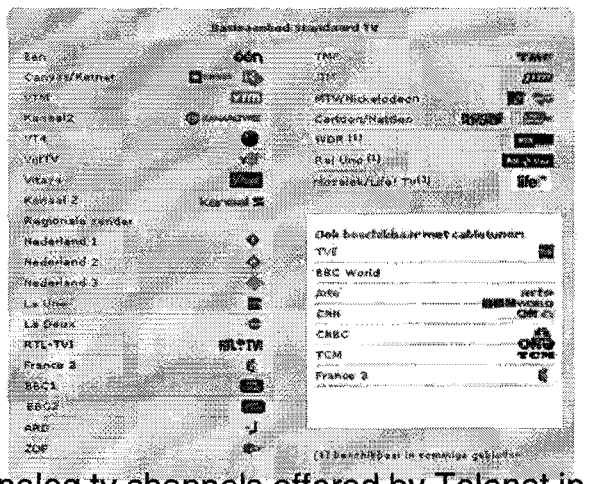
A
**public broadcaster**
is about ...

# Content


# Distribution



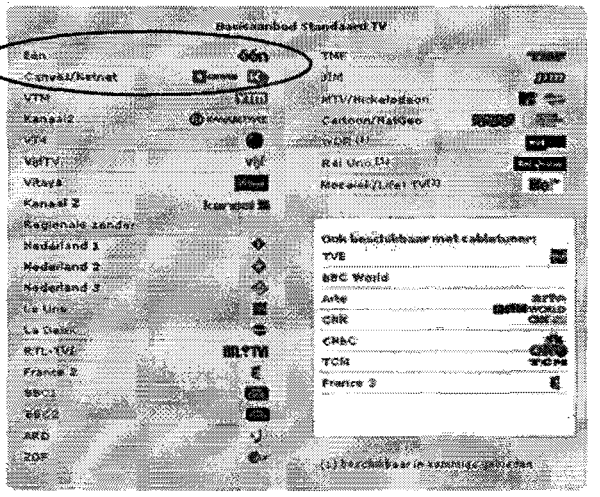
# Broadcast TV 2006




35 analog tv channels offered by Telenet in Flanders

# Broadcast TV 2006

VRT

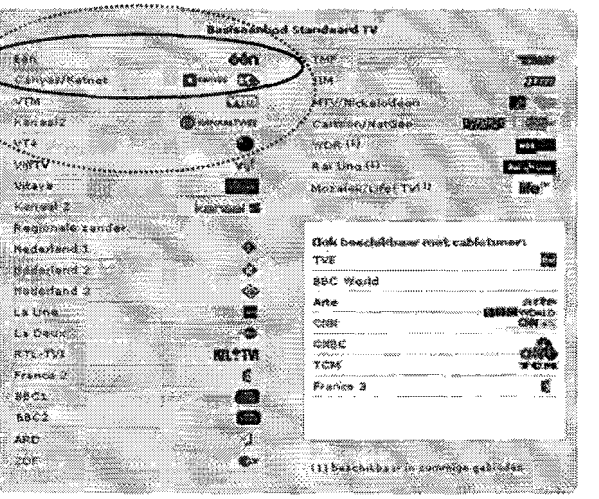



3 of the 35 analog tv channels offered by Telenet in Flanders

# Broadcast TV 2006

VRT

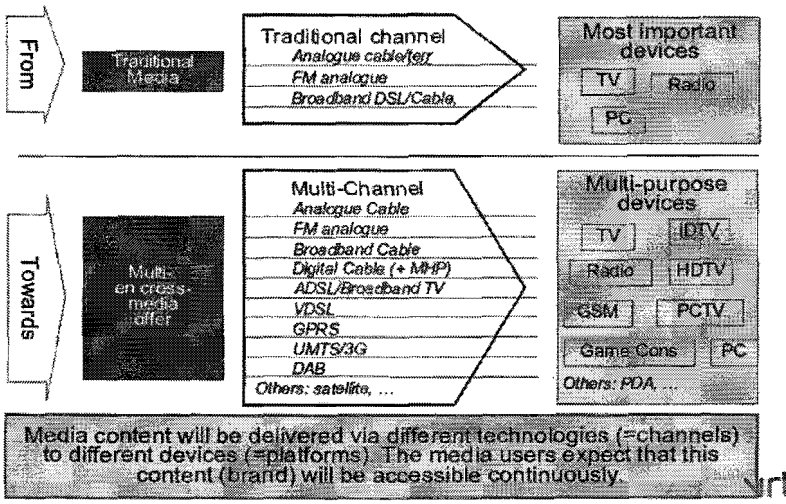
90% view



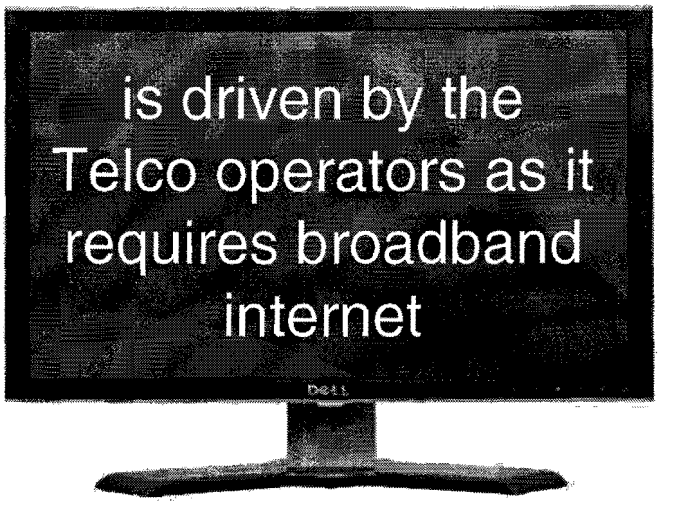
6 of the 35 analog tv channels offered by Telenet in Flanders

# New Consumer patterns

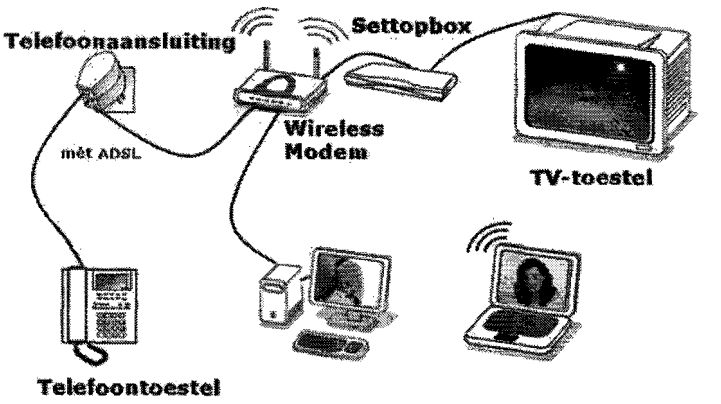
# Challenge : Crossmedia




# Digital TV

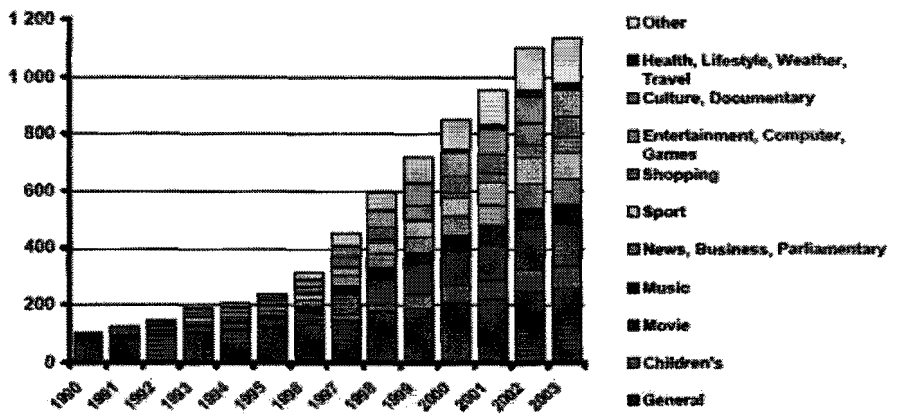


# Digital TV : Belgacom TV




# Growth of tv-channels

**Figure 1:** Number of television channels by genre in Europe (1990 to 2003)



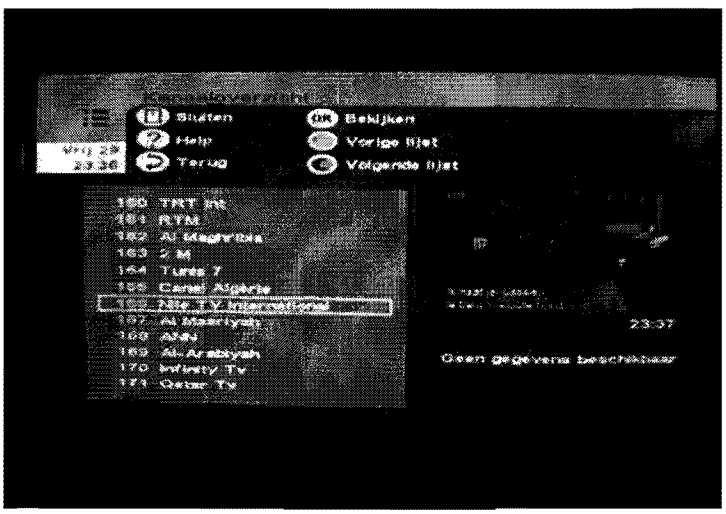

*Source: Screen Digest*

The public will get a more choice in in generalist and thematic channels

# Growth of tv-channels

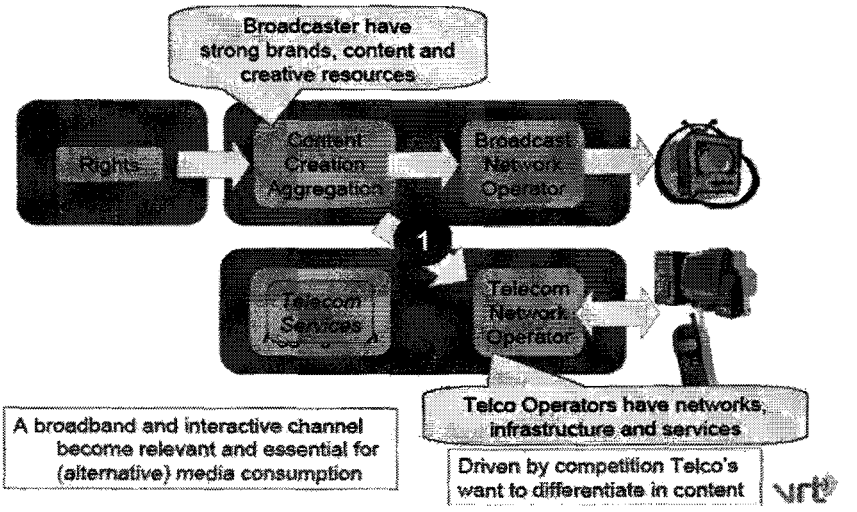
- 277 channels launched in Europe in 2004
- Situation in the UK (2005)
  - 416 channels of which
    - 47 home shopping
    - 32 music
    - 30 documentary
    - 29 adult

# Digital TV : EPG

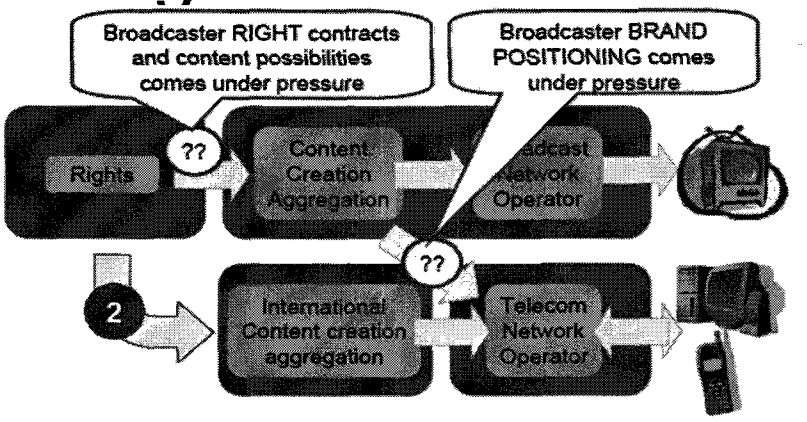


# Stand out from the crowd

# Broadcast vs Telco : content



# Challenge : content rights and brands



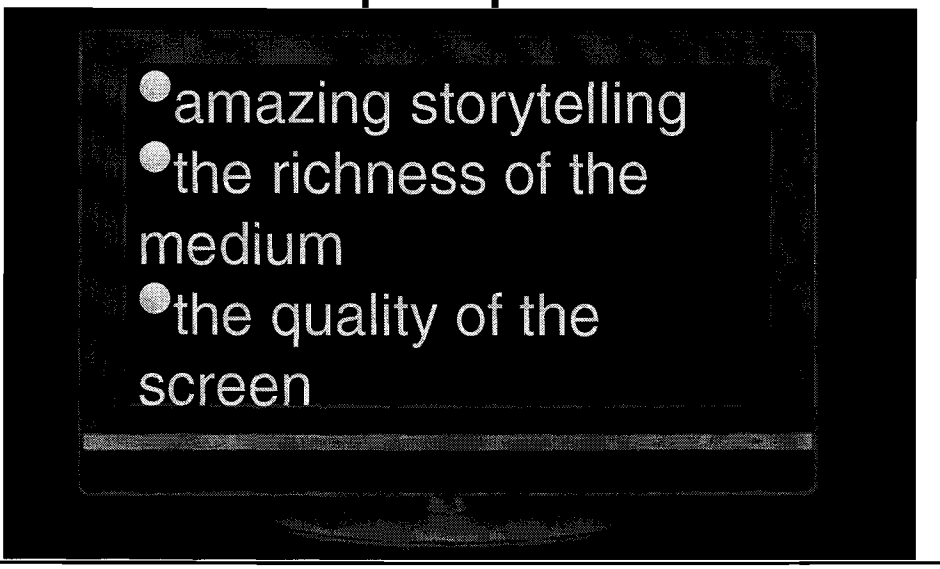

Telco's becoming international, will search for global partnerships or alliances in content rights and production

**5,3%**

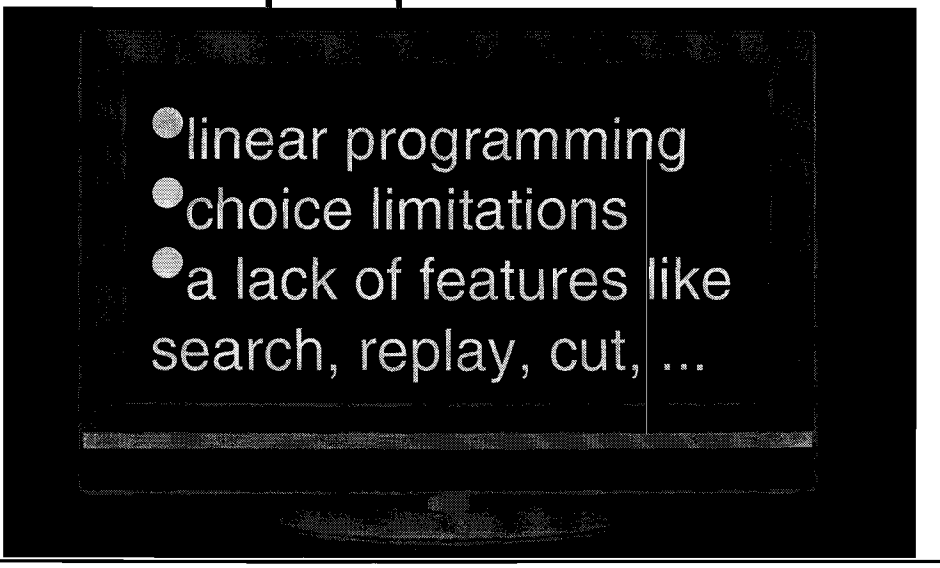
of all broadband internet subscribers have an IP-TV subscription

Source : Belgacom (2006)

# TV : people like

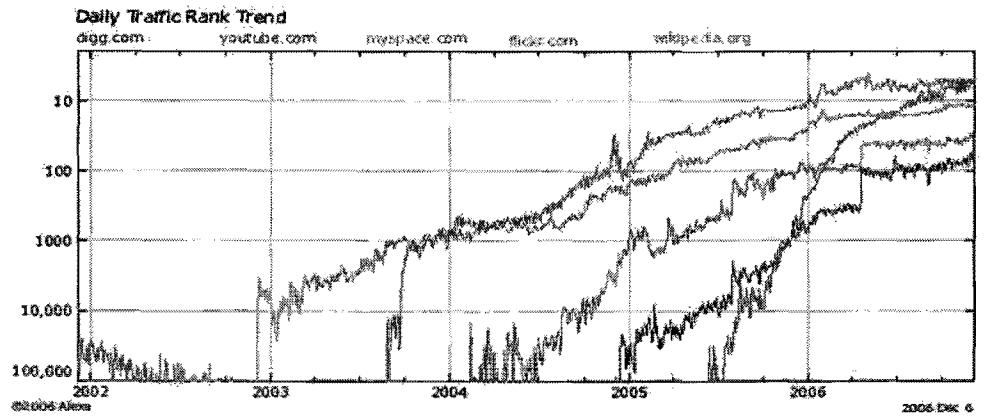



# TV : people don't like



**The internet**
is all about
personal choice

# Social Software




digg YouTube Broadcast Yourself™ myspace.com a place for friends flickr WIKIPEDIA

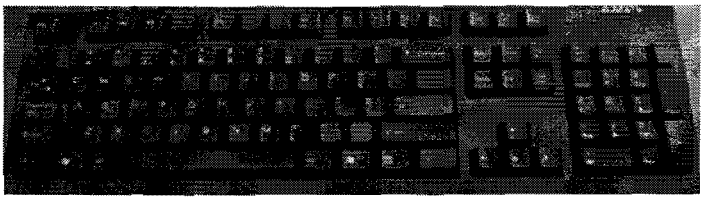
# A recipe

- An individual should get value from their contribution
- These contributions should provide value to their peers as well
- The organization hosting the service should derive aggregate value and be able to expose this back to the users.

TV will not be replaced by the YouTube's and Google video's

TV viewers want this

not this



# Your TV will connect to the internet

# Open TV platform

- Linear network programming
  - *"broadcast"*
- A la carte TV
  - *iTunes, XBox, DVD, on demand, ...*
- Peer created content
- Branded entertainment

# Apple TV

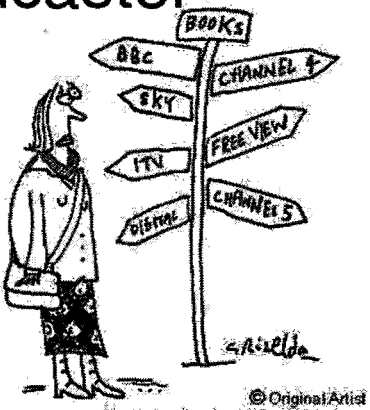

# TV in 2008


http://flickr.com/photos/epenglei/256693349/

**507 channels and nothing on**

# Continuous role for the public broadcaster

Help people choose



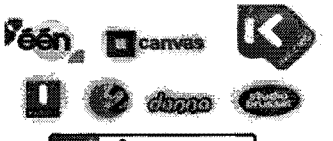



# Help people choose: trusted brands

BBC

BBC NEWS

CNN.com




## Help people choose : trusted source

## Continuous role for the public broadcaster

Provide (local) news and content not covered by commercial stations.

*Public service*

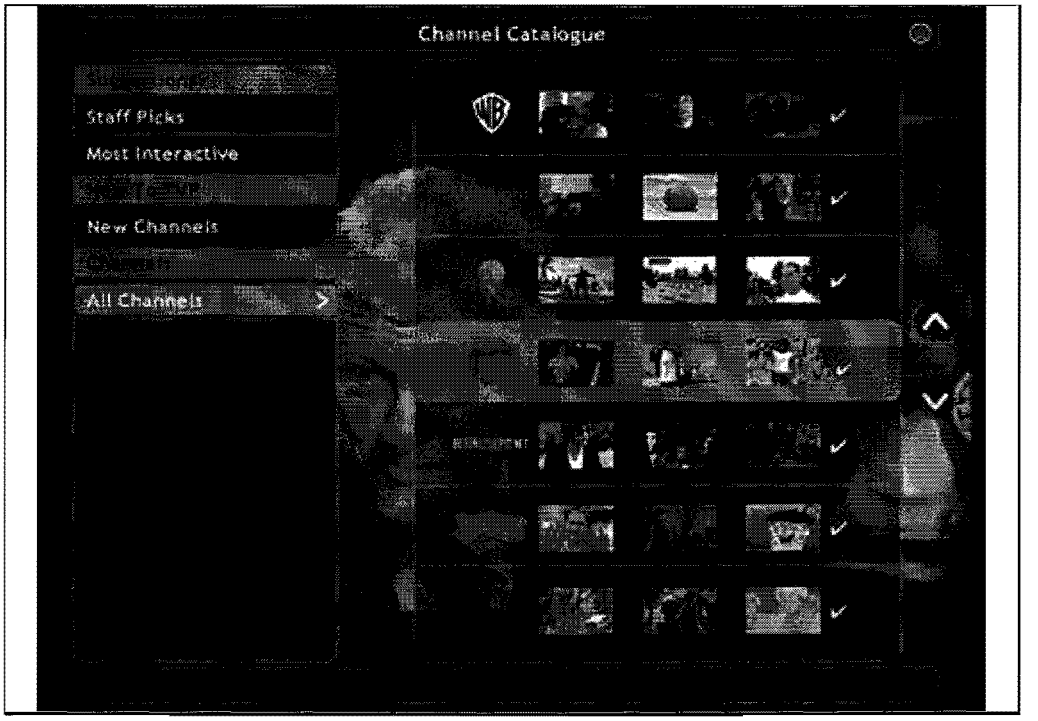
# 16plus.be = localized UserGen


# Challenge
# On-demand IP-TV

# On-demand IP-TV and P2P

- The challenge : everyone wants to view the same show but at a different time
- A solution : use secure P2P and make every viewer also a broadcaster

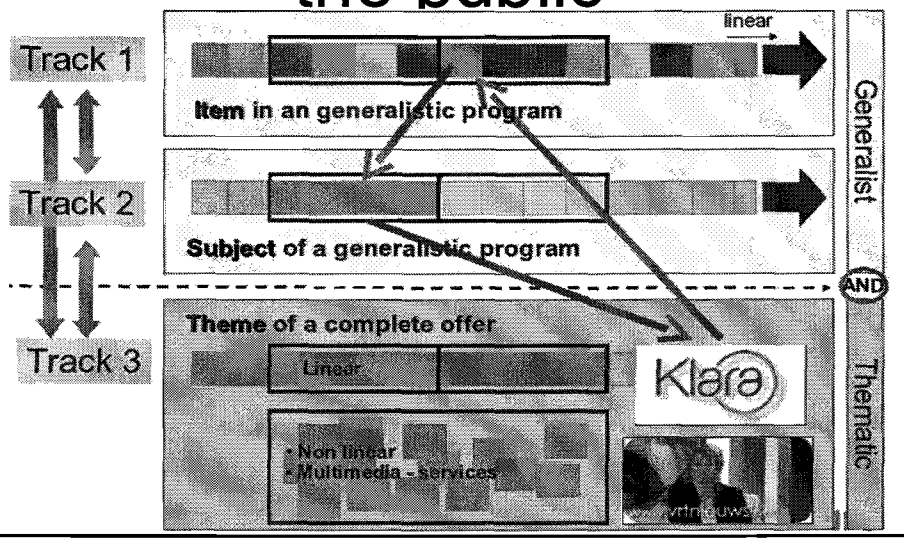
# Kazaa, Skype and now


Channel Catalogue
Staff Picks
Most Interactive
New Channels
All Channels

# Bandwidth usage compared

| | |
|---|---|
| Digital satellite tv | 14-70 Gb/hr |
| Compressed digital tv | 900 Mb-3 Gb/hr |
| TV D/L through file-sharing | 350 Mb/45' |
| Veniceproject P2P | D/L : 220-320 Mb/hr<br>U/L : 105 Mb/hr |

# Challenge : keep access to the public




# Who decides what will be successful ?

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# IP-TV
## Challenges for a public broadcaster

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# The IP in IP-TV: the Networking Aspects

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# The IP in IP-TV

## The Networking Aspects


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## Acknowledgment

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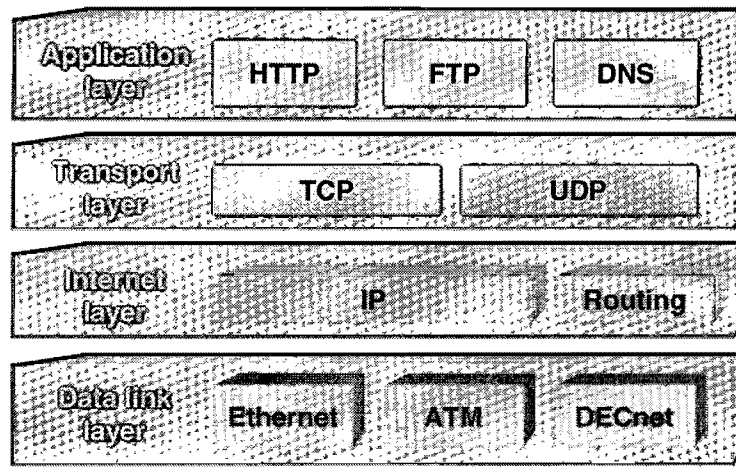
# The Internet Protocol suite

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# IP networks and the Internet

- IP networks are based on the Internet Protocol suite
  - Internet protocol, IP
    - Two versions: version 4 (current) and 6 (coming)
    - Format of data packets (datagrams)
      - Variable length from 0 to 65 kB
      - Header 20 or 40 B (versions 4 and 6), longer with options
    - Address structure for data packets
      - 32-bit addresses for version 4
      - 128-bit addresses for version 6
      - Unicast and multicast (group) addresses
  - Transmission control protocol
    - Reliable delivery by means of retransmission
    - Congestion control that regulates the sending rate
    - Port numbers to map data streams onto applications
  - User datagram protocol
    - Unreliable delivery, no congestion control
      - For application or network to provide
    - Port numbers
- The Internet is a global public IP network
  - Composed of IP networks owned and operated by different parties
  - One common address structure
    - Each IP address must be unique in the Internet
    - Controlled by Internet Assigned Numbers Authority
      - also domain names and protocol number assignments

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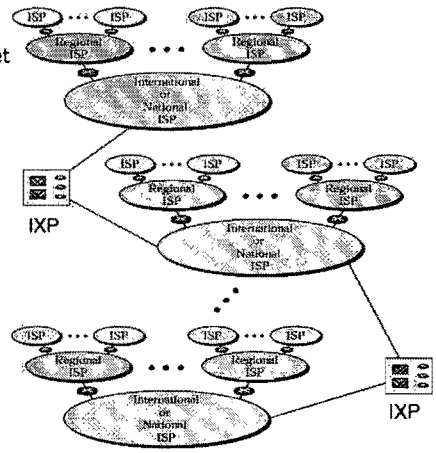
# Structure of the Internet

- Internet service providers
  - Offer access to the Internet
  - IP-level connectivity
    - Provided by internal routing protocols
      - OSFP, IS-IS
    - Based on generic cost metric
      - Number of hops
- Peering
  - ISPs connect to one another
    - Directly or via IXP
      - Internet exchange point
    - Routing based on cost and policy
      - BGP4

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# Internet design philosophy

- IP over everything
  - Common interchange format across underlying network technologies
    - Ethernets
    - Optical WDM networks
    - Wireless
- The end-to-end argument
  - Functions placed at low levels of a system may be redundant or of little value when compared with the cost of providing them at that low level.
    - *End-to-End Arguments in System Design,* J.H. Saltzer, D. P. Reed, and D. D. Clark, ACM Trans. Computer Systems, 1984
  - Provides a separation of roles between the network and the hosts
- Best-effort service model
  - Service performance is not ensured by the network operation
- Soft state
  - The state is recurrently refreshed
  - Failsafe mode when state times out

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# Internet design philosophy


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- Decentralization
  - No one owns or controls the Internet
- Consequences
  - Scalability
    - Enormous growth
  - Swift development of applications
    - Eg. WWW, Google, BitTorrent, Skype
  - Incremental (slow) development of the whole network
    - Eg. introduction of IP version 6
  - Enforcement of rules
    - Source address verification
    - Congestion control
    - Accountability, security and privacy



# Outline of remainder


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- Video over IP networks
  - Unicast and multicast
  - Broadcast and video on demand
  - IP-TV network structure
  - IP-TV versus Internet television
- Network performance: Quality of service
  - Definition
  - Expectations
  - QoS in the network
  - Controlling delay and loss
- Conclusion

# Unicast and multicast


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- First remember
  - All links are bidirectional
    - Interactivity is inherently supported
  - Other data can be sent in addition to digital video and audio
    - Control information
    - Electronic program guides
- Unicast
  - Each received gets an individual data stream
    - Links may carry multiple copies of the same data packets
  - Relies on present IP routing protocols
    - Subject to instability
- Multicast
  - Constructs a distribution tree out to all receivers
    - No redundant packets sent on the links
  - Several routing protocols available
    - Find branching points as close to the receivers as possible
    - Update tree structure when receivers join and leave the session
  - *Internet group management protocol* (IGMP)
    - Allows the last router on a branch to track group membership
    - Receivers send join and leave messages
    - Soft state to allow for receivers leaving without notice



# Broadcast and on-demand


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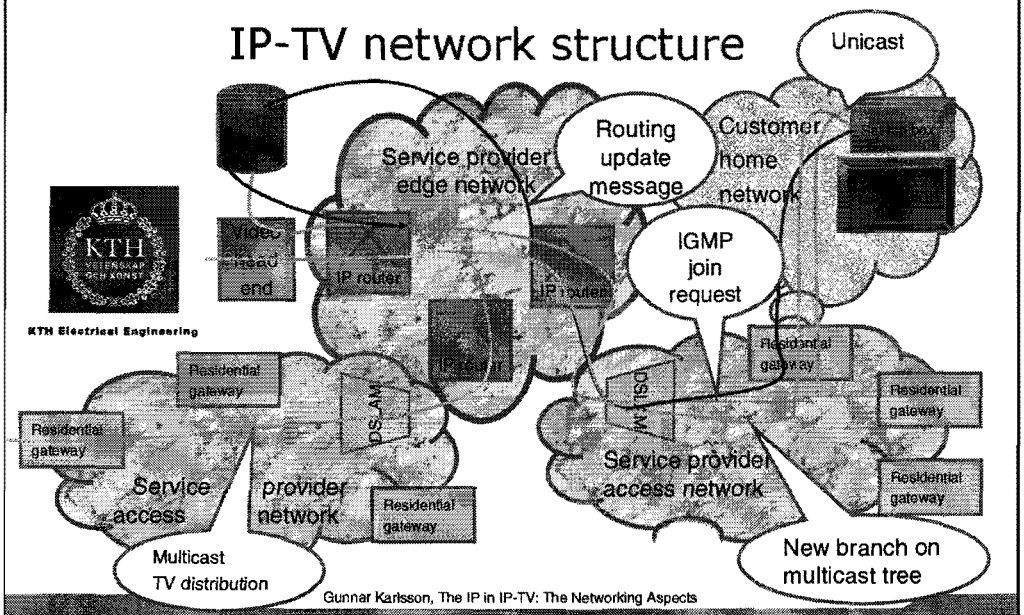
- Broadcast
  - Broadcast to limited user groups is called multicast
    - Only distributed where there are receivers
  - One broadcast channel is carried as one multicast group
    - Channel switching means change of groups
    - Join and leave times are potentially long
- Video on demand uses unicast communication
  - A selected program is streamed directly to the video client
  - Streaming controlled by the *real-time streaming protocol* (RTSP)
    - Allows remote VCR functionality

# IP-TV network structure

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# IP-TV vs Internet television

- IP television
  - Streaming of video over proprietary IP networks
    - Client-server
    - Charging for the contents
    - Digital rights management
    - Protected from attacks
  - Contents selected by operator
    - Licensing from commercial broadcasters
  - Service bundled with data, voice, mobile
    - Triple or quadruple play
    - Services can be combined
    - Interactivity
  - Issues
    - Management and operations
      - Responsibility ends in the set-top box
      - Includes transmission across customer's home network
    - *Competition from other video distribution services*
      - Cable, satellite, Internet television
    - Performance
      - Viewing experience
      - Channel switching
      - Price worthiness

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# IP-TV vs Internet television

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- Internet television
  - Streaming of video over the Internet
    - Client-server and peer-to-peer
    - Currently unicast
      - IP multicast possible, albeit slow deployment
      - End-system (peer-to-peer) multicast
  - Open to any party as broadcaster
    - Eg. video podcasts
    - Potential growth in content selections
  - Services combined with data, voice
    - Application-level software
    - Rapid evolution of the service
  - Issues
    - Digital rights management
    - Charging for contents
    - Vulnerable to security and denial-of-service attacks
    - Quality of service
    - Lack of multicast in the network
    - Connects computers, not television sets



# Quality of service

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- What is quality of service?
  - Expression of the applications' expectations on the network service
    - Pertains to delivery of messages
- Quality attributes
  - Order of delivery
    - Easily transformed into delivery delay by reordering at receiver
  - Replication of messages
    - Trivial to eliminate based on sequence numbers
  - Delivery delay
    - Unsurpassable limit: hard real-time communication
    - Surpassable limit with certain probability: soft real-time
    - No limit: minimize expected delay
    - Variations in delivery delay: to maintain synchrony
  - Reliability of delivery
    - Fraction of messages that is not delivered or contains errors
    - Reliability may be obtained at the cost of delay by retransmission
    - Fraction of time that the service is unavailable: failures and denial of service attacks
  - Security of the delivery
    - Integrity of messages: delivered as sent, not more nor less, no tampering
    - Privacy of communication
      - Recording of communication end points and times
      - Snooping of contents

# Quality expectations


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- Delay
  - Round-trip: Lowers interactivity
    - Up to 300–400 ms acceptable for conversations
      - Late is lost
      - Unclear whether asymmetry is disturbing
  - One-way: Lowers responsiveness
    - Latency from click to view
      - Subsecond values
    - Delay variations might need to be equalized
      - Equalization adds to total latency
      - *Acceptable values for residual variations are not clear*
- Packet loss
  - Affects the quality of the reconstructed signal
    - Application, user, coding and context dependent
  - Temporal distribution and average levels
    - Independent losses usually worst case for a given average
    - Burst losses might be worse for error correction
- Consistency matters, fluctuations annoy
  - The reliability of the QoS metrics
- Bit error
  - Not dependent on traffic load for wired networks
  - Ignored in this talk



# QoS in the network


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- The effect of the network load on the service performance
  - Best effort
    - The network forwards packets with its best effort
      - Reliability handled end-to-end (TCP)
    - Quality varies with the traffic load in the network
      - Congestion (overload) occurs
      - Packets are delayed and occasionally lost
- Over dimensioning
  - The load will never or only with low probability cause congestion
    - Wastes resources
      - Could be uneconomical
    - Requires good forecasting, dimensioning and deployment
      - Might be difficult to know whether the network has enough resources for all cases
      - Low average utilization does not mean absense of congestion
  - Network unprotected against unforeseen load surges
- Service differentiation (diffserv)
  - Give important traffic high priority
    - May starve low priority traffic
  - Ensure that high-priority traffic has enough resources
    - Over dimensioning or admission control
- Admission control
  - Do not admit more data streams on a route than what it can handle
  - Ensures QoS but introduces blocking of channel requests
  - Requires knowledge of network state and properties of new stream

# QoS in the network

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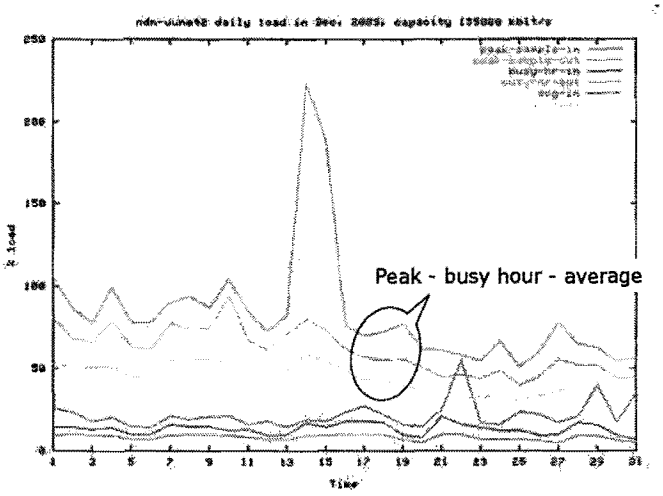




# QoS in the network

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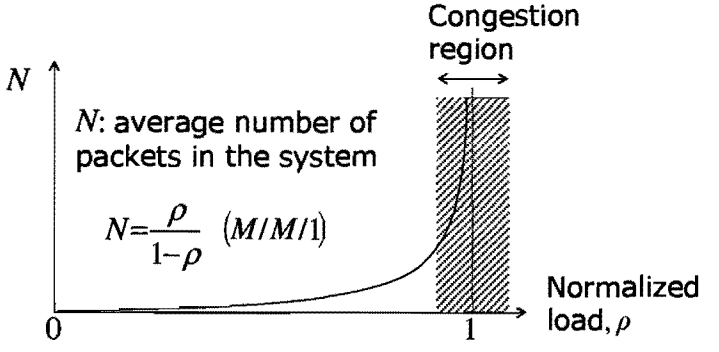

# Controlled Load Service

- Design a service class for minimum delay
  - Packet-scale buffering
    - Minimizes delay and jitter
      - Buffering due to asynchrony
    - No smoothing of load variations
  - Packet loss is the main degradation
    - Network state represented by the loss level
  - Fixed amount of capacity allocated to service class
    - Unused capacity available for best effort traffic
- Limit the loss rate in the network
  - Probe-based admission control
  - Admission based on estimated loss level
    - Setup aborted if probe loss exceeds target value
    - Blocked sessions back off a random time before probing again
  - Suitable for
    - Streaming data, video and audio
    - Interactive voice and video

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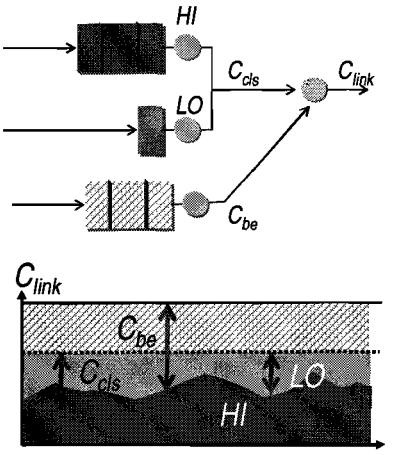
# Configuration in a router

- Fixed capacity partition on all links
  - Allocated rate cannot be exceeded
    - Unused capacity available at best effort
- Two service priorities
  - High priority for accepted sessions
  - Low priority for probes

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# Probing procedure


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- Sender issues stream of probe packets
  - Sent at desired peak rate (constant rate)
    - Small share of total capacity for the class
  - Probe packets have low priority
    - See only available capacity in service class
  - Probe length not specified
    - Short probes lead to estimate with poor confidence
- Receiver measures loss of probe packets
  - Estimates packet-loss probability with some confidence level
    - Estimate based on normal distribution
  - Compares estimate with decision level
    - Accepts the call if loss below the level
    - Notifies the sender of the decision
- Successful establishment
  - Sender may now transfer data at high priority
    - Sending rate may not exceed probe rate
      - Rate may at any time be reduced
      - Increase in rate requires probing for increment
- Failed setup
  - Sender waits a random time before issuing new probe
    - Interval for distribution doubled for each new failed attempt
    - Will randomize retrials if failure is due to too many simultaneous probes



# PBAC Performance


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- Analytic model
  - Single probe session, single packet buffer
    - Probe packet lost if not sent before the next arrives
    - Depends on the residual time of the busy period for the high-priority queue
  - Loss of probe packets independent
    - Probe rate low compared to total rate
  - Infinite buffer for high-priority data packets
    - Modeled as an M/D/1 queue
    - High degree of multiplexing, small sessions
- NS-2 simulations
  - Accepted sources:
    - On-off Markov, peak rates 100 kb/s and 1 Mb/s
    - Average on 20 ms and off 35.3 ms
    - Packet size 128 bytes
    - Average session length 50 s, exponentially distributed
  - Probing
    - Duration 2 s
    - Packet size 64 bytes
    - Confidence level for loss probability estimate 95%
  - Link
    - Two cases 1 Mbs/s (for $r_{pr}$ 100 kb/s) and 10 Mb/s for ($r_{pr}$ 1 Mbs/)
    - Sessions arrive as Poisson process, average arrival rate sets load

# PBAC for Multicast

- Two multicast groups per session
  - Data group
  - Probe group
- Admission control for senders and receivers
  - Senders probe to root of tree
    - Accepted senders probe receivers continuously
      - Only distributed if there are probing receivers
  - Receivers join probe group
    - Join data group if loss less than threshold
    - Drop out of the probe group
    - Blocking probability given by bottleneck link in tree


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# Conclusion

- IPTV
  - Technical solutions available
    - Proprietary network allows fast deployment
  - Charging for contents
    - Allows telcos to have part of content-provider profits
  - Service bundling and combined services
    - One-stop provider for all communication services
    - Evolution of the television concept
- Network challenges for IP-TV
  - QoS *mechanisms*
    - Scheduling
    - Admission control
  - Management
    - The network includes the customer's home network
    - Monitoring and troubleshooting
    - Customer support
  - Performance
    - Channel switching times
      - Multicast join and leave
      - Play out buffering in set-top box
      - Decoding delays
    - Dimensioning
      - Number of simultaneous channels per residential gateway
        - » Limited by DSL capacity
      - Number of simultaneous channels in edge network
        - » Both multicast TV broadcast and VoD unicast
      - Popularity distribution over provided channels and over time
      - Cost efficiency


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# Conclusion

- IP-TV vs Internet television
  - Possibly complimentary
    - IP-TV provides contents for broad audiences
    - Internet television provides broad contents for niche audiences
  - Competition possible
    - Most IP-TV functions possible to provide in the hosts
    - The Venice project


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# Under the hood of iDTV technical aspects

**Dr. Chris Lefrere**

**Telenet, Belgium**

*Slides of Dr. Lefrere were not made available for printing on his explicit wish.*