

 Institute of Computer Science
 Department of Distributed Systems
 Prof. Dr.-Ing. P. Tran-Gia

Modeling and Evaluation of an Online TV Recording Service

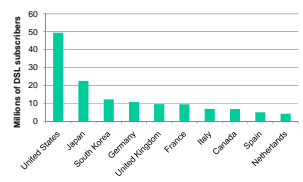
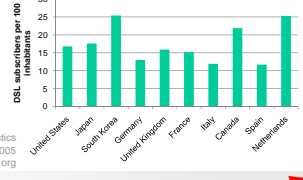
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 leibnitz@ist.osaka-u.ac.jp

Session 3
 Wednesday, June 13
 1:30 - 3:30



Osaka University
 Information Science and Technology
 Advanced Network Architecture Lab

Number of DSL Subscribers

- ▶ Broadband access is still increasing
- ▶ Allows IPTV and high-quality multimedia services
- ▶ 1 Mbps DSL user downloads 700 MB in ~90 min
- ▶ 16 Mbps DSL user downloads 700 MB in ~6 min








source: OECD Broadband Statistics
 December 2005
<http://www.oecd.org>


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Television in the Current Internet

- ▶ Real-time streaming (broadcast, application layer multicast, ...)
- ▶ Non-real-time streaming (video on demand, podcasts, ...)
- ▶ Download platforms and video recorder platforms
 - Advantage: shows can be cut before viewing




- ▶ Technologies
 - centralized systems: client/server (farms)
 - distributed systems: peer-to-peer


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Outline of the Talk


- ▶ Online TV Recording Service
- ▶ Modeling the service and its users
- ▶ Markovian Model for Steady-State Analysis
- ▶ Time-Dynamic Evaluation with Fluid Model
- ▶ Numerical Results
- ▶ Conclusions


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Online TV Recording Service

- ▶ Free web service for registered users
- ▶ Focus is on German TV channels
- ▶ User requests recording of TV show before broadcasting
 - ▶ TV show recorded at server, converted to several video formats (mp4,wmv,divx,hq), and provided for download
- ▶ (Specialized) Mirror servers offer same content after some time
- ▶ Users support distribution via P2P (eDonkey or BitTorrent)


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Download of a TV Show

1. Choose file format
2. Choose way of download and download TV show


Name_der_Aufzeichnungsdatei.Format.otbkey


Click here to see preview


SENDER: Sender

Titel: Titeltxt

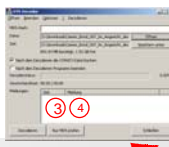
Sie können Ihre Sendung auf verschiedenen Wegen herunterladen. Wählen Sie dazu eine der folgenden Downloadarten aus.








3. Download key of TV show to decode file (only possible if registered for this show at the server)
4. Decode file
5. Watch TV ☺




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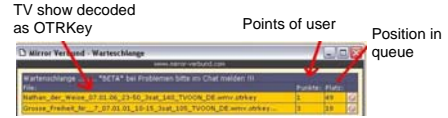
Making Money with Server / Mirror

- ▶ Tons of ads on web pages: several clicks required to start
- ▶ Best-effort user and priority users
 - priority scheduling in queues are offered
 - user paying money get a better position in queue

Channel	DLs	File	Parall.	Rec.	0-speed	Total Speed
ISAT	7	0	-	-	10	138.0 KB/s
ARD	42	13	-	-	33	145.0 KB/s
ARD KIN	0	-	-	-	0	0.0 KB/s
ARD KINSESTIVAL	3	-	-	-	151.0 KB/s	0.4 MB/s
ARD KINSPURS	1	-	-	-	12.0 KB/s	0.0 MB/s
ARTE	10	2	-	-	174.0 KB/s	0.5 MB/s
BATZ	4	1	1	4	137.0 KB/s	0.5 MB/s
BR ALPHA	4	1	-	-	35.0 KB/s	0.1 MB/s
CHN	0	-	-	-	0.0 KB/s	0.0 MB/s
EURONEWS	0	-	-	-	0.0 KB/s	0.0 MB/s
EUROSPORT	3	1	-	-	77.0 KB/s	0.2 MB/s
KABEL 1	5	2	2	5	225.0 KB/s	0.5 MB/s
KEKA	3	1	-	-	34.0 KB/s	0.1 MB/s
NRW	0	-	-	-	0.0 KB/s	0.0 MB/s
NTV	17	1	-	-	130.0 KB/s	0.2 MB/s
Total	241	55	7	120	139.0 KB/s	32.8 MB/s

Waiting Queue at Mirrors

- ▶ User requests download of an OTRKey at a mirror
- ▶ Download request is queued
- ▶ Position in queue depends on credit points of the user
- ▶ Points can be gained by clicking on ads, paying for a download, or donating



- ▶ User does not know
 - how long he has to wait before being served
 - which download speed he will get

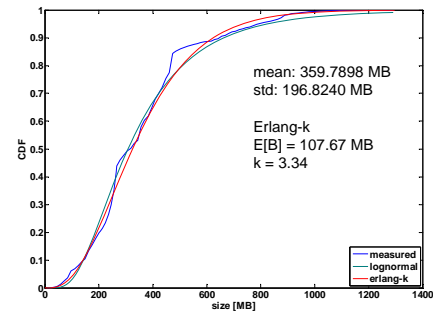
Modeling the Server and its users

- ▶ Impatience of users
 - balking: a customer views a queue and does not enter it because it is too long.
 - renegeing: a customer joins the queue, but then leaves it because the waiting time was too long
 - unsatisfied: experienced service rate too low
- ▶ We do not consider different user classes
- ▶ Download requests are scheduled in FCFS manner
- ▶ At most N users are served in parallel
- ▶ Due to large number of users we assume Poisson arrivals
- ▶ But flash crowd arrivals:
 - popular shows are broadcast late (?)
 - users requests download in the evening (?)

Stats	
Besucher gesamt:	2.110.743
Downloads gesamt:	1.267.792
Besucher heute:	10.235
Downloads heute:	14.130
Besucher gestern:	14.420
Downloads gestern:	18.145
Besucher online:	99
Traffic:	1.05 Gbit/s
Online online:	2804
Über am heruntergeladen:	1547

Fitting the File Size

- ▶ measurements in April 2007 over 11563 TV shows (19 channels)



General System Model

- ▶ $M(t) / GI / 1^N - PS$ with impatience θ
- ▶ Nonstationary Poisson process of download requests
- ▶ Generally distributed file sizes F
- ▶ At most N users are served in parallel
 - guarantees minimal bandwidth per user
- ▶ Capacity C of server is equally shared among n users
 - homogeneous users with equal access speed
- ▶ Bandwidth of user is restricted by downlink capacity
 - admission control by restricting queue size
- ▶ If N users are served, a new user is served according to FCFS
 - state-dependent patience time more accurate to capture nearly finished downloads
- ▶ User leaves after generally distributed impatience time θ

Service Rate

- ▶ State-dependent service rates
 - at time t the number of served/downloading users is $D(t)$
 - service rate is inverse of download time for file of size f_s
- $$\mu(t) = \frac{1}{f_s} \min \left\{ \frac{C}{\min \{D(t), n\}}, R \right\}$$
- ▶ If $n \leq \lfloor \frac{C}{f_s} \rfloor$, user access speed R is limiting
 - service rate is constant
 - $\rightarrow M(t)/GI/n-FCFS$
 - ▶ Otherwise, state-dependent service rates
 - ▶ For $n \rightarrow \infty$ and $R > C$, system goes towards real processor sharing
 - $M(t)/GI/1-PS$

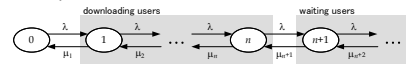
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Steady State Analysis with Markov Model

- ▶ We consider simplest case
 - arrival rate gets constant: $M(t) \rightarrow M$
 - file size is exponentially distributed
 - patience time is exponentially distributed
- ▶ User leaves system if patience time exceeded or download ready $\rightarrow \min\{\theta, T\}$ is exponential RV with rate $\theta / (\theta + T)$
- ▶ Birth-death process



$$\mu_i = \frac{i}{\theta} + \min\{i, c\} \frac{1}{T} \min\left\{\frac{C}{\min\{i, c\}}, R\right\} \quad i = 1, 2, \dots$$



Performance Metrics for Markov Model

- ▶ Waiting probability for a newly arriving customer

$$p_w = \sum_{i=n}^{\infty} x(i)$$
- ▶ Occupied server slots

$$E[X_B] = \sum_{i=0}^{n-1} ix(i) + n \sum_{i=n}^{\infty} x(i)$$
- ▶ Average queue length

$$E[X_w] = \sum_{i=n}^{\infty} (i-n)x(i)$$
- ▶ Waiting time with Little's theorem

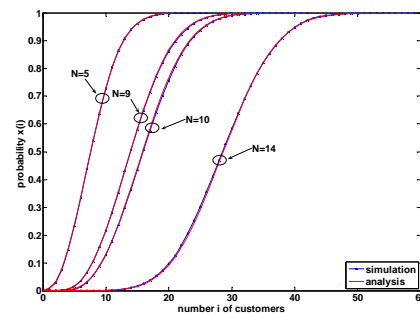
$$E[X_w] = \lambda E[W] \Rightarrow E[W] = \frac{E[X_w]}{\lambda}$$
- ▶ Success probability to finish a download is loss rate

$$p_s = \frac{E[X] \theta^{-1}}{\lambda}$$



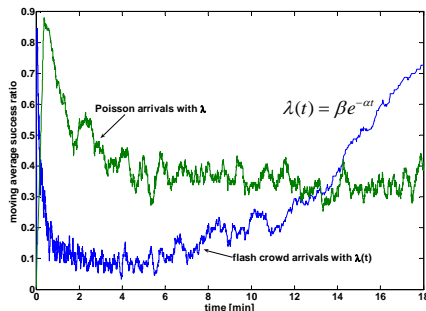
Steady State Population Distributions

- ▶ Parameters chosen that $N=9 < C/R$ and $N=10 > C/R$



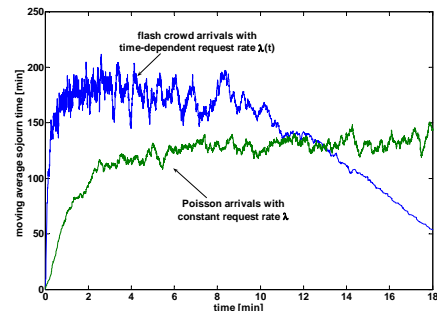
Simulation of Flash Crowd and Poisson Arrivals

- ▶ Cumulated arrival intensities are equal in both scenarios of time t



Flash Crowd vs. Poisson Arrivals

- ▶ Number of arriving users in the system is limited $\lim_{t \rightarrow \infty} \lambda(t) dt = \frac{\beta}{\alpha}$



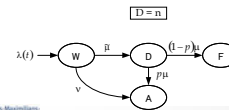
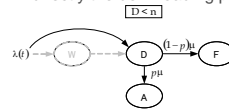
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Fluid Model

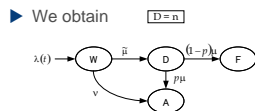
- ▶ Consider population sizes at time t : **W**aiting users, **D**ownloading users, **F**inished downloads, **A**borted downloads
- ▶ A newly arriving customer enters
 - directly the downloading population, if $D(t) < n$



Fluid Model

- ▶ Waiting users
 - get impatient and leave system with rate $\nu = 1/E[\theta]$
 - proceed to downloading state with $\tilde{\mu} = \mu D$
- ▶ With probability $1-p$ download is finished successfully

$$\dot{D}(t) = \frac{\nu}{\nu + \tilde{\mu}} = \frac{D(t)E[s_1]}{D(t)E[s_1] + CE[\theta]}$$
 with impatience rate $\nu = 1/E[\theta]$, download rate $\dot{p}(t) = \tilde{\mu} - C(t)/E[s_2]$ and time-dependent capacity per user $C(t) = \min\left\{\frac{c}{\min\{D(t), n\}}, R\right\}$



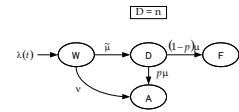
Differential Equations

- ▶ Waiting population

$$\dot{W} = \begin{cases} 0 & \text{if } D < n \\ \lambda - D\mu - \nu W & \text{otherwise} \end{cases}$$
- ▶ Downloading population

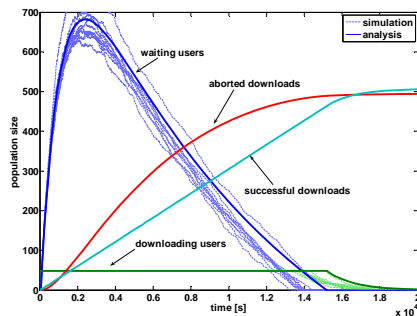
$$\dot{D} = \begin{cases} \lambda - D\mu & \text{if } D < n \\ 0 & \text{otherwise} \end{cases}$$
- ▶ Aborting and finishing downloads

$$\dot{A} = Dp\mu + \nu W \quad \dot{F} = D(1-p)\mu$$



Population Changes with Fluid Model

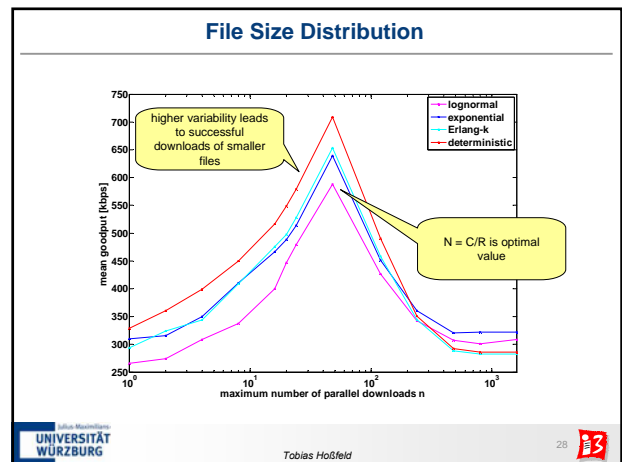
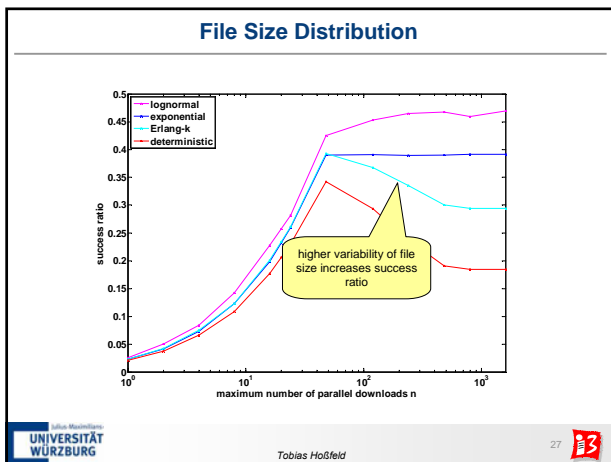
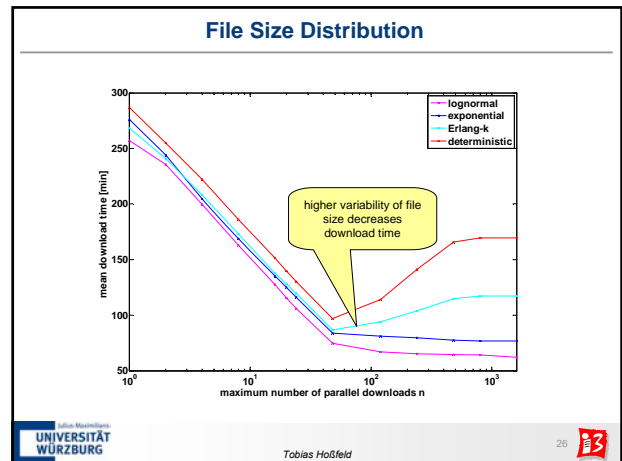
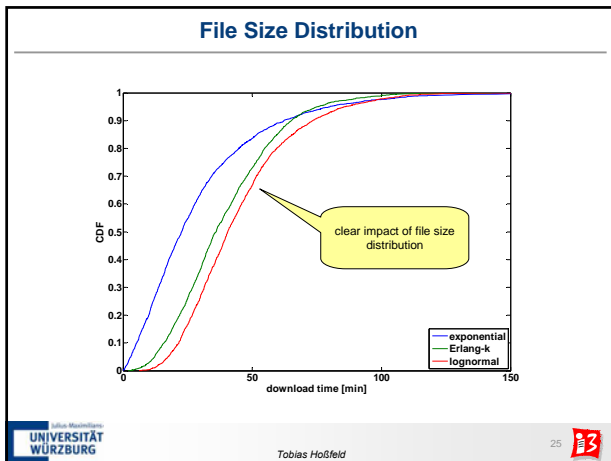
- ▶ Analytical results obtained with Runge-Kutta



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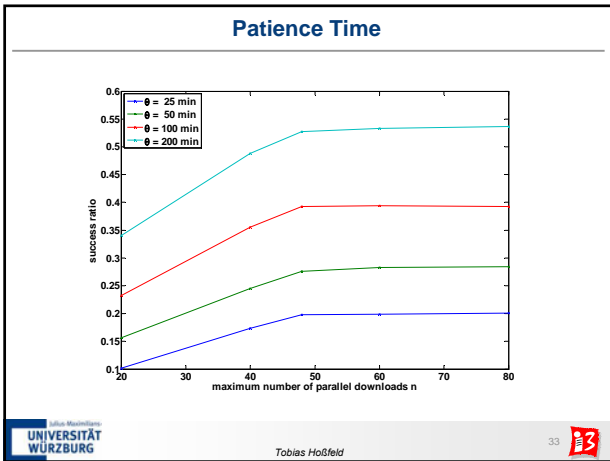
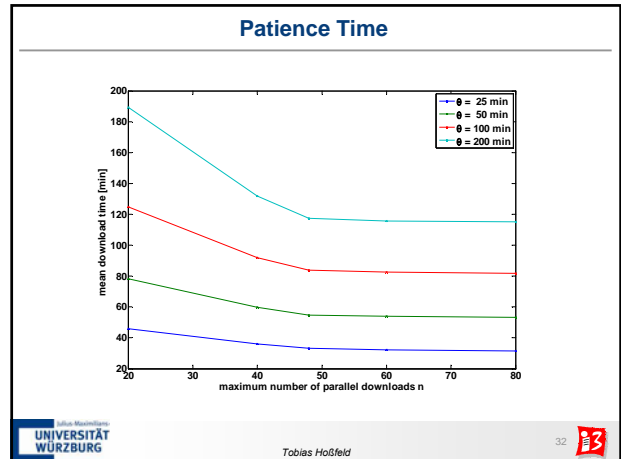
- ### Conclusions
- ▶ Online TV recording service for distributing large volume video files
 - ▶ System model proposed: $M(t)/GI/1^n$ -PS with impatient users
 - ▶ Simple analytical results derived
 - steady state analysis with Markov Model
 - time-dynamic evaluation with fluid model
 - ▶ Impact of file size distribution is interesting
 - ▶ Several open issues: general distributions, priority users, impatience based on experienced performance, ...
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- ### Discussion and Open Issues
- | | |
|---|---|
| <ul style="list-style-type: none"> ▶ 1957 Barrer: $M/M/1+D$ ▶ 1959 Brodi: $M/M/1+D$ ▶ 1965 Daley: $GI/GI/1+GI$ ▶ 1966 Gnedenko: $M/M/s+D$ ▶ 1970 Jarkevic: $M/M/s+\min(D,M)$ ▶ 1971 Jarkevic: $M(m)/M/s+GI$ ▶ 1980 Haugen: $M/M/s+GI$ ▶ 1981 Baccelli: $M/M/s+GI$ ▶ 1997 Brandt: $M(n)/M(m)/s+GI$ ▶ 2002 Garnett: $M/M/n+M$ | <ul style="list-style-type: none"> ▶ Processor sharing ▶ 1994 Coffman: $M/M/1-PS+M$ ▶ Boyer, Guillemin, Robert, Zwart, Bakker ... ▶ 2006 Gromoll: $GI/GI/1-PS+GI$ |
|---|---|
- renegeing before and while service
 - state-dependent service rates
 - impatience time based on QoE
 - priority classes
 - heterogeneous access speeds
 - scheduling
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Julius Maximilians-
UNIVERSITÄT WÜRZBURG

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BACKUP



Normaler Download

Lieber OTN-Anw.,
die Warteschlangenlänge für Downloads ist derzeit 144.
Um die Warteschlange zu überspringen, wählen Sie bitte die Downloadart 'Expressdownload'.
Seit März 2007 gibt es hierzu auch eine kostenlose Variante.
Beim folgenden kostenlosen normalen Download werden Sie hinten in die Warteschlange eingereiht (auch bei hohem DNR/GWR). Es gilt: 20 min. Wartezeit.
Die Wartezeit beträgt ca. 20 Minuten.

WEITER ZUM DOWNLOAD

Es ist keine Happyhour für Free-Kontingent wird durch diesen Download verringert.

Die Kontingente außerhalb der Happy-Hour sind:

- 1 täglich können Sie 3 GB gratis downloaden.
- 1 pro Woche können Sie 9 GB gratis downloaden.
- 1 pro Monat können Sie 36 GB gratis downloaden.

Die nächste Happy-Hour beginnt um 01:00 Uhr.

Allgemeine Hinweise zum Download-Beispiel:

- 1 Beispiel für eine keine speziellen Download von Probanden: Parallel Downloads sind nur via Terminal oder Mover möglich. Sie können Download-Manager verwenden.
- 1 Ein Beispiel Download werden Ihnen in 0:00 Minuten abgefragt.
- 1 Auch ohne Happy-Hour (unabhängig vom Traffic-Daten des Probanden): Die nächste beginnt um 01:00 Uhr und dauert bis 06:00 Uhr. Hier werden erneut keine Kontingente berücksichtigt und keine DNR-Punkte abgezogen (keine Hosen und Schuhe).

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1,00 € 1,00 € 1,00 €

Die Plattform für viele Downloadserver!

Hier lassen wir für www.Freemove.com, die coolste TV-Plattform im Netz, die Bits rasen.
Um die Serverkosten zu decken, wurde das Ziel für den Spendenbarometer im Juni auf 1201 Euro gesetzt, was 50% der Serverkosten entspricht. Die andere Hälfte sollte über Werbeeinnahmen fließen.

Besten Tarif DSL-Flatrate: freenet
Quelle: Deutsches Institut für Servicequalität

Köcher Filme freischalten
Neue Funktionen beim Freenet-Verein:
Alle Sender werden aufgenommen.
Sendungen von den neu aufgenommenen Sendern können von der hier freigeschalten werden.
Für ein Freigeschalten eine werden pro 100 MB 5 Punkte abgezogen.

Von uns automatisch gesungene Sender

Titel	ADD	AKTIV	REIS	Buy 1	DNAX	Label	VOX	WDR	ZDF	ARD	RTL	TV	Phonax	Pro7	RTL II	Sat 1
Alle Sender - inkl. alle Files die von unseren Benutzern freigeschalten wurden sind	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Elton	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AKB1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AKB1 Einzelcover	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AKB1 und WDR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AKB1 ohne	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Einzelcover/Album	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AKB1 & WDR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Freemove	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
KAROL 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Spenden: 43 gefunden

Heike B. San Diego : EUR
Christine H. Sabine : EUR
Roman H. Bremen : EUR
Rainer C. Berlin : EUR
Holger B. Hamburg : EUR
Jürgen C. Berlin : EUR
Anna B. Bordeaux : EUR
Johanna H. Paderborn : EUR
Liliane O. Wien : EUR
Patrick V. : EUR
Gabriele W. Leinfelden : EUR
Gisela L. Wiesloch : EUR
Thomas B. Wiesloch : EUR

Download a TV show

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kino_of_queens_06_10_02_18-45_label_30_TVVOON_DE.mpg.avi.otfkey 197963752
kino_of_queens_06_10_04_18-15_label_30_TVVOON_DE.mpg.avi.otfkey 96526396
kino_of_queens_06_10_04_18-15_label_30_TVVOON_DE.mpg.avi.otfkey 194307610
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Peters_Kreuzfahrt_06_10_07_10-15_label_30_TVVOON_DE.mpg.avi.otfkey 409748666
Mittel_und_Kreuzfahrt_06_09_22_10-30_label_30_TVVOON_DE.mpg.avi.otfkey 159165388
LadArcher_06_09_23_23-15_label_60_TVVOON_DE.mpg.avi.otfkey 533496459
Wibben_und_Todesstrafen_06_11_09_06-00_label_30_TVVOON_DE.mpg.avi.otfkey 271594462
Lindenstrasse_06_09_24_11-30_label_30_TVVOON_DE.mpg.avi.otfkey 376331594

Mythbusters_Die_Wissensjäger_06_10_03_17-00_vid_120_TVVOON_DE.mpg.avi.otfkey 690747306
mpo_06_09_22_18-30_label_30_TVVOON_DE.wmv.otfkey 194602667
Natural_Born_Moms_06_09_18_09-45_label_30_TVVOON_DE.mpg.avi.otfkey 792650996
Navy_GIS_06_10_01_20-15_label_60_TVVOON_DE.mpg.avi.otfkey 189771416
Navy_GIS_06_11_09_22-15_label_60_TVVOON_DE.mpg.avi.otfkey 384292370
News_06_10_01_20-30_vid_15_TVVOON_DE.mpg.m4.otfkey 49320883
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NZZ_Format_06_10_01_09-00_vid_60_TVVOON_DE.mpg.avi.otfkey 275484196
O_C_California_06_09_24_08-30_pro7_45_TVVOON_DE.mpg.avi.otfkey 263864282
Phantom_Control_06_09_28_18-00_label_30_TVVOON_DE.wmv.otfkey 563366666
  
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UNIVERSITÄT WÜRZBURG

Tobias Hoßfeld

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Modeling the service and its users

► as

TV show

