

Multimedia Content Adaptation for Universal Access

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Outline

- Introduction (Multimedia Communication @ UNIKLU)
- Universal Multimedia Access
- Adaptation Decision-Taking
- Multimedia Content Adaptation
- International Standard's Support for UMA
- Selected IST Projects: DANAE and ENTHRONE
- Conclusions and Future Work Item(s)

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Multimedia Communication @ UNIKLU

- **Group Leader**
 - Prof. DI Dr. Hermann Hellwagner
- **University Assistants**
 - DI Dr. Klaus Leopold
 - DI Martin Prangl
 - **DI Dr. Christian Timmerer**
- **System Engineers**
 - Andreas Griesser
 - Markus Waltl
- **Secretary**
 - Angelika Rossak
- **Project Assistants**
 - DI Michael Ransburg
 - DI Ingo Kofler
 - DI (FH) Alexander Abl
 - DI Janine Lachner
 - DI Robert Kuschnig
 - DI Bernhard Reiterer
- **Project Staff Members**
 - Martin Bürger
 - Hubert Gressl
 - Ingomar Preiml

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Research Areas

- **Multimedia Communication and Adaptation**
 - Adaptive video streaming, protocols
 - Knowledge-based multimedia adaptation
 - Ambient, personalized, user-centric multimedia (UMA)
- **MPEG-21 Standardization**
 - Digital Item Adaptation (DIA)
 - Metadata compression (MPEG-B) and streaming, file format
 - Reference software and conformance
- **Distributed MPEG-21 Infrastructure and QoS Provisioning**
 - Metadata streaming, compressed processing
 - Distributed adaptation, cross-layer QoS mapping
- **Prototype Adaptive Multimedia Tools and Services**

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Research Projects (and Funding)

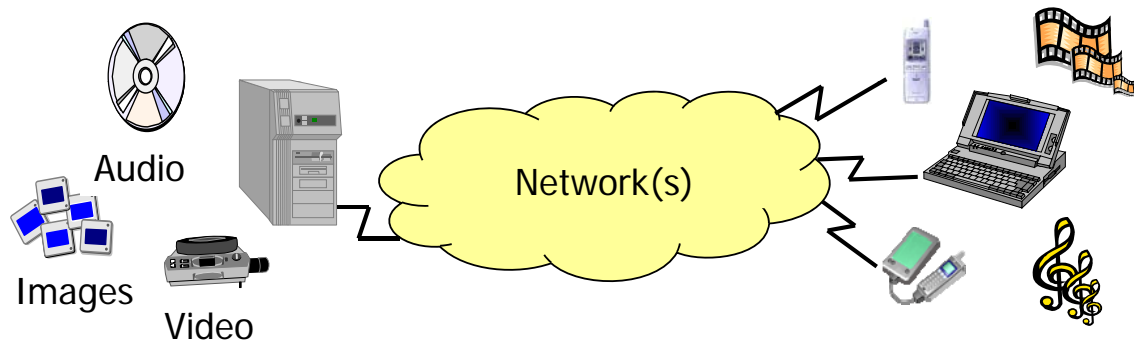
- **Industry (partial funding):**
 - MPEG-21 standardization: in cooperation with Siemens CT IC 2, Munich
- **European Commission (IST FP6):**
 - **DANAE (STREP; 01/2004 – 06/2006):** “Dynamic and distributed Adaptation of scalable multimedia coNtent in a context-Aware Environment”
 - **ENTHRONE II (IP; 09/2006 – 08/2008):** “End-to-End QoS through Integrated Management of Content, Networks and Terminals”
 - **INTERMEDIA (NoE; 10/2006 – 09/2010):** “Interactive Media with Personal Networked Devices”
- **Austria Science Fund (FWF) – Basic Research:**
 - Quality Adaptive Video Caching and Transport (QAVCT)
 - Adaptive Streaming of Secure Scalable Wavelet-based Video (ASSSV)
- **FWF and Austrian Network for E-Tourism (ANET):**
 - Context-Aware Multimedia Services (CAMUS), Mobile Tour Guide
- **Klagenfurt University:**
 - Independent PhD Theses

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Universal Multimedia Access

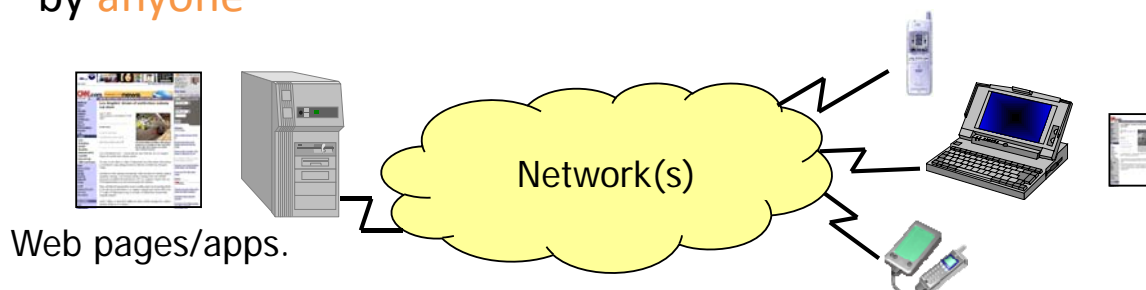
- Any content should be available anytime, anywhere



- [Universal Multimedia Experiences :=
 - User should have worthwhile, informative experience anytime, anywhere]

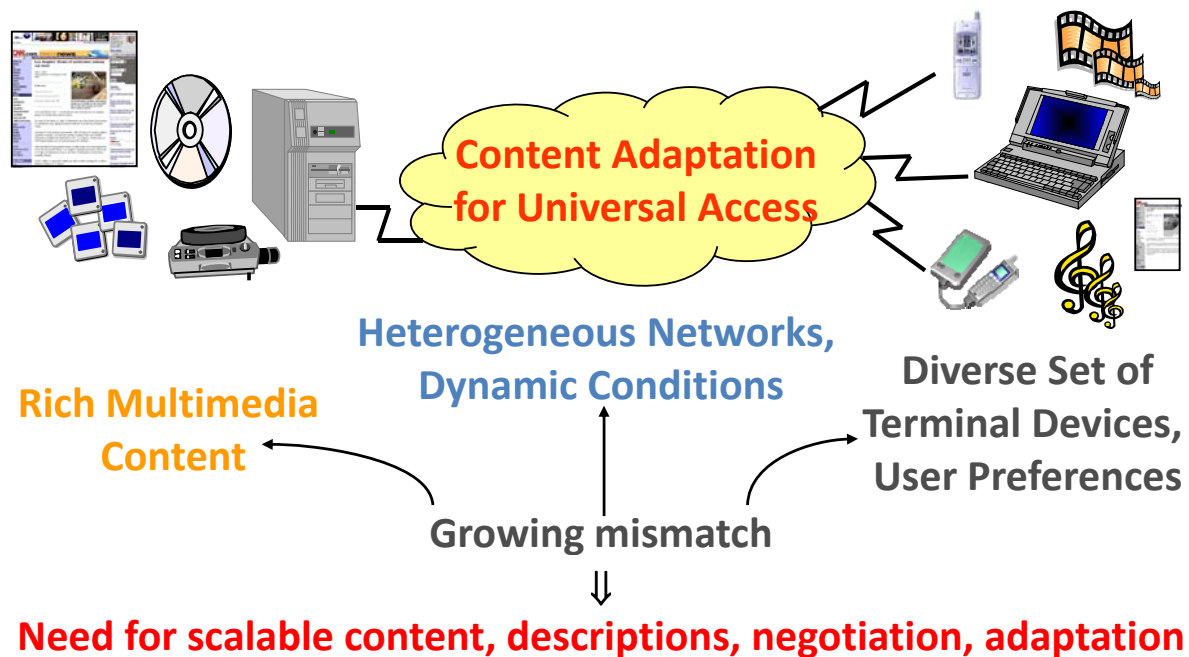
Device Independence (W3C) :=

- Access to a unified Web from any device in any context by anyone



- [Harmonized User Experience :=
 - A functional user experience that is sufficiently harmonized with the delivery context to meet the quality criteria of the author]

UMA Challenge and Concept



UMA Challenge: Content

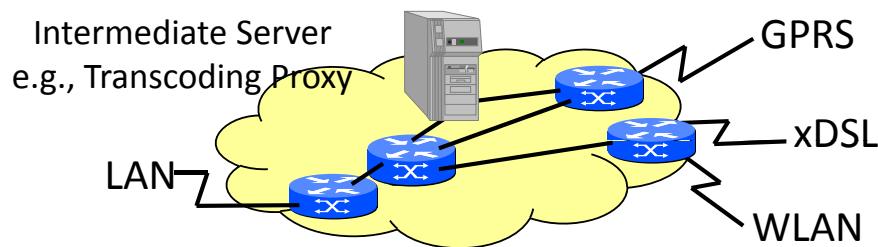


Rich Multimedia Content

- **Different media types and formats**
 - **Video:** MPEG-2, -4, AVC, QuickTime, ...
 - **Audio:** MP3, AAC, WAV, ...
 - **Still images:** GIF, PNG, JPEG[2000], ...
 - **Graphics, animation, VR/AR, ...**
 - **Text:** .html, .txt, .doc, ...
 - ...

- **Scene descriptions:** how media streams are related, e.g., BIFS
- **Interactive content elements**
- **Metadata:** descriptive information about the actual data, e.g., MPEG-7

UMA Challenge: Networks



Heterogeneous Networks, Dynamic Conditions

- **Heterogeneous network infrastructure:**
 - Backbones, ISPs, ...
 - Wired access: LAN, xDSL, Cable, ISDN, ...
 - Wireless access: WLAN, GSM, GPRS, UMTS, Bluetooth, ...
- **Fluctuating conditions:** due to number of users, traffic, roaming, ...
- **Different intermediate active nodes:** proxy, cache, gateway,

...
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UMA Challenge: Devices

- **Different devices:**
 - **Stationary:** workstation, PC, Web TV, ...
 - **Mobile:** notebook, tablet, PDA, smart phone, wearable, appliances in intelligent environment, ...
- **Different capabilities:**
 - A/V support: display, speakers, ...
 - Multimedia decoders/players
 - Modes of interaction
 - OS, processing, memory, bandwidth, energy, ...
 - ...



Diverse Set of Terminal Devices

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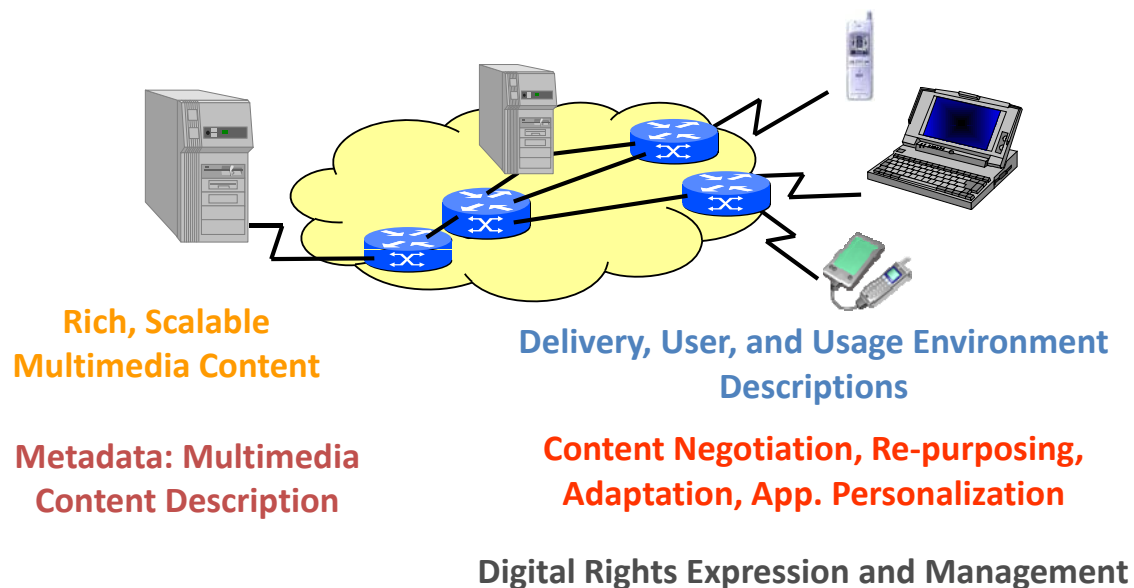
UMA Challenge: User/Usage Prefs.

- **User preferences:**
 - **Personal characteristics:** age, impairment, ...
 - **Content preferences:** genre, interest, ...
 - **Presentation preferences:** modalities, quality, ...
 - **Interaction preferences:** voice, stylus, ...
- **Usage environment (context):**
 - **Localization:** time, place, natural environment, ...
 - **Mobility:** stationary, on the move, speed, ...
 - **Current situation:** office, home, public, meeting, ...
 - **Access:** single- or multi-device / -modal
 - ...

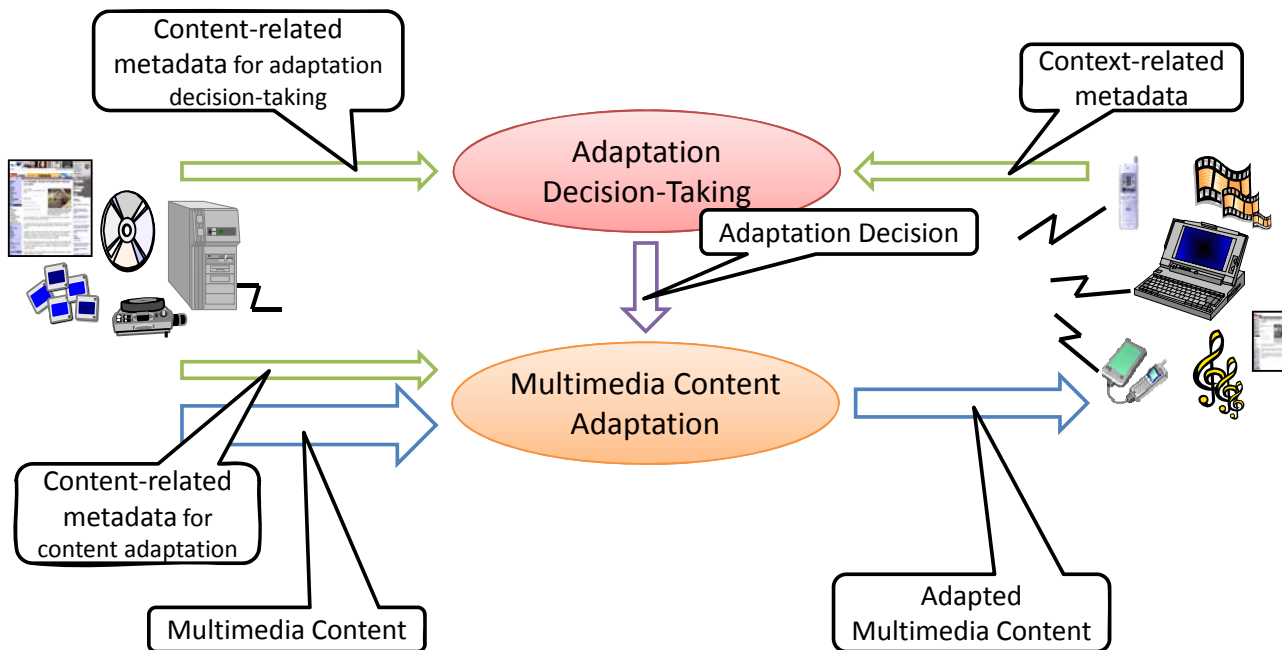


Diverse User and Usage Preferences

UMA Key Components



Simplified Adaptation Framework



Context- and Content-related Metadata (1)

- **Context-related metadata**
 - **End user:** preferences (content, presentation, interaction, etc.), disabilities, location, environment, requested perceived QoS (PQoS)
 - **Terminal:** A/V capabilities, codecs, type of terminal, battery status, etc.
 - **Network:** available bandwidth, delay, jitter, packet loss, etc.
 - **Adaptation:** which adaptation operations are supported by devices along the delivery path?
- **Content-related metadata**
 - **Media characteristics:** bit-rate, frame-rate, frame width/height, etc.
 - **DRM information:** which adaptation operations are allowed under which conditions
 - **Adaptation QoS:** relationship between **usage environment constraints**, **feasible adaptation operations** satisfying these constraints, and **associated utilities** (i.e., qualities)
- **Static metadata:** usually constant during the multimedia delivery
- **Dynamic metadata:** frequently varying during the multimedia delivery

Context- and Content-related Metadata (2)

	Content	Adaptation	Network	Terminal	User
Static	Creation Information	Conversion Capabilities	Characteristics	Codec	Characteristics
	DRM Information			Audio/Display Capabilities	Requested PQoS
Dynamic	Media Characteristics	Adaptation QoS	Conditions	Battery status	Delivered PQoS
	Bitstream Syntax Descriptions			Location	
	Adaptation QoS			Date/Time	

Adaptation Decision-Taking

Goal of adaptation decision-taking

- The **optimal selection of parameter settings** for the actual multimedia content **adaptation engines** that **satisfy constraints** imposed by actors of the content distribution chain (e.g., **content/service/network providers, terminals, end users**) while **maximizing QoS**
- Known approaches for adaptation decision-taking
 - Static look-up approach
 - **Optimization**-based approach
 - **Knowledge**-based approach

Adaptation Decision is based on Three Inputs

- **Content-related metadata** describes the relationship between **constraints**; **feasible adaptation operations satisfying these constraints**; **associated utilities (qualities)**;
e.g., **available bandwidth is 384kbps**, **terminal display is CIF**; **reduce bit-rate**; **quality at QCIF/30fps/QP=10 versus CIF/10fps/QP=15**
- **Context-related metadata** describes the **usage environment in terms of terminal capabilities**; **network characteristics**; **user characteristics**; **natural environment characteristics**;
e.g., **codec capabilities = mp2, ML@MP**; **available bandwidth=1500kbps**; **visually impaired**; **high-level ambient noise**;
- **Adaptation tools related metadata** provides information regarding the **adaptation capabilities of devices** along the delivery path and how to **enable constraints to be imposed on adaptation** (allows for DRM support w.r.t. fine-grained adaptation);
e.g., **can transcode MPEG-2 to MPEG-4/AVC**, **temporal adaptation of MPEG-4/AVC**; **spatial resolution of media > 70% of terminal resolution**

Optimization-based Adaptation Decision-Taking

- **Mathematical approach based on an optimization problem**
 - Adaptation parameters and effects modeled as **variables v with a given domain**
 - **Causal dependencies described as functions** (e.g., look-up tables, stack functions)
 - **Limitation constraints / restrict the feasible adaptation parameters**
 - **Optimization constraint o represents the objective function (optimization goal)**, e.g., in most cases: maximize quality
 - **Adaptation decision-taking: find values for the variables representing adaptation parameters that do not violate the limitation constraints (feasibility) and maximize the optimization constraint**

$$\begin{aligned} & \min o_i(v) \\ & \text{subject to } l_j(v) \rightarrow \text{true} \quad \forall 0 \leq i < k, \forall 0 \leq j < m \end{aligned}$$

Example: Temporal Video Adaptation

- Variables

- frame-rate, bit-rate, psnr

frame-rate [fps]	15	20	25
bit-rate [kbps]	400	480	600
psnr [dB]	35.5	36.8	38.5

- Limitation constraint

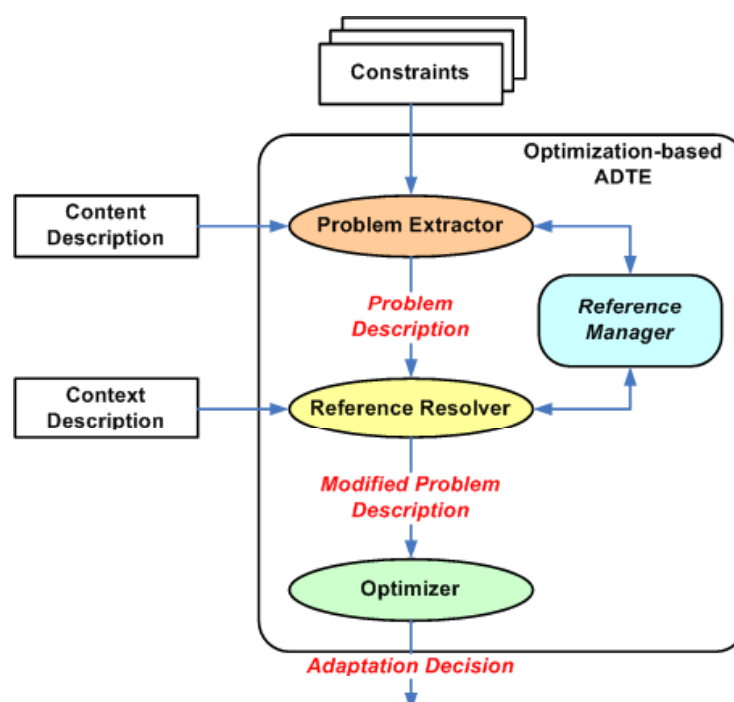
- bitrate \leq available bandwidth
(e.g., 520kbps)

feasible?	✓	✓	✗
optimal?	✗	✓	

- Optimization constraint

- maximize psnr

Optimization-based ADTE



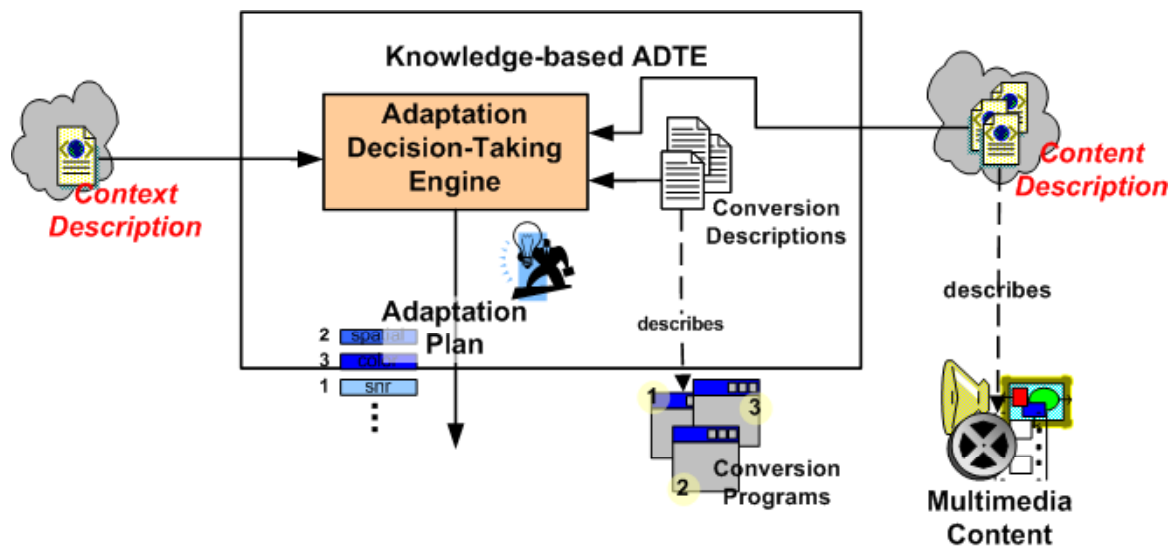
Knowledge-based Adaptation Decision-Taking

- Motivation
 - Not realistic having a **all-in-one adaptation device** suitable for all usage environments
- “Planning” adaptation sequences
 - View the problem of determining and executing adequate adaptation sequences as a **classical state-space planning problem**
 - **Declarative knowledge** representation: IOPE
 - **Inputs**: describe the input (format)
 - **Outputs**: describe the output (format)
 - **Preconditions**: describe conditions that must be satisfied
 - **Effects**: describe the changes (“world-altering” actions)
 - AI-based planning
 - **Start state**: multimedia content descriptions
 - **Goal state**: context description
 - **Actions**: adaptation capabilities

Example: Complex Transcoding

- **Multimedia content description**
 - `coding_format(mpeg_4_Visual_ES). color_domain(true). frame_size(640,480)`
- **Terminal capabilities**
 - `decoding_capabilities(mpeg_1). color_capabilities(false). display_size(320, 240).`
- **Adaptation tool capabilities**
 - Assume **encoding** (*encode*) and **decoding** (*decode*) available
 - **Grey scaling** (*greyscale*):
 - Input: image
 - Output: greyimage
 - Precond.: `yuvImage(image), color(true)`.
 - Effects: `yuvImage(greyimage), color(false)`.
 - **Spatial scaling** (*spatialscale*):
 - Input: image, x, y, newx, newy
 - Output: scaledimage
 - Precond.: `yuvImage(image), width(x), height(y)`
 - Effects: `yuvImage(image), width(x), height(y), horizontal(newx). vertical(newy)`.
- **Adaptation plan**
 1. `decode(fb1,mpeg_4_visual_es,fb2)`
 2. `spatialscale(fb2,640,480,320,240,fb3)`
 3. `greyscale(fb3,fb4)`
 4. `encode(fb4,mpeg_1,fb5)`

Knowledge-based ADTE

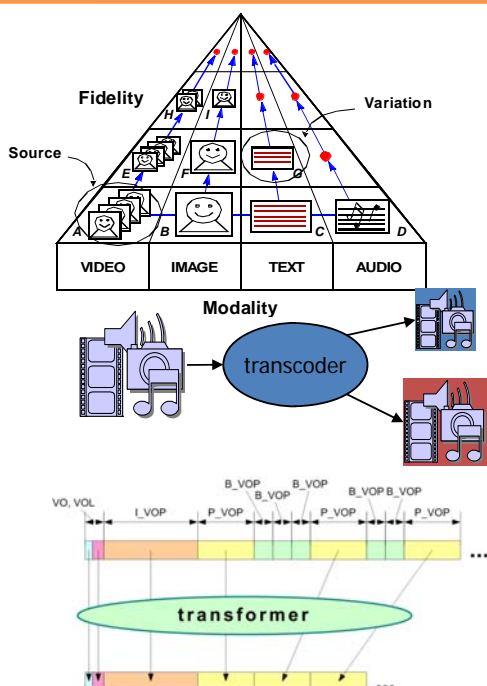


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Multimedia Content Adaptation



- Adaptation by **selection**
 - Store **several versions** of the content on the server
 - cf. choice/selection mechanism in MPEG-21 DID
 - cf. MPEG-7 variation descriptor
 - Waste capacity on the server
- Adaptation by **transcoding**
 - Need much processing power
 - Separate **transcoder for each transcoding step**
 - Difficult to manage
- Adaptation by **transformation**
 - Make use of **scalable formats**, i.e., by retrieving parts of the content; possibility to render a degraded version
 - Types of **scalability**: temporal, spatial, SNR quality, ROI, complexity..
 - Examples: JPEG2000, MPEG-4 audio/visual, MPEG-4 SVC, ...

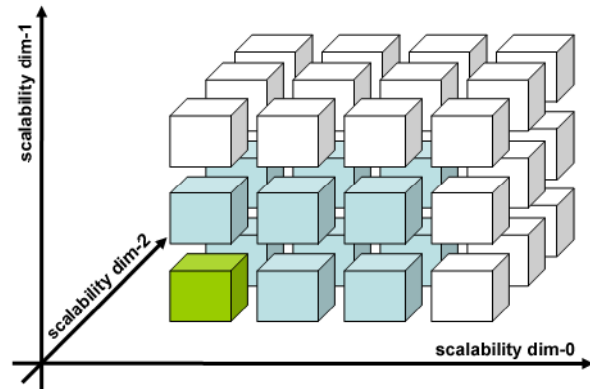
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Abstract Model for Scalable Bitstreams (1)

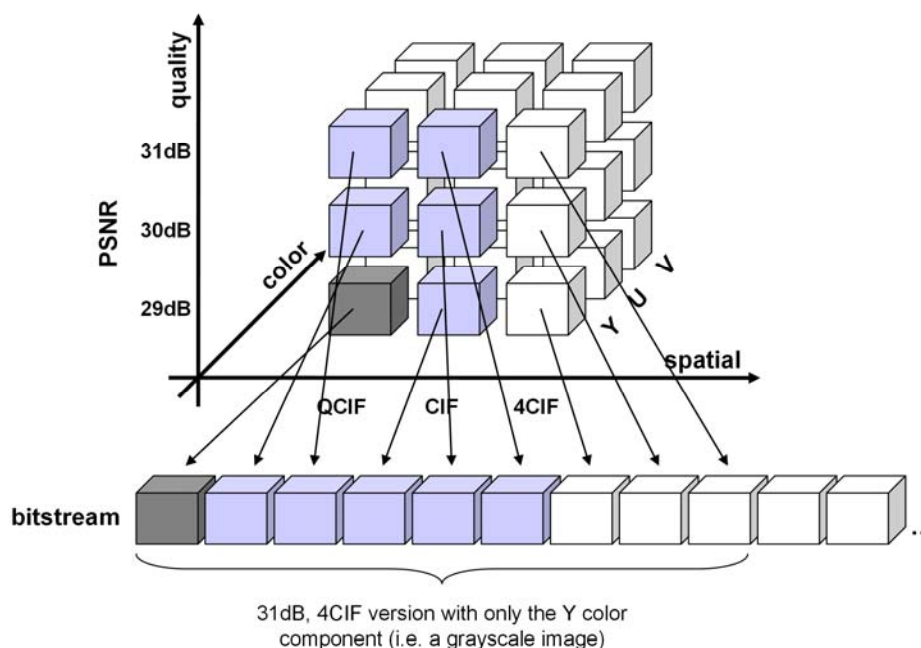
- Organization of scalable bitstreams in **layers**, **levels**, **tiers**, **parcels** ⇒ **hypercube**
- **Encode once**, then truncate layers (or bits) for lower quality / resolution ...
- Requires relatively simple operation: **remove**, **update**, (insert)



[D. Mukherjee, et al., *A Framework for Fully Format-Independent Adaptation of Scalable Bit Streams*, *IEEE Trans. on Circuits and Systems for Video Technology*, vol. 15, no. 10, pp 1280-1290, Oct. 2005]

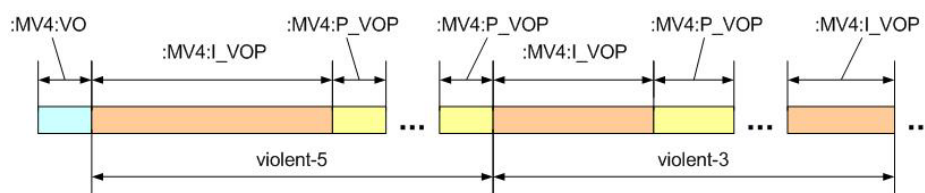
[S. Lerouge, et al., *Fully Scalable Video Coding in Multicast Applications*, *SPIE Electronic Imaging: Science and Technology 2004*, vol. 5308, pp. 555-564, (San Jose, CA, USA), January 2004.]

Abstract Model for Scalable Bitstreams (2)



Bitstream Syntax Description

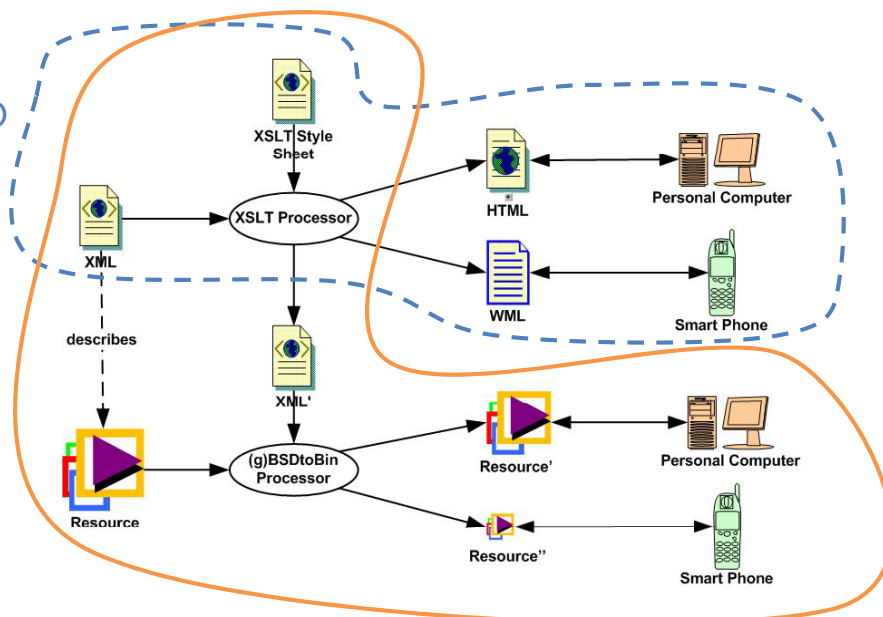
- XML document describing the high-level structure of a bitstream (i.e. in headers, packets or layers, not bit-per-bit)
- Not an alternative format, but additional layer = metadata
- Finer or coarser levels of detail, depending on the application



BSD-based Multimedia Publishing

traditional
Web (XML/XSLT)
publishing

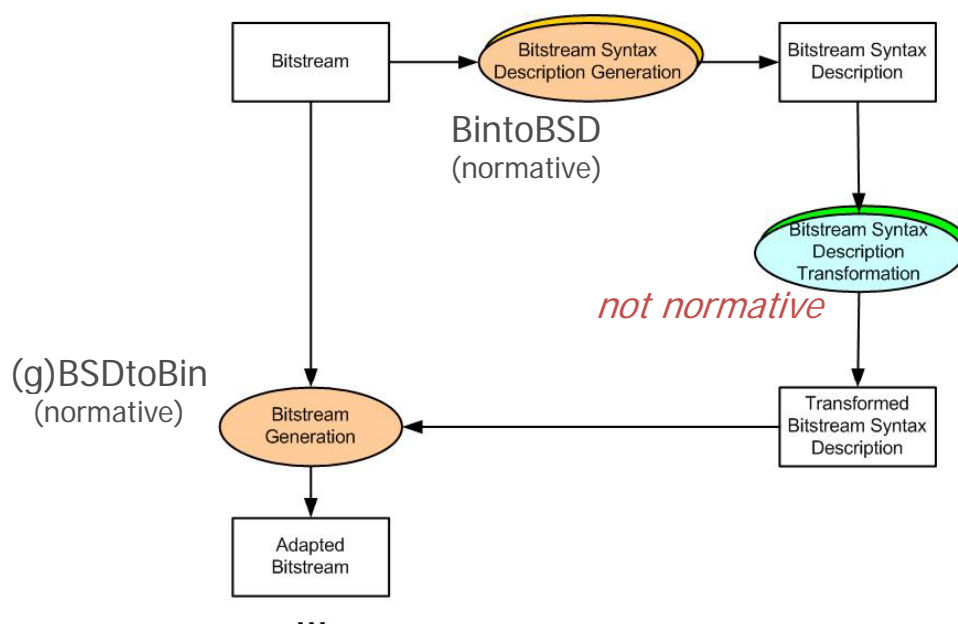
BSD-based
multimedia
"publishing"



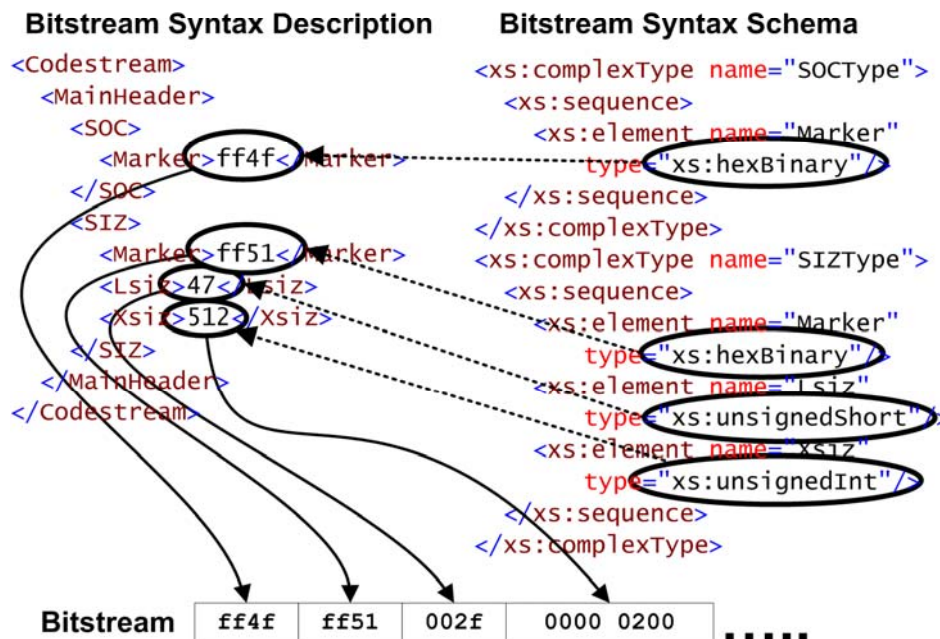
Bitstream Syntax Description Language (BSDL)

- Standardized as part of MPEG-21 Digital Item Adaptation (21000-7) and currently promoted to MPEG-B BSDL (23001-5)
- New language based on W3C XML Schema
 - restrictions and extensions w.r.t. multimedia
- Enables the design of BS Schemas
 - Defines constraints on XML documents in terms of structures and data types
- Functionality
 - Validate (in the XML Schema meaning) the BSD against its BS Schema
 - Parse a BSD and generate the bitstream
 - Parse a bitstream and generate its BSD

BSDL Model



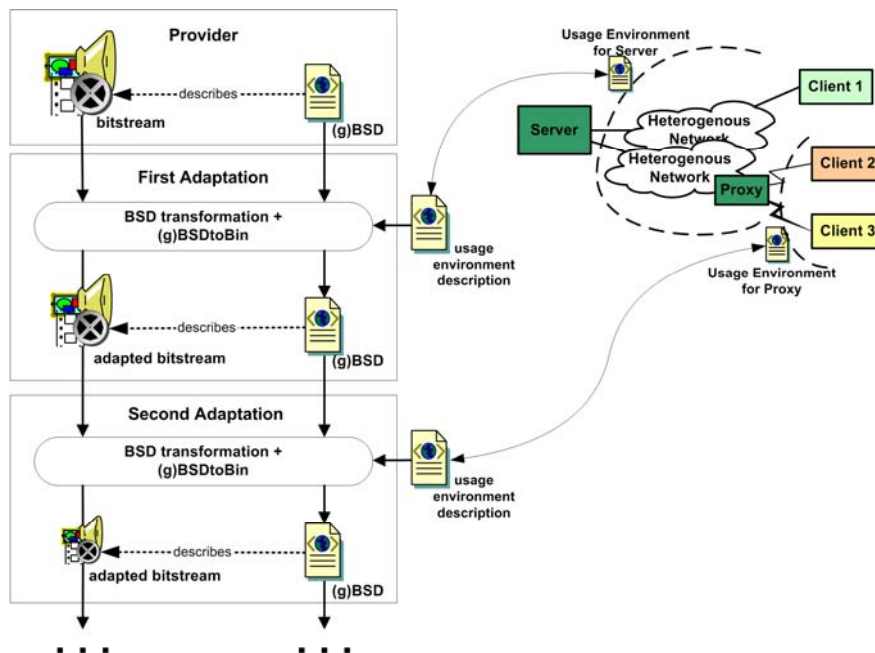
BSDL Example: JPEG2000 images



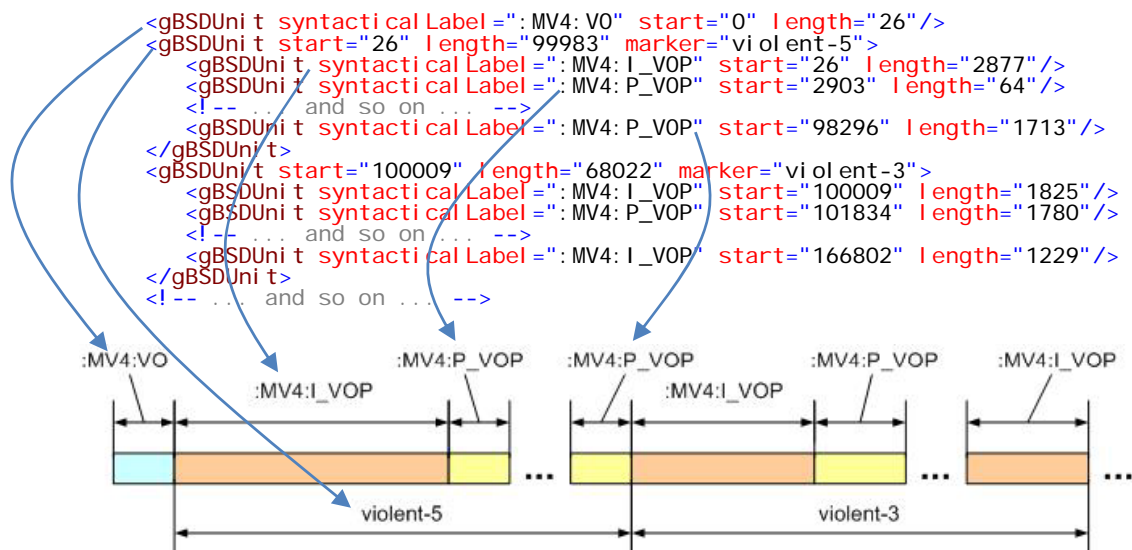
generic Bitstream Syntax Description

- gBS Schema is conforming to BSDL
- Predefined elements: gBSDUnit and Parameter
- Advanced functionalities
 - Format independence
 - Semantically meaningful marking
 - Hierarchies of gBSDUnit elements
 - Flexible addressing scheme
 - Distributed adaptation in terms of multi-step adaptations

Example: Multi-step Adaptation



Example: gBSD



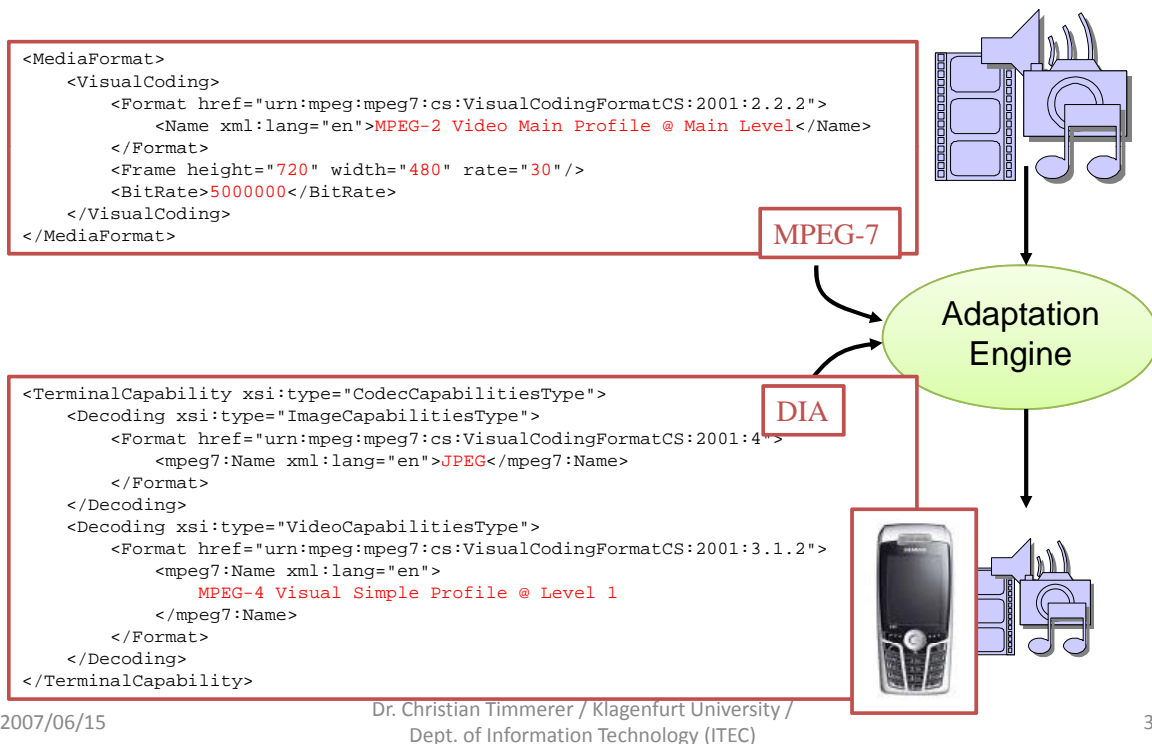
International Standard's Support for UMA

- Focus: MPEG-7 MDS and MPEG-21 DIA
- Context-related metadata
 - Usage Environment Description (UED)
 - Universal Constraints Description (UCD)
- Content-related metadata
 - Media Information
 - (generic) Bitstream Syntax Description
 - AdaptationQoS
 - Universal Constraints Description (UCD)

UED: Terminal Capabilities

- Codec capabilities
 - Specify both **encoding** and **decoding** formats (profiles and levels)
 - Image, video, audio, system, graphics formats
 - MPEG-7 has specified Classification Schemes (CS's) to indicate coding formats
 - For alignment between content and terminal, the same CS's are referenced by MPEG-21 DIA to describe the terminal side
 - Specify **parameters related to the modality**, e.g., max bit-rates
- Input-output characteristics
 - **Display capabilities**, e.g., resolution, rendering format, bits/pixel, color capable
 - **Audio output capabilities**, e.g., frequency ranges, output power, SNR
- Device properties
 - **User interaction support**, e.g., mouse/pen properties, other types of input devices
 - **Power**, e.g., average ampere consumption, battery time remaining
 - **Storage**, e.g., size, transfer rate, if it is writable or not
 - **Device class**, e.g., PC, PDA, Set-top-box
 - **Data IO**, e.g., bus width and speed

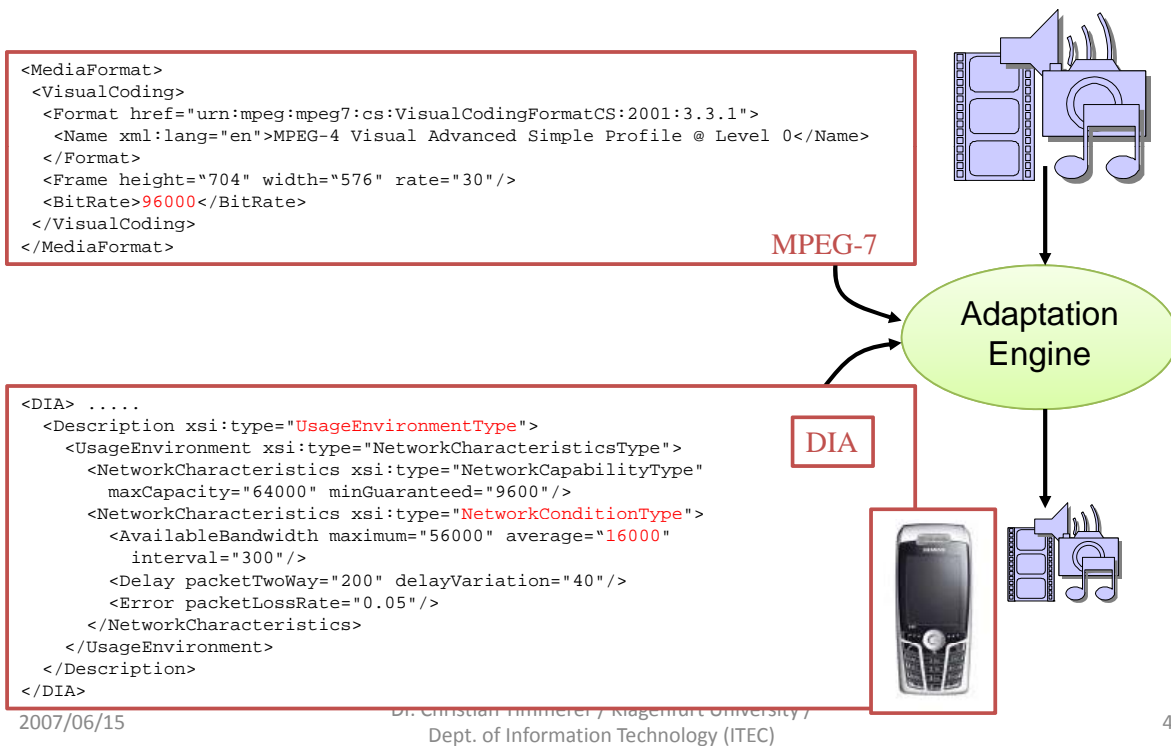
Use Case: Format Compatibility



UED: Network Capabilities

- Static: **network capabilities**
 - Capacity of a given channel
 - Minimum guaranteed bandwidth
 - In-sequence delivery, i.e., are the order of packets guaranteed
 - Error delivery, i.e., how does the network deliver erroneous packets
- Dynamic: **network conditions**
 - Error, e.g., packet loss rate, bit error rate
 - Delay, e.g., one-way delay, round-trip delay, delay variation
 - Available Bandwidth, e.g., max, min, average
 - Timing stamp information also specified, i.e., start time and duration of measurements for condition attributes

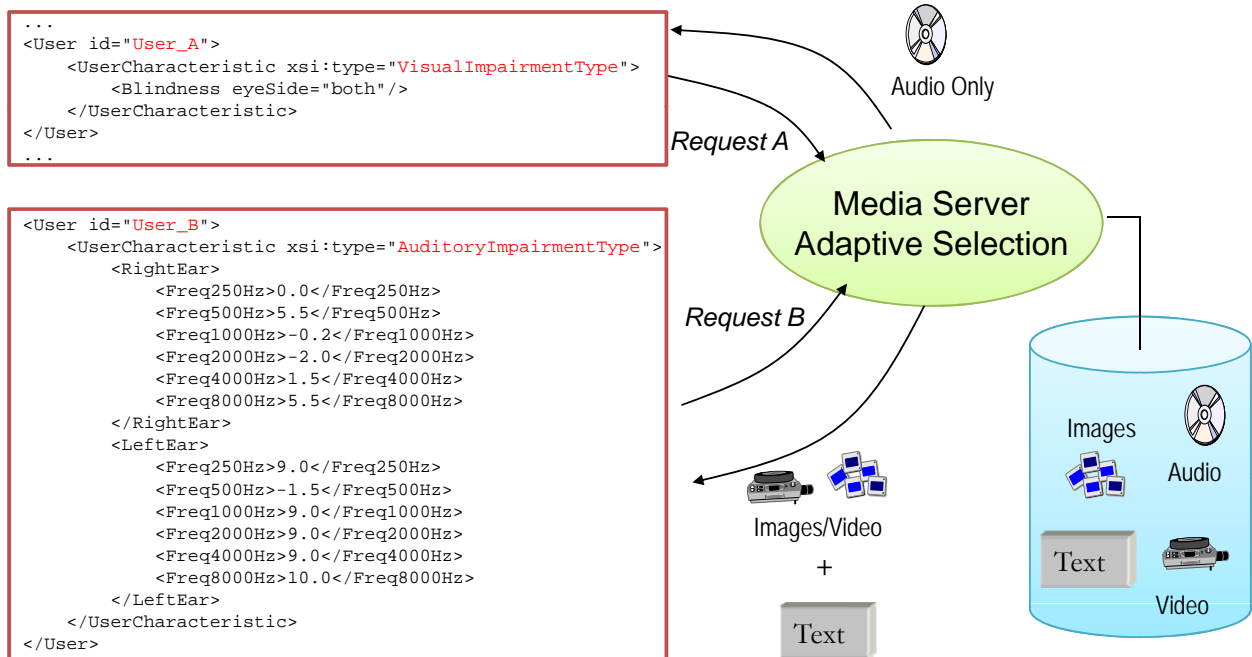
Use Case: Bandwidth Compatibility



UED: User Characteristics

- User info
 - Reference **MPEG-7 Agent DS** to specify, e.g., name, contact info
- Content preferences
 - Reference **MPEG-7 User Preference** and **Usage History DS's**
- Presentation preferences
 - **Audio-related preferences**, e.g., equalizer settings, frequency, volume
 - **Display preferences**, e.g., color temperature settings, contrast, brightness
- Accessibility
 - **Auditory impairments**, e.g., characterize hearing loss in right/left ear
 - **Visual impairments**, e.g., blindness, color-vision and low-vision deficiencies
- Location
 - Describes **mobility** and **destination of Users** for location-aware services
 - Mobility description enable **classifications of users**, e.g., highway, pedestrian

Use Case: Adaptive Selection of Resources



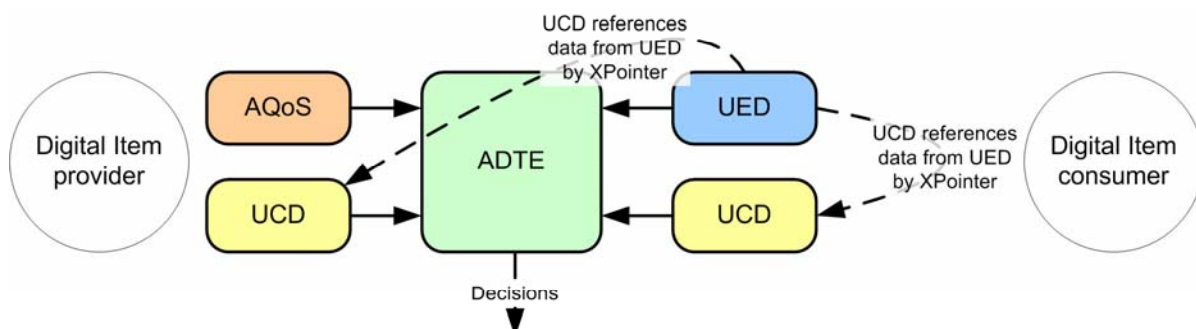
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Universal Constraints Description

- Allows to further constraining the usage and usage environment of a Digital Item
- Types of constraints
 - Limitation constraints
 - Optimization constraints
- Formulated using the stack function syntax

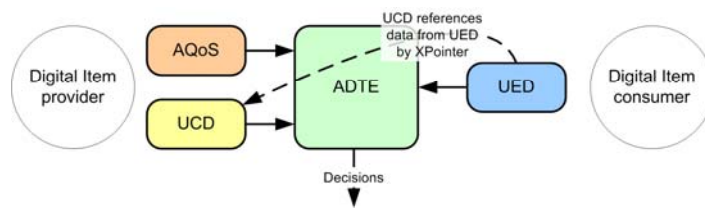


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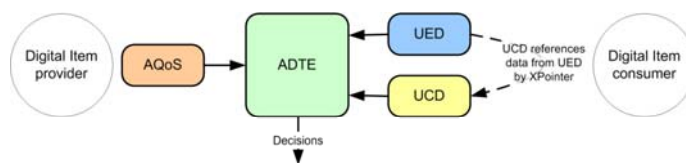
Christian Timmerer, Department of Information
Technology, Klagenfurt University

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Example: Universal Constraints Description



- Usage
 - ! (image resolution < 20% of display resolution)
 - max. image dimension

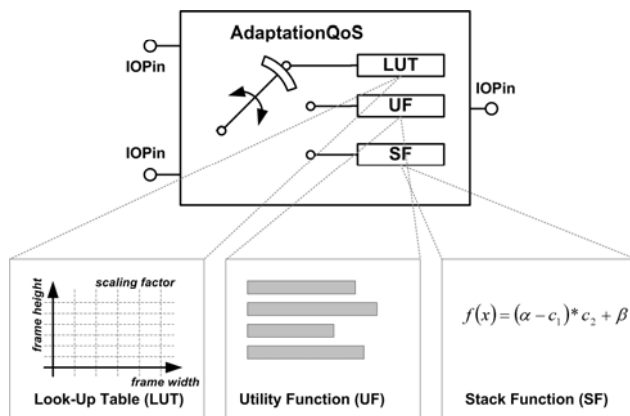


- Usage environment
 - image resolution < 75% of display resolution
 - max. according to the available network bandwidth

Terminal and Network Quality of Service

- aka **AdaptationQoS** (AQoS)
- **Goal**
 - Select optimal parameter settings
 - For media resource adaptation operators that
 - Satisfy constraints imposed by terminals and/or networks
 - While maximizing Quality of Service
- Establish **a priori resource budgets on various platforms**
- Select/drop information at different level of scalability
- Specifies the **relationship** between
 - **Constraints**,
 - Feasible **adaptation operations satisfying these constraints**, and
 - Associated **utilities (qualities)**.

AQoS – Modules and IOPins



- Three types of modules
 - **Look-up table:** non-sparse, discrete data representation
 - **Utility function:** sparse, discrete data representation
 - **Stack function:** functional, continuous data representation

- Generic interface to these modules
 - Input/output pins (**IOPins**)

Selected IST Projects: DANAE

- DANAE: **IST FP6 STREP** project (01/2004 – 06/2006)
- “Dynamic and distributed Adaptation of scalable multimedia content in a context-Aware Environment”
- Major **objectives:**
 - Development of an **advanced MPEG-21 infrastructure** focusing on **end-to-end QoS support, personalization, DIA, and DI Processing**, as well as integrating MPEG-4 and MPEG-7 tools
 - Development of **efficient scalable video coding tools** (including contributions to standardization) and further adaptability means
- General information:
 - <http://danae.rd.francetelecom.com/>

DANAE Vision: Adaptive MM Information in a Museum

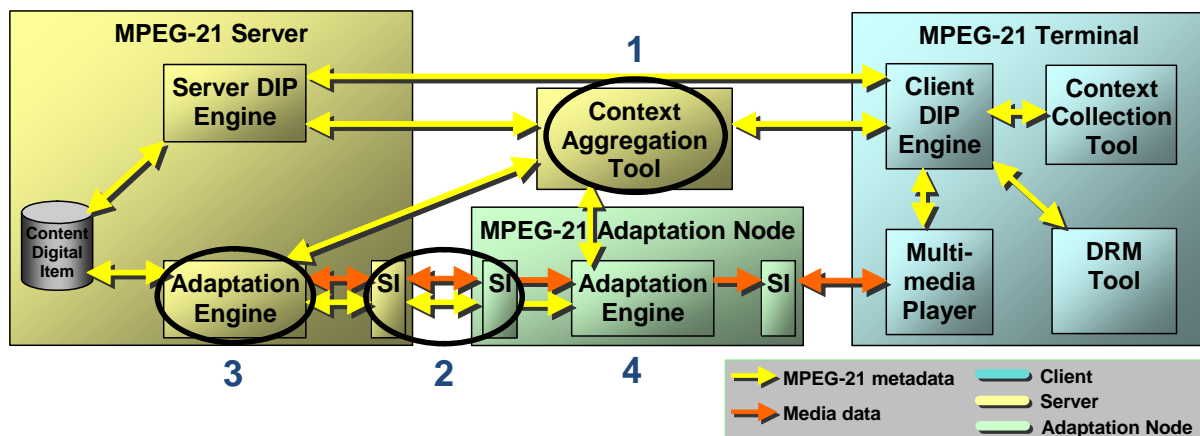
- Application and demo in [Museon, Den Haag](http://www.museon.nl) (<http://www.museon.nl>)
- Visitor should be able to receive ...
 - **Multimedia content** (images, video, audio, text, virtual character, interactives) ...
 - On **mobile device** (PDA) ...
 - **Location-aware** (specific to current zone/theme/s the exhibition) ...
 - **Personalized** (e.g., acc. to age, thematic interests, expert level) ...
 - Adapted to current **usage environment** (e.g., network conditions)
- Fully **compliant to MPEG-21** and integrating other standards
- **Technically, a great success**
Yet, museum installation did not work out as expected



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DANAE: Our Contributions

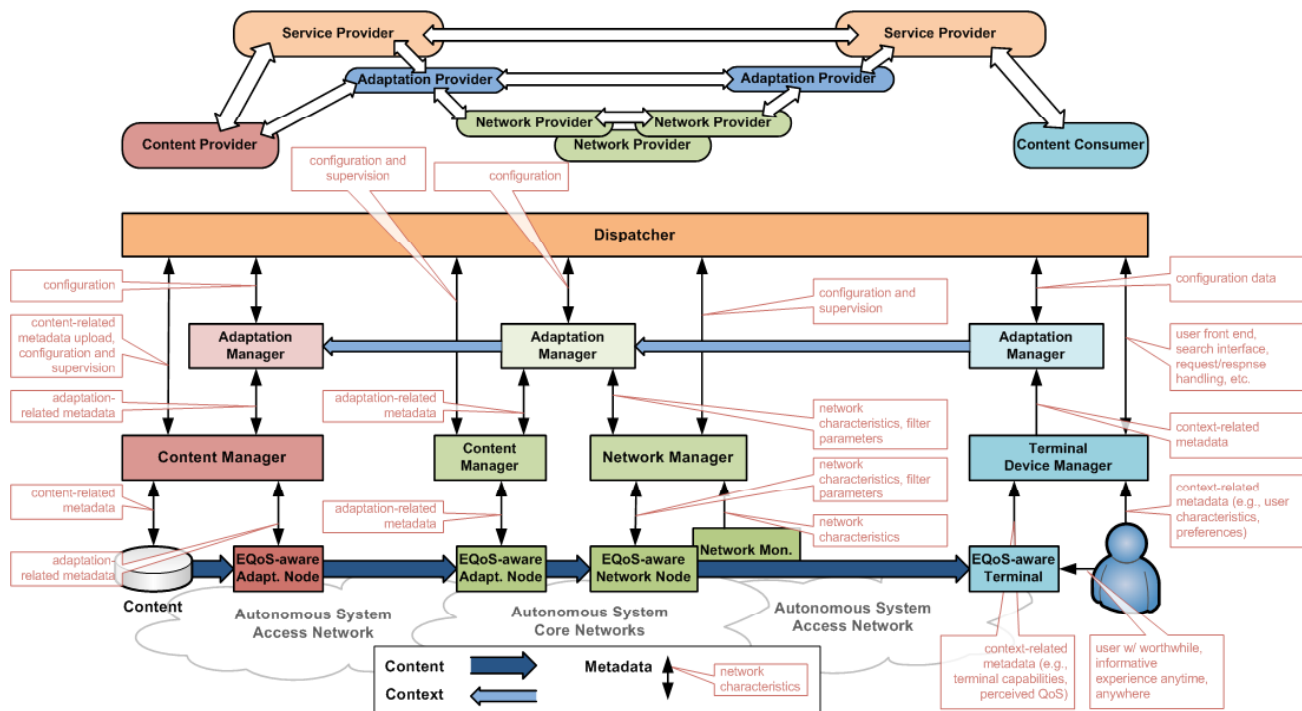
1. Context collection and aggregation
2. (MPEG-21) metadata streaming
3. Semantic adaptation
4. Distributed adaptation framework



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Selected IST Projects: ENTHRONE

Cross-network/provider, cross-layer interactions, MPEG-21 based adaptation



Conclusions and Future Work Item(s)

- **Multimedia Content Adaptation**
 - A tool which serves the aim of UMA
 - **Adaptation decision-taking**: find optimal parameter settings for actual adaptation engines
 - **Coding format-independent multimedia content adaptation**: deploy ones, use many times
- **Transcoding**
 - Like a **fix to the current problem** (and the ones to come); **specific solutions needed** for a growing number of instances
- **Scalable coding**
 - Would be a **generalized solution to the interoperability problem**, but only if widely adopted across domains
 - Would facility **UMA in a generic way**
- **Future Work Item(s)**
 - Combine optimization-based and knowledge-based approach for adaptation decision-taking
 - Quality of adaptation decisions/plans
 - Standardized mark-up language for describing adaptation capabilities (i.e., for multimedia service composition)
 - Adoptions of these techniques/approaches within projects

Most Relevant Recent Publications

International Journals

- Martin Prangl, Tibor Szkaliczki, Hermann Hellwagner, “A Framework for Utility-based Multimedia Adaptation”, [IEEE Transactions on Circuits and Systems for Video Technology \(Special Issue on the Convergence of Knowledge Engineering, Semantics and Signal Processing in Audiovisual Information Retrieval\)](#), to appear in 2007.
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... questions, comments, etc. are welcome ...

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