The Tenth International Conference on Digital Telecommunications

ICDT 2015

April 19 - 24, 2015 - Barcelona, Spain

IARIA

Research Challenges and Proposed Solutions to Improve Availability and Quality-of-Experience in Future IPTV Systems

Prof. Dr. Bernd E. Wolfinger

Department of Computer Science
University of Hamburg

UHH Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Content of Talk *versus* CfP of ICDT 2015

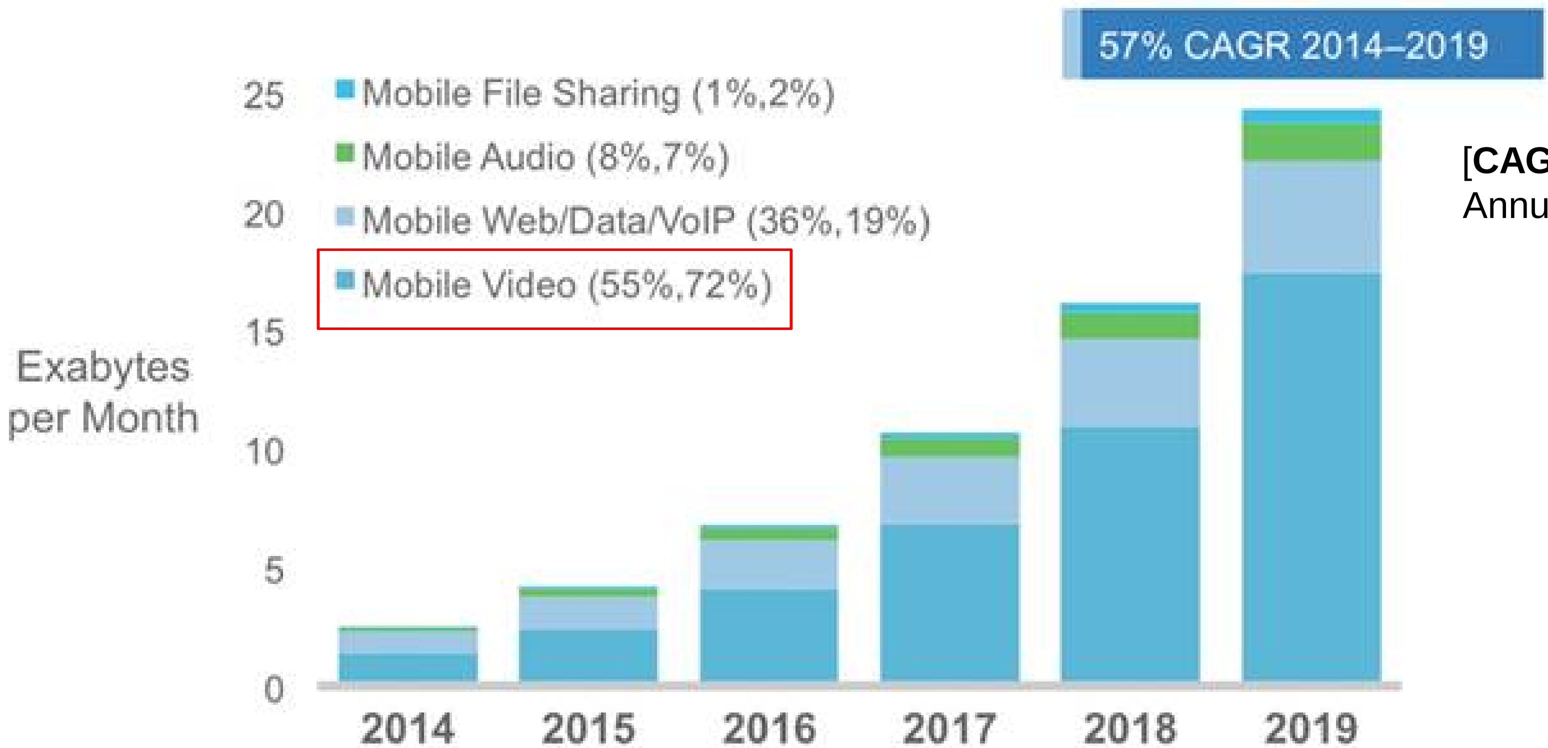
The conference has the following specialized events:

- **SIGNAL: Signal processing in telecommunications**
- **DATA: Data processing**
- **AUDIO: Audio transmission and reception systems**
- **VOICE: Voice over packet networks**
- **VIDEO: Video, conferencing, telephony**
- **IMAGE: Image producing, sending, and mining**
- **SPEECH: Speech producing and processing**
- **IPTV: IP/Mobile TV**
- **MULTI: Multicast/Broadcast Triple-Quadruple-play**
- **CONTENT: Production, distribution**
- **HXSIP: H-series towards SIP**
- **MULTE: Multimedia Telecommunications**
- **MOBILE: Mobile technologies**
- **MEDMAN: Control and management of multimedia telecommunications**
- **SARP: Software architecture research and practice**
- **STREAM: Data stream processing**
- **TRACK: Tracking computing technologies**

Cisco-Study: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014 – 2019

published: February 3, 2015

Mobile Video Will Generate ≈ 72 % of Mobile Data Traffic by 2019



[**CAGR**: Compound Annual Growth rate]

Figures in parentheses refer to **2014**, **2019 traffic share**.
Source: Cisco VNI Mobile, 2015

Exabytes = 10^{18} Bytes = 1.000.000.000.000.000.000 Bytes

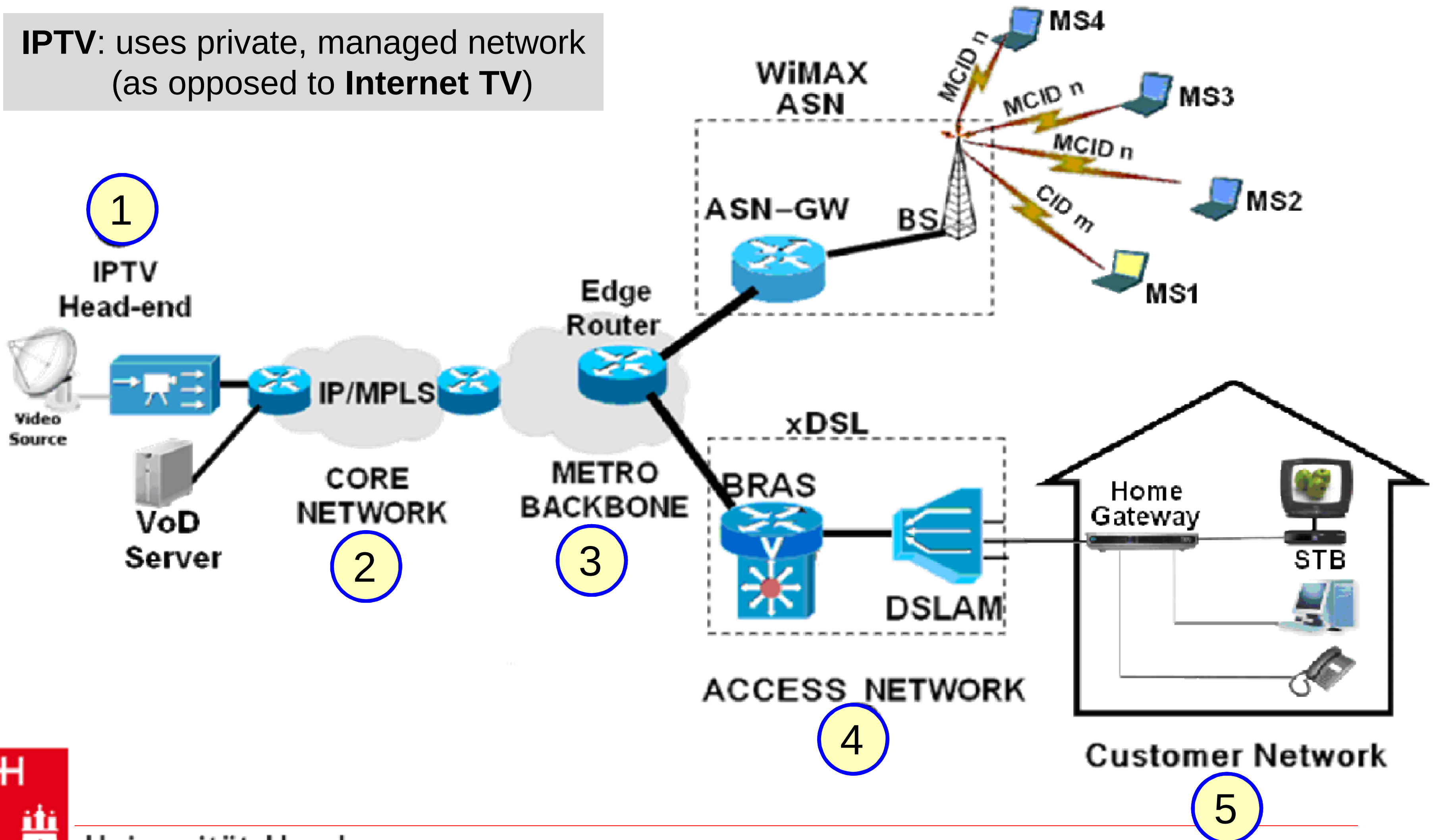
cf. http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.html [last access: 3/26/2015]

Outline

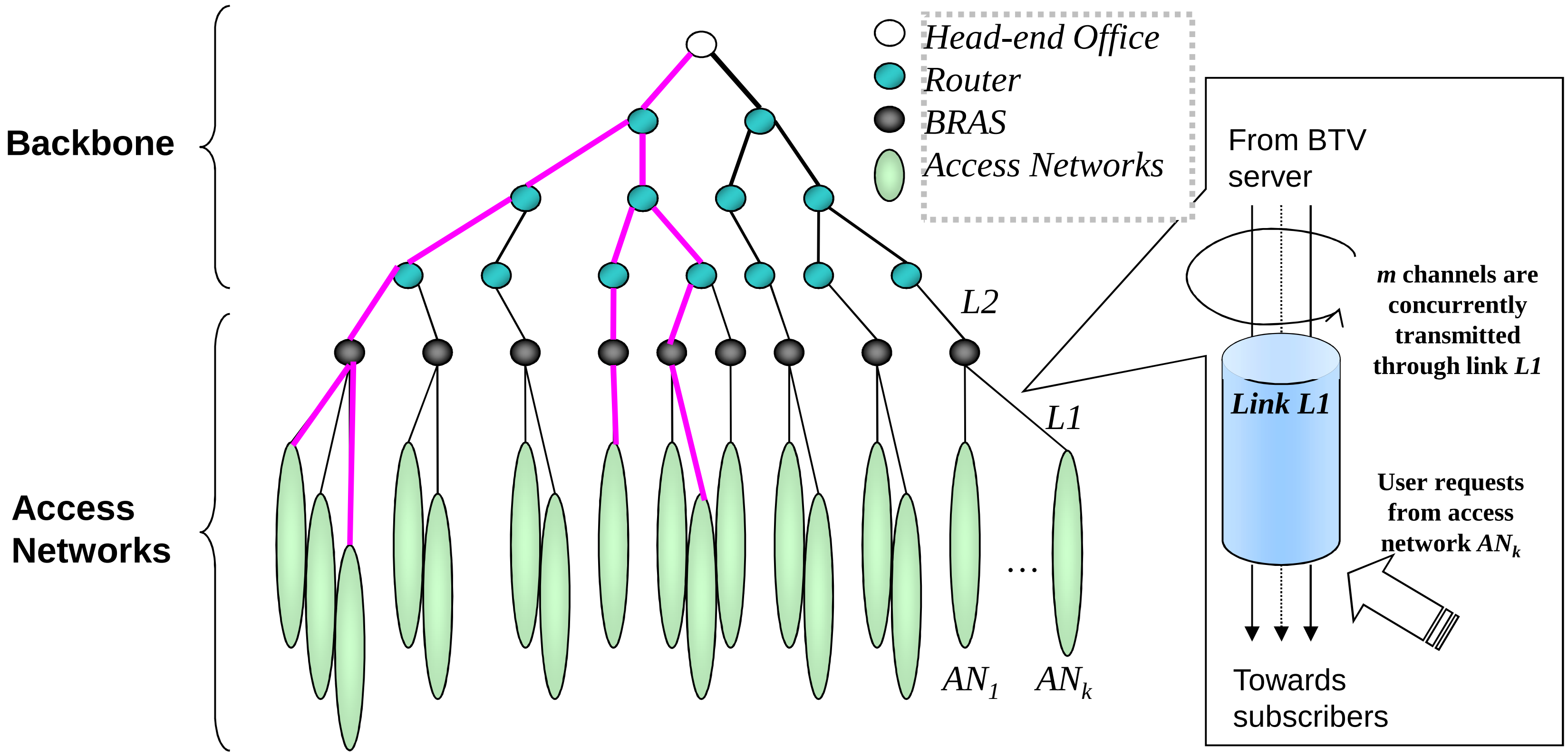
- I. Prologue: Motivation and Overview on IPTV Systems
  - IPTV System Structure
  - Overview of Access Networks (e.g., DSL, WiMAX)
- II. Research Challenges and Proposed Solutions
  - II.1 Comparison between Multicast and Unicast : Multicast Gain
  - II.2 Modeling the Behavior of IPTV Users
  - II.3 Reduction of TV Channel Blocking Probability
  - II.4 How to treat Heavily Zapping Users ?
- III. Epilogue: Additional Research Challenges, Lessons Learned, Outlook

IPTV System Structure: WiMAX- and DSL-based Access Networks

IPTV: uses private, managed network
(as opposed to **Internet TV**)



Multicast Tree Topology of a BTV Distribution Network Architecture



Potential Bottleneck (PB)-link:
Link on which blocking of user requests may occur

: Multicast tree for a given TV channel at $t=t_0$

Some Background w.r.t. WiMAX Networks

- Worldwide Interoperability for Microwave Access (WiMAX) technology; based on IEEE 802.16 air-interface standard
- Provides wireless last-mile broadband access for fixed and mobile subscribers in Metropolitan Area Network (MAN)
- Operates in MAC ~ and Physical Layer

Some Useful Features of WiMAX

- QoS support
- Multicast Broadcast Service (MBS)
- Wide coverage range
- High bandwidth
- Power saving mode (necessary for handheld devices)
- Mobility support (up to 120 km/h in 802.16e and up to 350 km/h in 802.16m)

Requirements to *Live* IPTV Services and Measures for their Quality

- Requirements of IPTV users:

  Get same quality as in conventional TV broadcast systems, e.g.

  - *R1:* get <u>all</u> channels delivered upon request
  - *R2:* get (at least) comparable audio/video quality
  - *R3:* quick switching between different channels demanded by a single user

- Quality measures for

  - *R1:* **TV Channel Blocking Probability** (CBP), i.e. *probability that a desired channel cannot be provided,*

    cf. call blocking probability in “good-old” telephone networks
  - *R2:* **Quality of Experience** (QoE) Measures such as Mean Opinion Score (MOS)
  - *R3:* **Channel Switching Delay**

Outline

I. Prologue: Motivation and Overview on IPTV Systems

- IPTV System Structure
- Overview of Access Networks (e.g., DSL, WiMAX)

II. Research Challenges and Proposed Solutions

II.1 Comparison between Multicast and Unicast : Multicast Gain

II.2 Modeling the Behavior of IPTV Users

II.3 Reduction of TV Channel Blocking Probability

II.4 How to treat Heavily Zapping Users ?

III. Epilogue: Additional Research Challenges, Lessons Learned, Outlook

Comparison between Multicast and Unicast : Multicast Gain

Unicast may make you happier than **Multicast !**

Our Goals in Multicast Research

- How to quantify the benefits of multicasting in Live TV delivery systems (or other real-time content distribution systems)?
  $\rightarrow$ *New measure(s) for Multicast Gain*

- Evaluation/prediction of (expected) gain to answer question: *Is it worthwhile to use multicasting or not ?*

- *How much "bandwidth" (BW) will be saved when using multicasting ?*

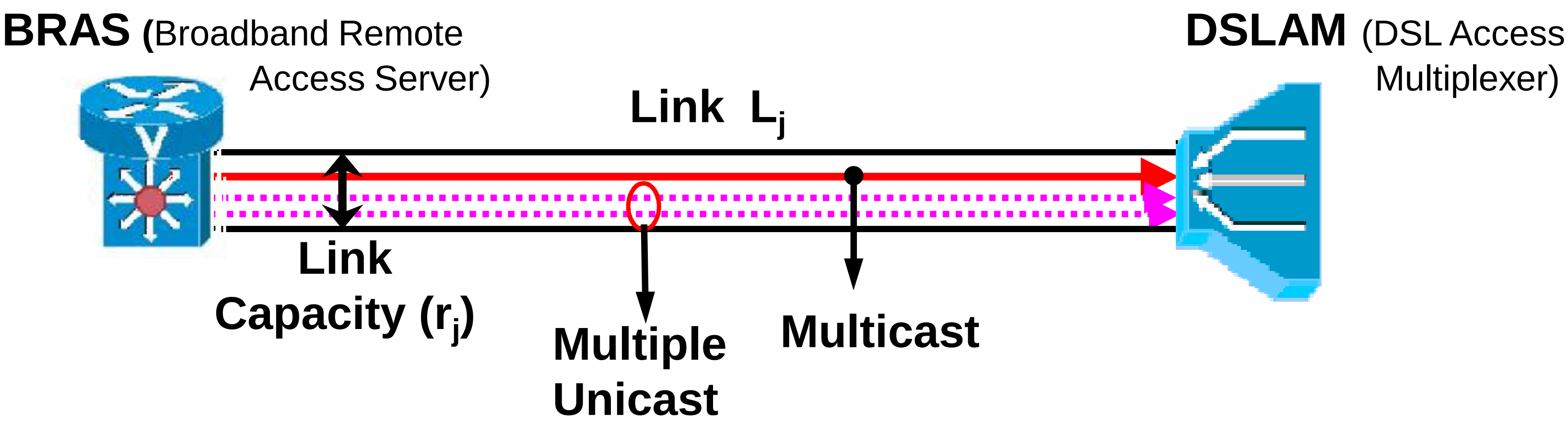
Requirements to our Definition of Multicast Gain (MG)

- Definition should cover different types of links (fixed & variable data rates)
- The new measure for multicast gain should
  - be easy to evaluate and to apply
  - be able to reflect different boundary conditions
- The focus should be on bandwidth possibly saved by multicast (as, in networks offering IPTV service, link bandwidth is typically the most important resource)
- The measure should not only be applicable to Live IPTV service but also to other services using multicast

Corresponding publications:

[Abdollahpouri & Wolfinger → WWIC 2010, SPECTS 2011, WMNC 2011, Telecommunication Systems Journal (Springer) 2014, Journal of Networks (Academy Publisher) 2012]

Link Model I:
MG for Links with Fixed Data Rate



Let $D_m(i)$ / $D_u(i)$ be the average data rate required in the long-term when transmitting a given TV channel C_i by means of multicast / unicast.

We then calculate the difference in bandwidth required for multicast *versus* unicast transmission $G_i = D_u(i) - D_m(i)$

Thus, our first **elementary definition** ***MG_0*** **of** ***multicast gain*** for channel C_i is :

$$MG_0 \cong G_i$$

MG for Links with Fixed Data Rate:
Generalized Definitions of MG

1- Considering the link data rate r_j :

$$MG_1 \cong \frac{G_i}{r_j}$$

2- If α [×100%] of the link capacity is reserved a priori for IPTV:

$$MG_2 \cong \frac{G_i}{\alpha \cdot r_j}$$

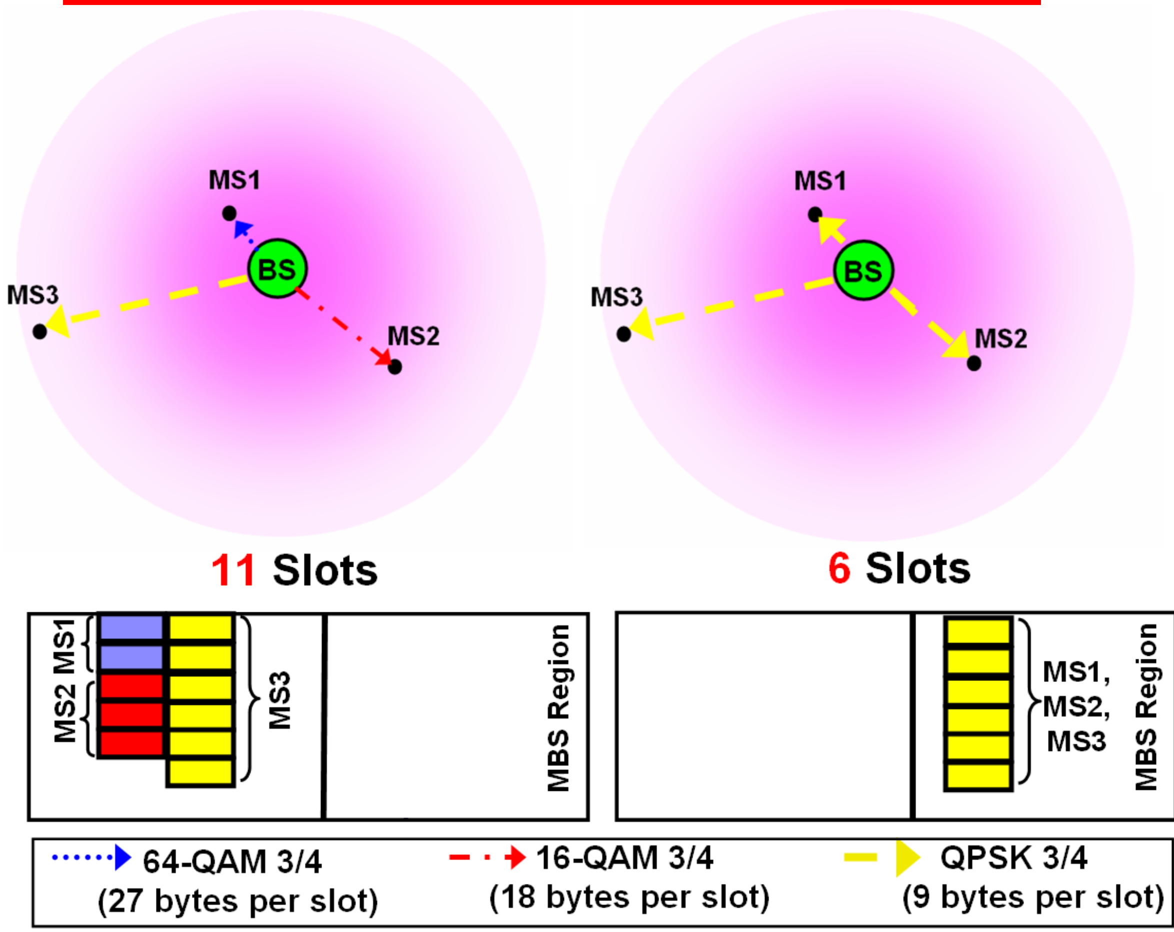
$0 < \alpha \leq 1$; $\alpha \in \mathbb{R}$; α is constant

3- Generalizing all of the three previously introduced measures by means of adding a new parameter β :

$$MG_3 \cong \frac{G_i}{\alpha \cdot \left(r_j\right)^{\beta}}$$

$0 < \alpha \leq 1$; $\beta \geq 0$; $\alpha, \beta \in \mathbb{R}$; α, β are constant

Link Model II:
MG for Shared Links with Variable Data Rate



Absolute Multicast Gain:

$$MG_a \cong S_u - S_m$$

Required slots for Multicast

In this example: MG_a= 11 - 6 = 5 slots

MG for Shared Links with Variable Data Rate:
Generalized Definitions of MG

Relative Multicast Gain:

$$MG_r \cong \frac{S_u - S_m}{S_t}$$

Maximum number of available slots

Relative Multicast Gain when α [×100%] **of link capacity is reserved for IPTV:**

$$MG_{r,\alpha} \cong \frac{S_u - S_m}{\alpha \cdot S_t}$$

Basic Information Required to Determine MG

- Bandwidth requirement to transmit a typical TV channel:

  QCIF format with 15 fps: ≈ 128 Kbps

  SD format with 30 fps: ≈ 4 Mbps

  HD format with 30 fps: ≈ 16 Mbps

- A distribution that matches well with the popularity of TV channels: e.g., Zipf-like distribution

- (Geographical) Distribution and number of IPTV subscribers

- Amount of available bandwidth of the link and the reserved bandwidth for IPTV

Case Study- Parameter Setting and Workload Assumptions

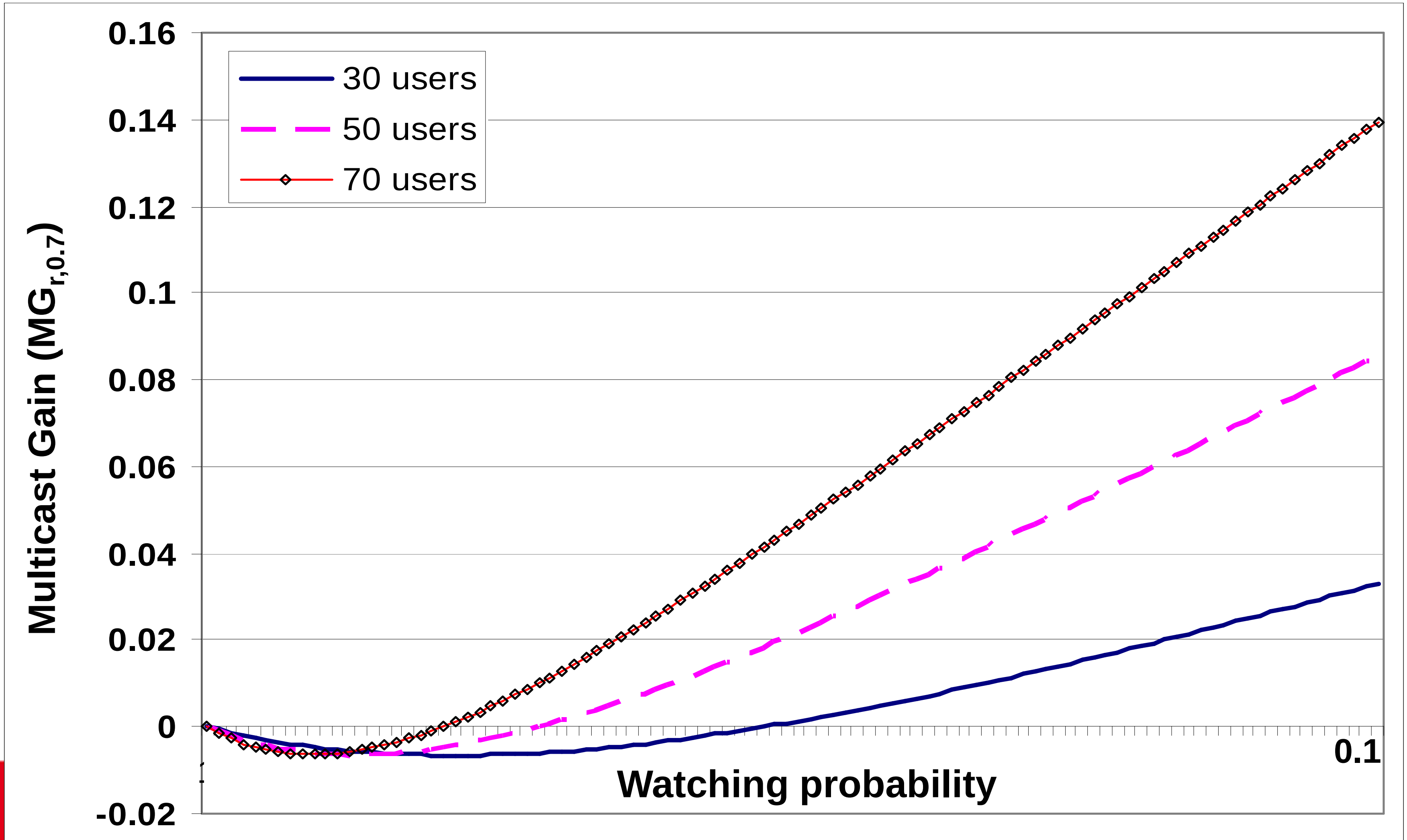
Parameter	Value
Bandwidth	10 MHz
Permutation mode	PUSC
No. of subcarriers	1024
Data subcarriers	720
Cyclic prefix	1/8
Useful symbol time (Tb=1/f)	91.4 μs
Guard time (Tg=Tb/8)	11.4 μs
OFDMA symbol duration (Ts=Tb+Tg)	102.825 μs
Number of subscribers	108
OFDMA symbols per frame	48
Data OFDMA symbols per frame	44
Frame duration	5 ms
Video format	QCIF(176 × 144)-15 fps
Bandwidth requirement for one stream	128 Kbps

128000/200=640 bits per frame (Ignore upper layer overheads)

QPSK 3/4: **9** slots
16-QAM 3/4: **5** slots
64-QAM 3/4: **3** slots

Effect of Number of Users

(single WiMAX cell with N_u IPTV users, α=0.7)

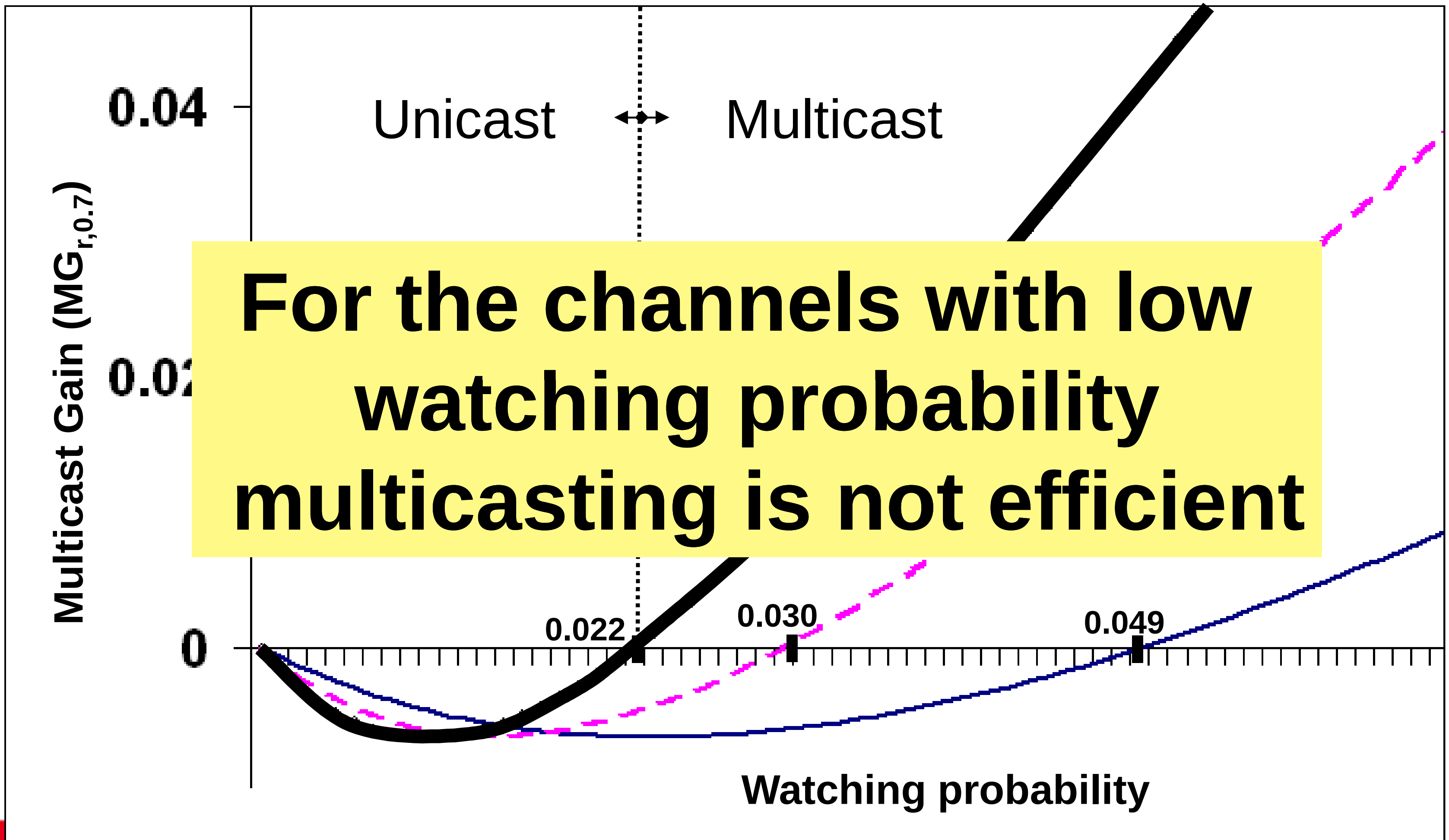


Universität Hamburg

DER FORSCHUNG | DER LEHRE | DER BILDUNG

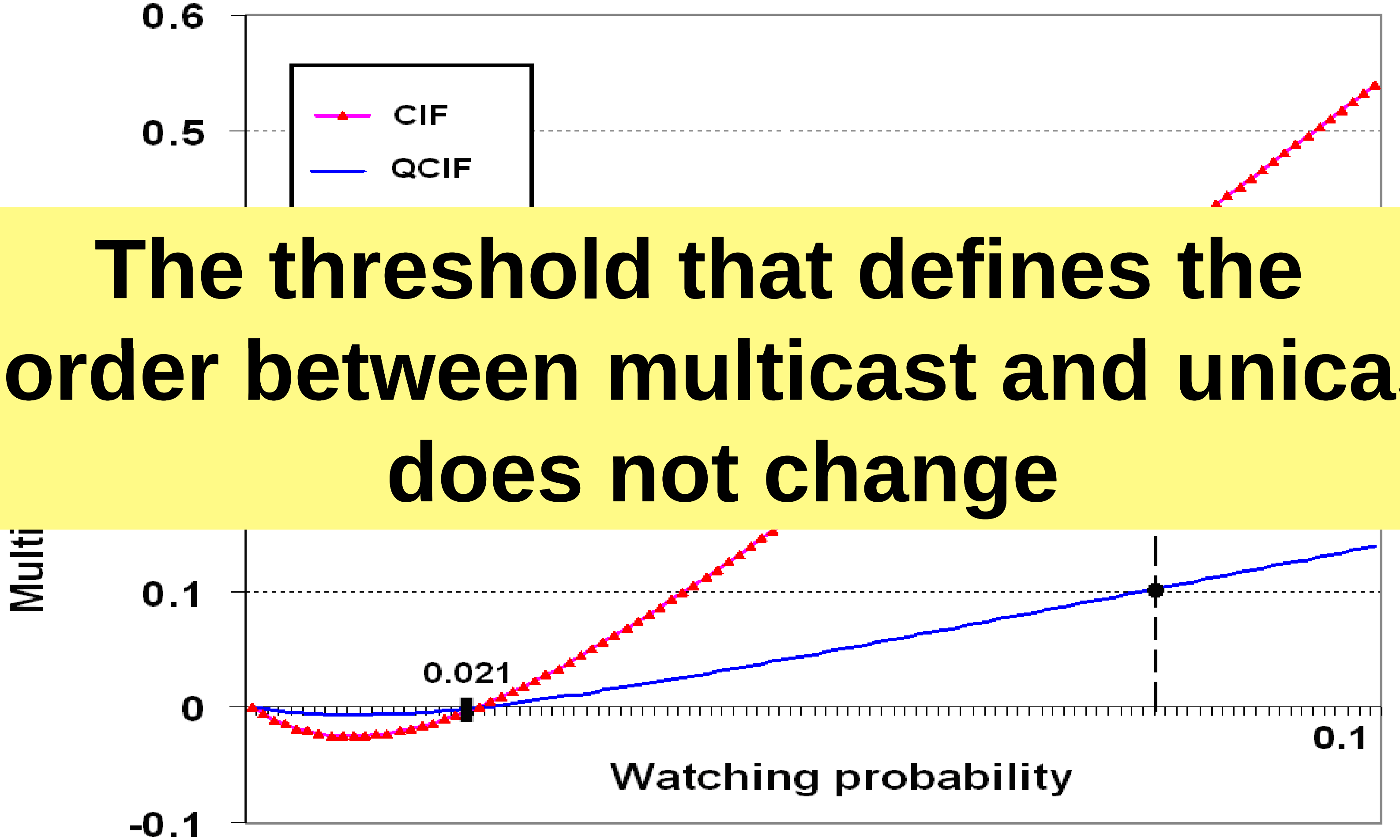
Effect of Number of Users

(single WiMAX cell with N_u IPTV users, α=0.7)



For the channels with low watching probability multicasting is not efficient

Effect of Video Format



The threshold that defines the border between multicast and unicast does not change

Outline

I. Prologue: Motivation and Overview on IPTV Systems

- IPTV System Structure
- Overview of Access Networks (e.g., DSL, WiMAX)

II. Research Challenges and Proposed Solutions

II.1 Comparison between Multicast and Unicast : Multicast Gain

➡ II.2 Modeling the Behavior of IPTV Users

II.3 Reduction of TV Channel Blocking Probability

II.4 How to treat Heavily Zapping Users ?

III. Epilogue: Additional Research Challenges, Lessons Learned, Outlook

Modeling the Behavior of IPTV Users

Don't underestimate the value of valid load models or user behavior characterization!

Motivation

- Modeling and analyzing user behavior can help IPTV service providers during system design & operation to *evaluate several "what-if" scenarios*

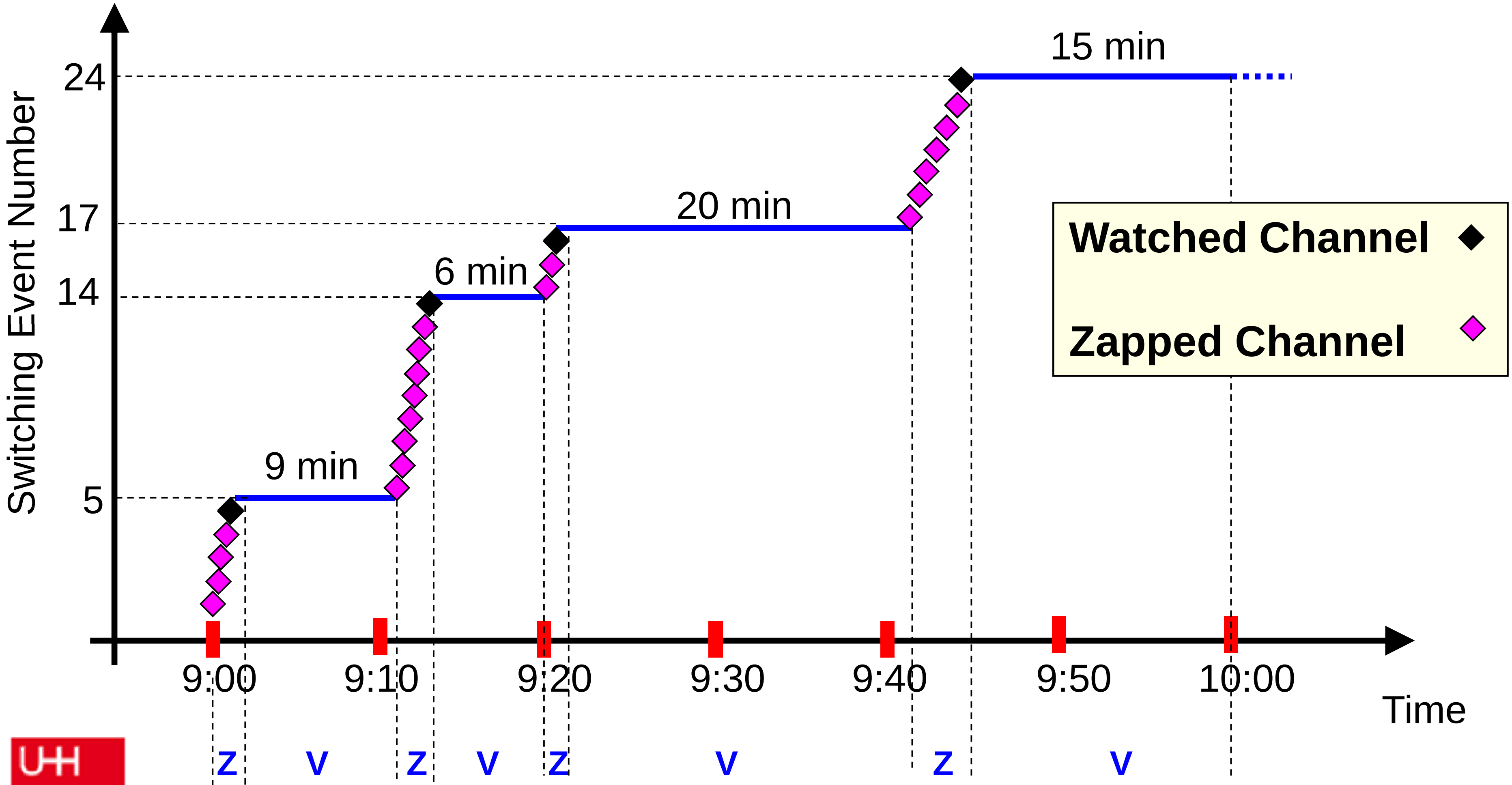
- Modeling necessary to *guide network design and management*, e.g. to optimize resource provisioning and performance/QoS

- Having a realistic model of the user behavior, the STB can request for the channels which are likely to be selected next (e.g. to reduce the channel switching delay)

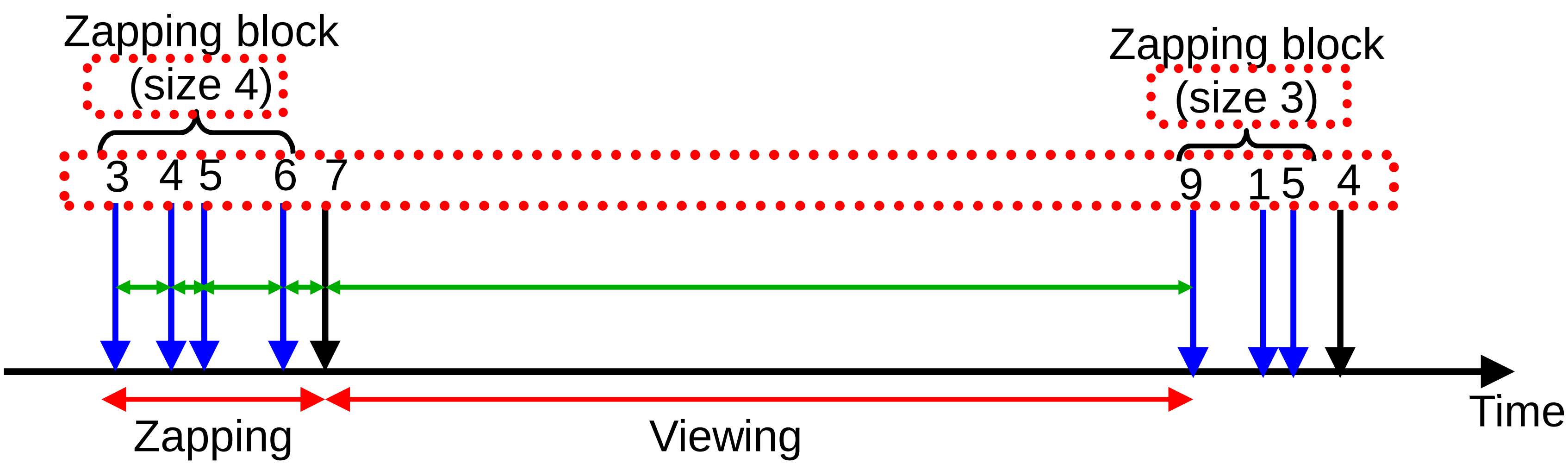
Corresponding publications:

[Abdollahpouri & Wolfinger & Lai → MMBnet 2011, PIK journal 2012]

Behavior of a Single User During an ON Session



Three Main Questions:

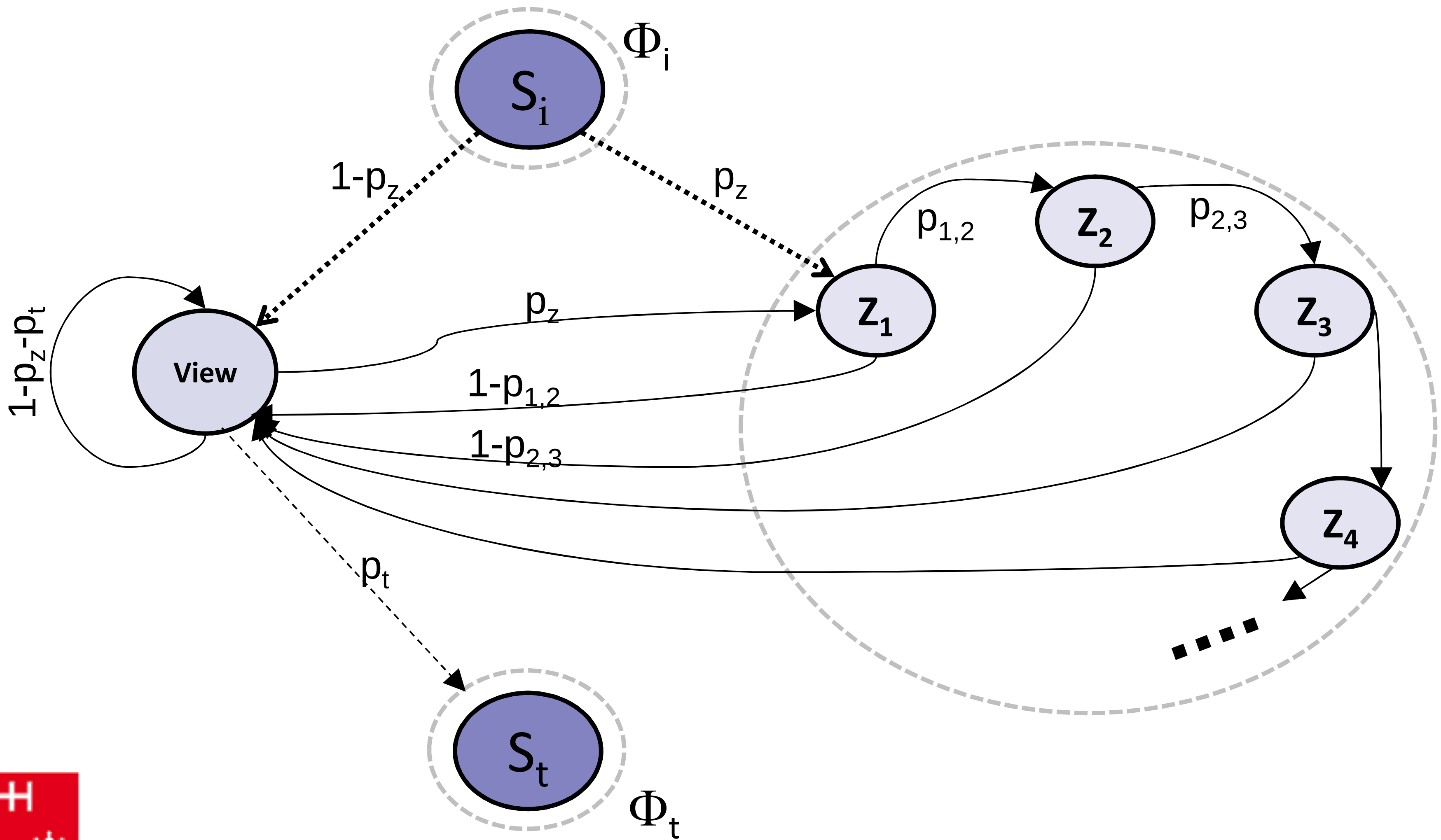


Q1. How many channels to zap in zapping mode? (size of zapping block)

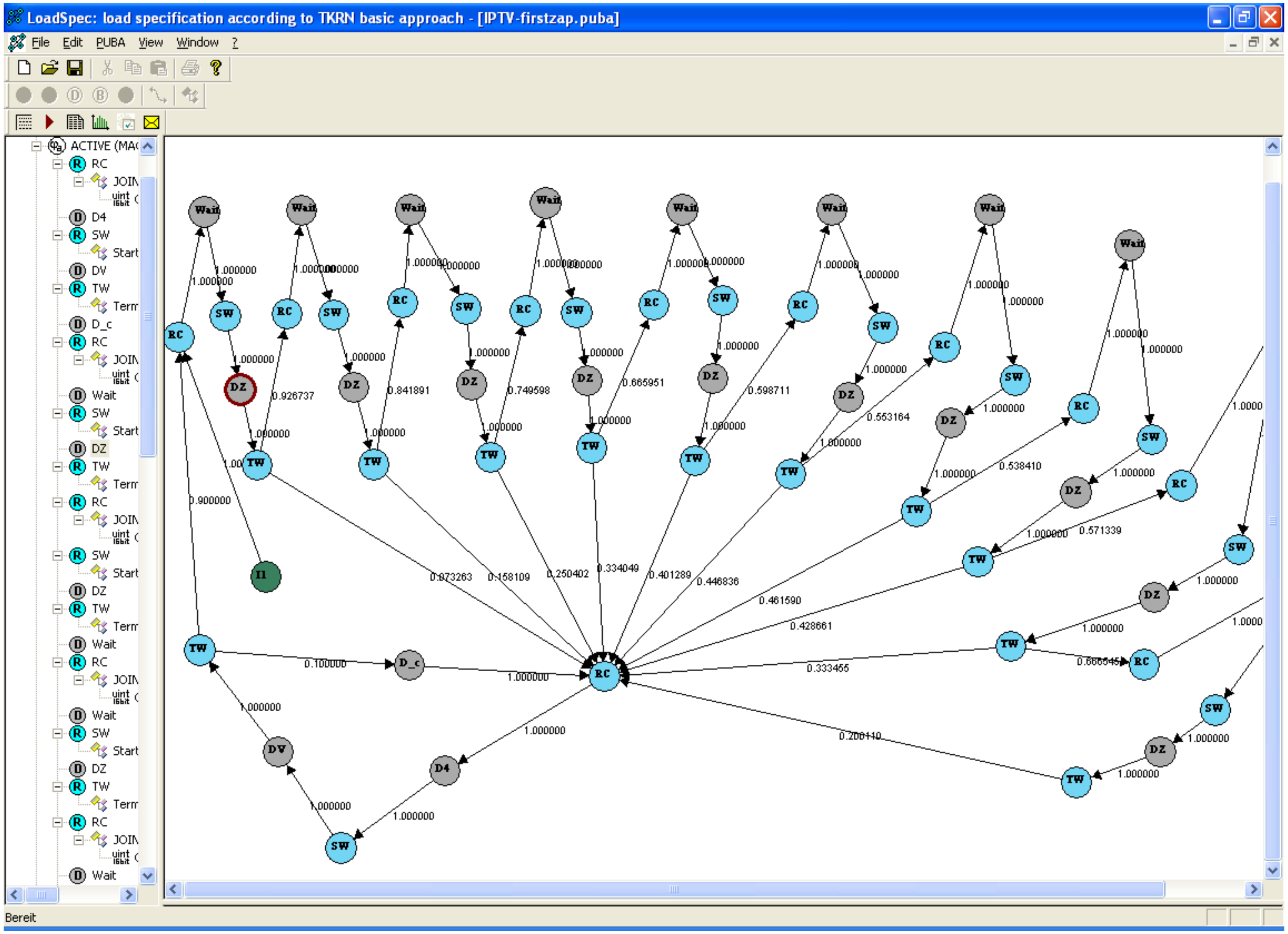
Q2. Which channels to watch or zap? (access frequency)

Q3. When to change the channel ? (channel dwell time)

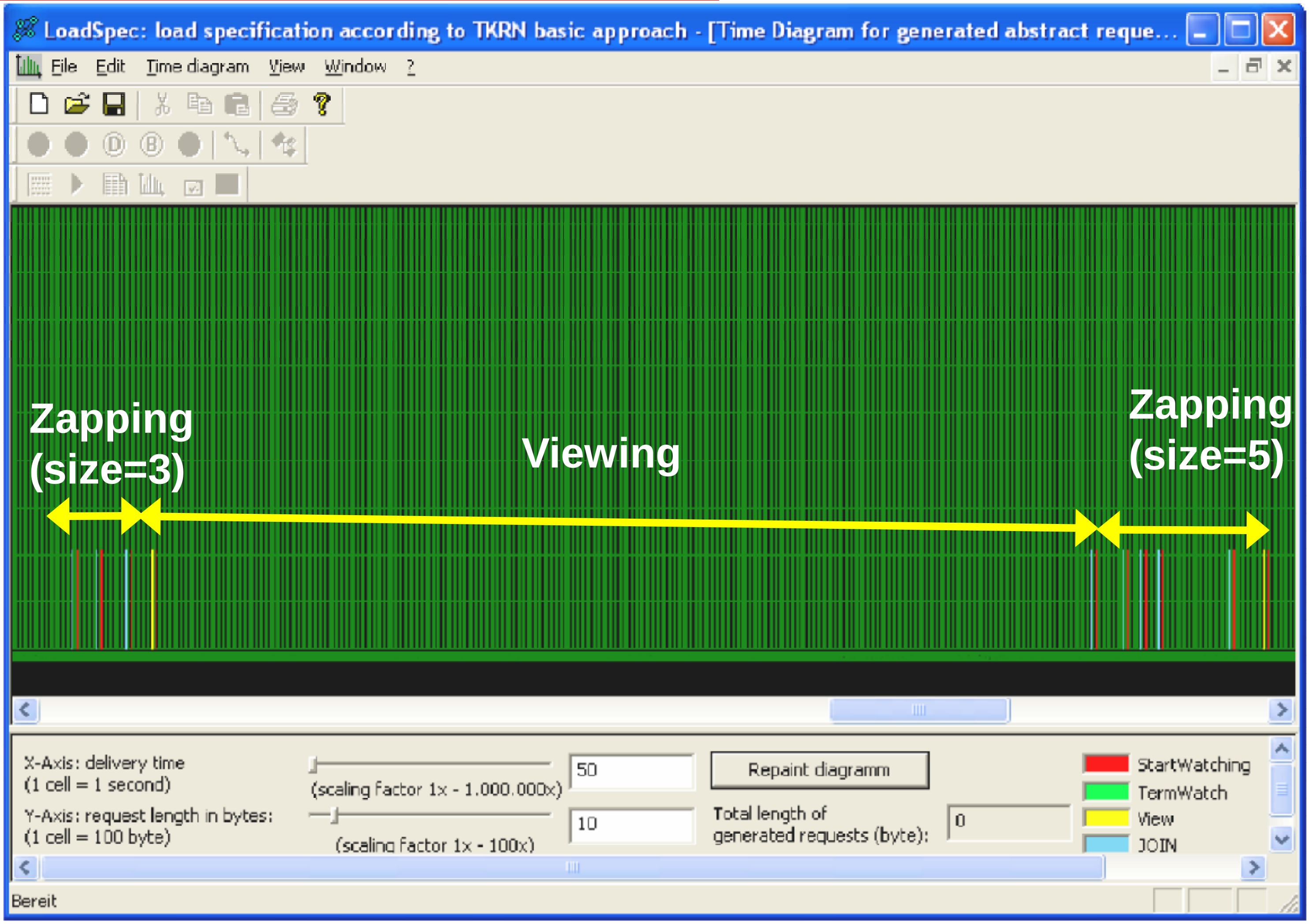
Proposed Model: TV User Behavior Automaton (TV-UBA)



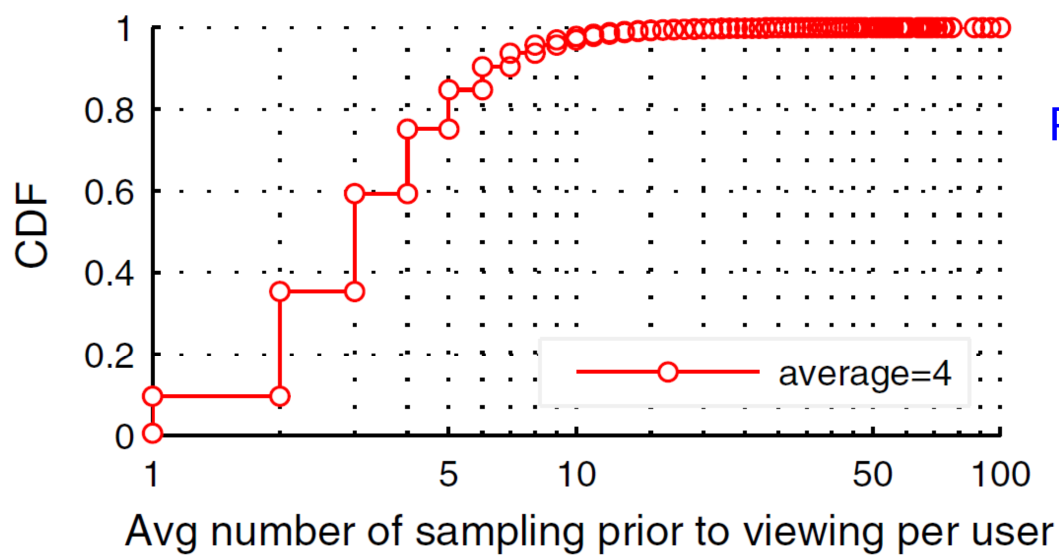
Implementation by LoadSpec



A Sample Output



Q1. The Size of Zapping Block



Probability that zap block size is equal to *k* $= \frac{e^{-\lambda} \cdot \lambda^k}{k!}$

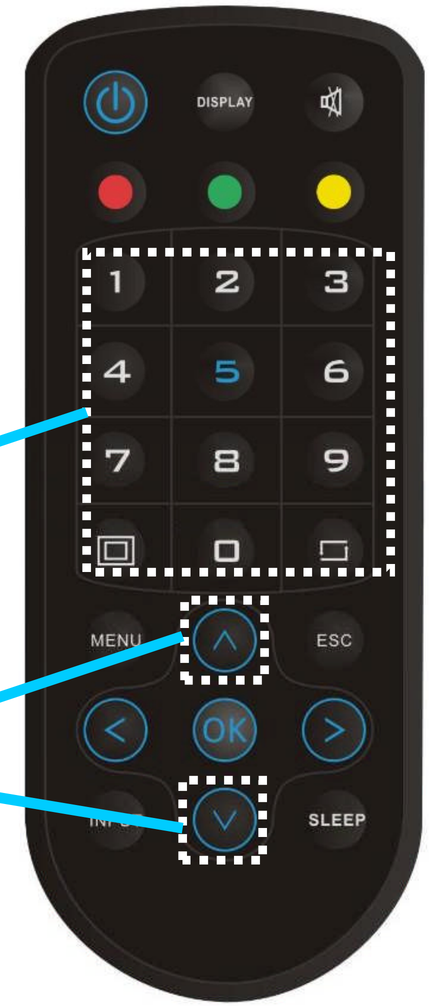
CDF of the number of changes prior to viewing a channel : approximated by CDF of *Poisson distribution* with a mean value of 4.

Q2. Which Channels?

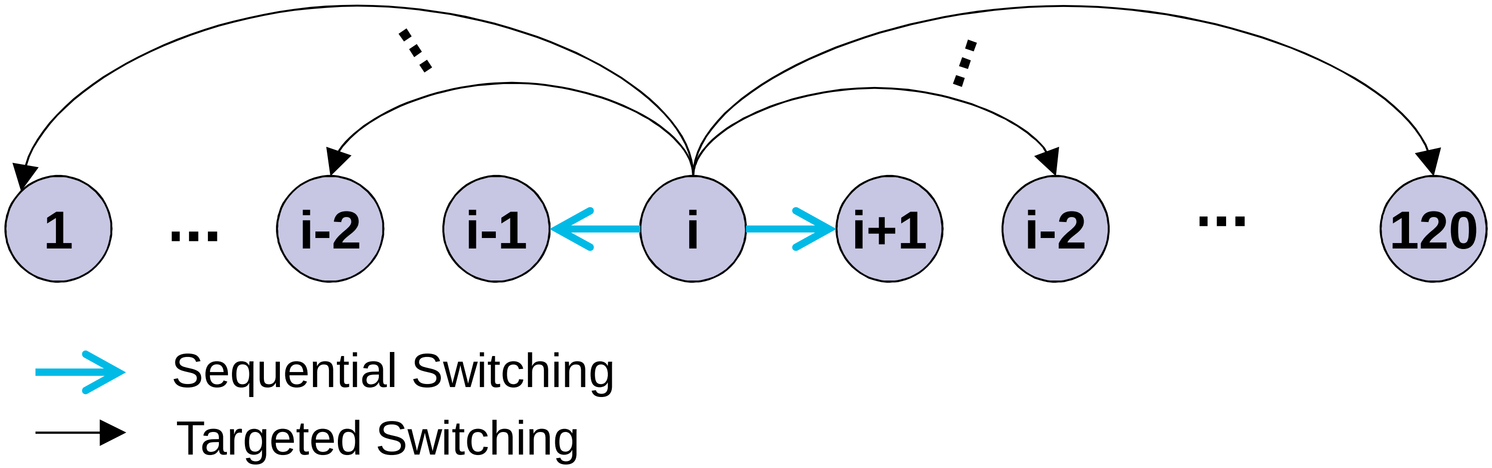
- In *view mode*: according to zipf
- In *zapping mode*:
  - Targeted zapping (according to zipf)
  - Sequential zapping (current+1 or current-1)

Targeted Switching

Sequential Switching



Q2. Channel Switching



$$\text{Probability} = \begin{cases} (1-p_{ta})p_u + p_{ta}P(C_j) & j = i+1, \\ (1-p_{ta})(1-p_u) + p_{ta}P(C_j) & j = i-1, \\ p_{ta}P(C_j) & |i-j| > 1. \end{cases}$$

$P(C_j)$: watching probability of TV channel with rank C_j

p_{ta} : Probability of Targeted switching

p_u : Probability of Sequential-Up switching

Q3. When Do Channel Changes Happen?

Modeling Channel dwell time:

- **Viewing dwell time (DV):** ***Gamma distribution*** **(mean=10 min)**

- **Zapping dwell time (DZ):** ***lognormal*** **or** ***burr distribution*** **(mean=10 sec)**

Outline

I. Prologue: Motivation and Overview on IPTV Systems

- **IPTV System Structure**
- **Overview of Access Networks (e.g., DSL, WiMAX)**

II. Research Challenges and Proposed Solutions

II.1 Comparison between Multicast and Unicast : Multicast Gain

II.2 Modeling the Behavior of IPTV Users

➡ **II.3 Reduction of TV Channel Blocking Probability**

II.4 How to treat Heavily Zapping Users ?

III. Epilogue: Additional Research Challenges, Lessons Learned, Outlook

Reduction of TV Channel Blocking Probability

Be careful when you spend your last resources !

Our Goals in Research on IPTV Service Availability

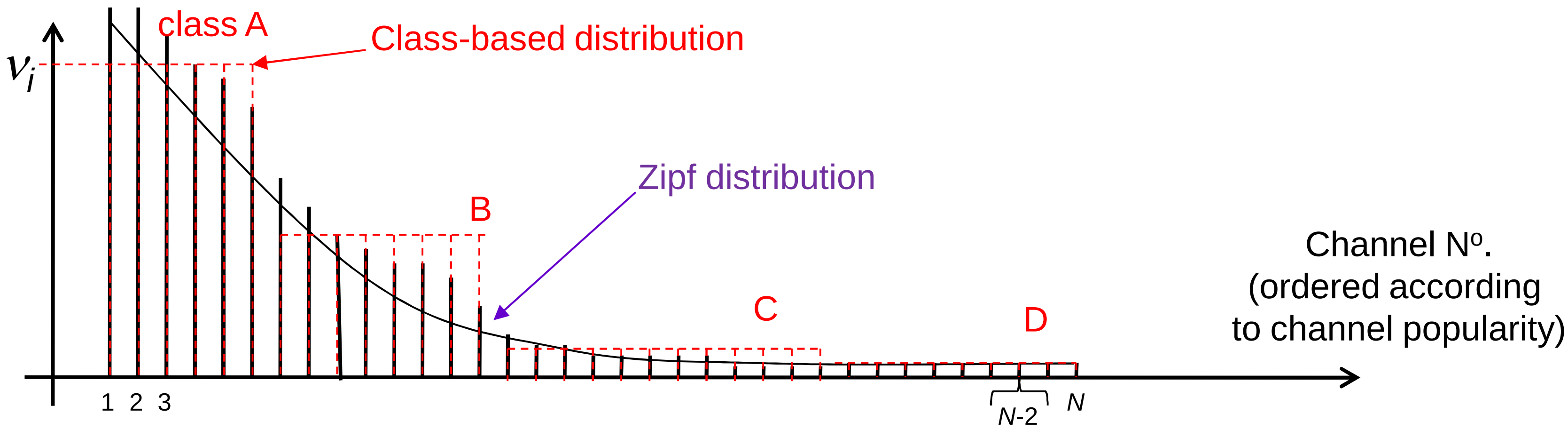
- Define Measure for IPTV Service Availability
  → (TV) Channel Blocking Probability [CBP]
- Elaborate Simulation Tools for CBP Analyses
  → Studies for Stationary *and* Peak Hour Scenarios
- Improve IPTV Service Availability (i.e. reduce CBP) by Means of a Clever TV Channel Access Control [TCAC] Scheme

Corresponding publications:
[Lai & Wolfinger & Heckmüller → ICUMT 2010, SPECTS 2011, PIK journal 2012, Journal of Networks (Academy Publisher) 2012]

Distribution Model of Channel Watching Probability

Measured Frequencies, Zipf & Class Based Distribution

To be measured : Channel watching frequencies v_i for all N TV channels provided



Advantages **of Zipf Distr.:**
- closed form solution
- most commonly used approx.

Disadvantages **of Zipf Distr.:**
- studies showed that Zipf distr. may be quite invalid for low popularity channels
- for some investigations channels with similar popularity should be grouped

... so: **What to do ???**

Advantages **of Class-based Distr.:**
- classes can be determined using clustering algorithms
- can approximate measured frequencies in an arbitrarily precise manner (for nº of classes $\rightarrow N$)
- homogeneous treatment of all channels within a class

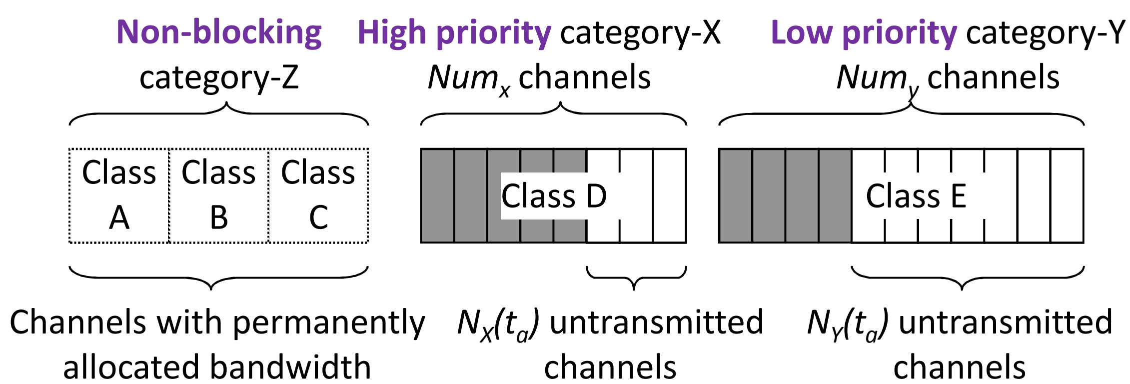
Disadvantages **of Class-based Distr.:**
- in some cases, one may need a lot of classes for good measurement approximation

Example of a Class-based Distribution Model

Class	Number of Channels in Each Class	Overall Watching Probability for Each Class	Individual Watching Probability for Each Channel of Different Classes
A	*7*	*63.9314%*	*9.1331%*
B	*13*	*21.5044%*	*1.6542%*
C	*20*	*9.9574%*	*0.4979%*
D	*40*	*4.2496%*	*0.1062%*
E	*40*	*0.3572%*	*0.0089%*

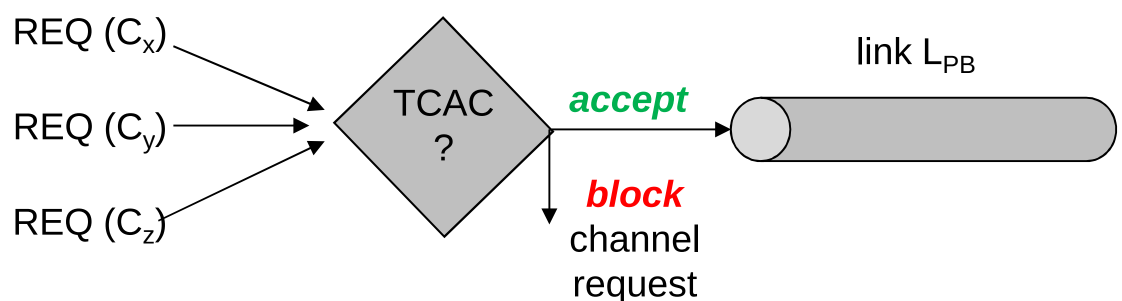
⇨ How to treat the channels of the 5 classes?

- Classes with highest popularity: Non-blocking Category (always transmitted)
- Classes with medium popularity: High Priority Category
- Classes with lowest popularity: Low Priority Category



Our New TV Channel Access Control Scheme (TCAC)
General Assumptions

- *TCAC applied at* a given *Potential Bottleneck (PB)-link* L_{PB}
- *N TV channels provided* in total, each of which consuming 1 unit of bandwidth capacity
- *Capacity of PB-link* considered: *BW* units, $BW < N$
- TCAC only applied in ***n_0-BW-scarce-period***, $n_0 \geq 1$ [i.e. periods in which currently exactly n_0 units of bandwidth remain on L_{PB}]
- *User arrival process* at PB-link: Poisson process, intensity λ
- *User behavior*: static watching probabilities, known a priori, users mutually independent
- *Channel watching time*: neg. exponentially distr., mean *T*
- *Interval between two successive channel releasing events*: neg. expon. distr., rate λ_r, where λ_r is measured
- *Distribution of channel watching probabilities*: class-based distr.



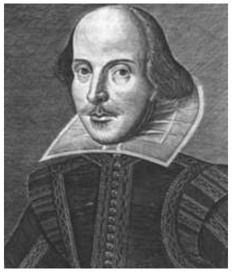
REQ (C_j) = Request for channel C_j

Basic Principles Underlying our TCAC Scheme: *The Basic Idea*

The basic idea:

At instants when remaining resources (i.e., the unoccupied link bandwidth available) become scarce:

⇒ it could be a good idea to deny (block) the demand *D* for a channel *i* (of low priority category-Y, *and* currently not yet available on the link considered).



So:

To b(lock) or not to b(lock) that is the question !!!

Important for TCAC decision:

- *What do we lose if we block D ? (i.e. what is expected loss L ?)*
- *What do we win if we block D ? (i.e. what is expected gain G ?)*

Our TCAC scheme:

Block (reject) a low prio channel request iff. G > L

or to put it differently:

Accept a low prio channel request iff. G ≤ L

Basic Principles Underlying our TCAC Scheme: *Expected Loss*

What leads to loss?

Disadvantage of denying a demand for low prio channel i (i.e., blocking a user request) quantified by our measure of **"expected loss"** L

Two negative consequences of blocking a request:

- **loss L_1** : We block a request which still could have been accepted, i.e. L_1 =1
- **loss L_2** : Future requests for the blocked channel i, which could arrive during the period the blocked user would have watched channel i, may be also (indirectly) blocked.

To summarize:

expected loss $L = L_1 + L_2$ leads to an increase of the CBP

Expected Loss in a 1-BW-Scarce-Period:

$$L = L1 + L2 = 1 + \frac{\lambda \cdot p_Y}{\lambda_r + 1/T}$$

Basic Principles Underlying our TCAC Scheme: *Expected Gain*

What leads to gain?

During a period of scarce resources (namely in ***1-BW-scarce-period***):

Accept only demands for unavailable channels in high priority category-X

$\Rightarrow$ **gains to be expected :**

- ***Basic gain*** G_1 to be expected only if $\geq$ 1 demand for a “new” (i.e. currently not yet transmitted) *high priority* channel will arrive during the time interval the blocked user would have watched i (i.e. the blocked low prio channel).
- If such a gain is brought by a demand for a channel j (of category-X) and occurs at time t_e ,

  $\Rightarrow$ **additional gain** G_2 to be expected if further demand(s) for j will occur sufficiently soon after t_e .

To summarize:

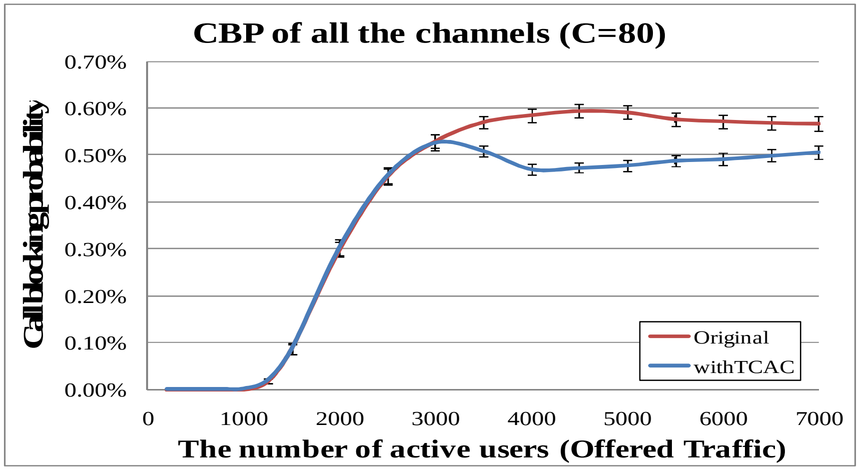
expected gain $G = G_1 + G_2$ leads to a decrease of the CBP

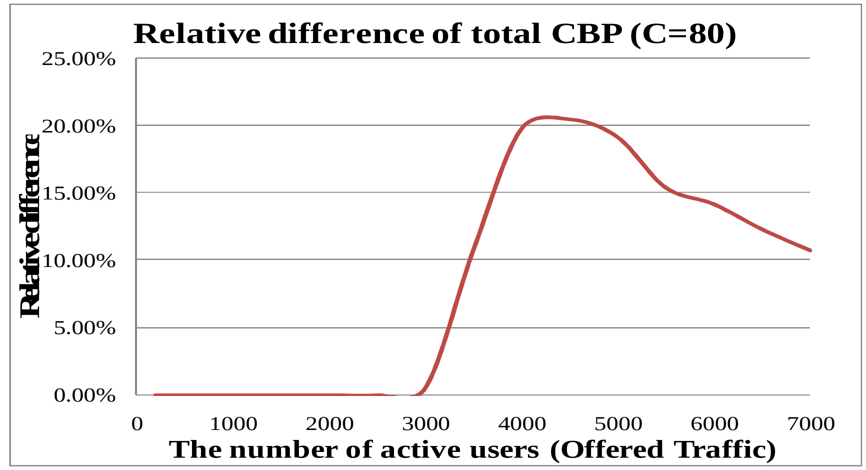
Case Study

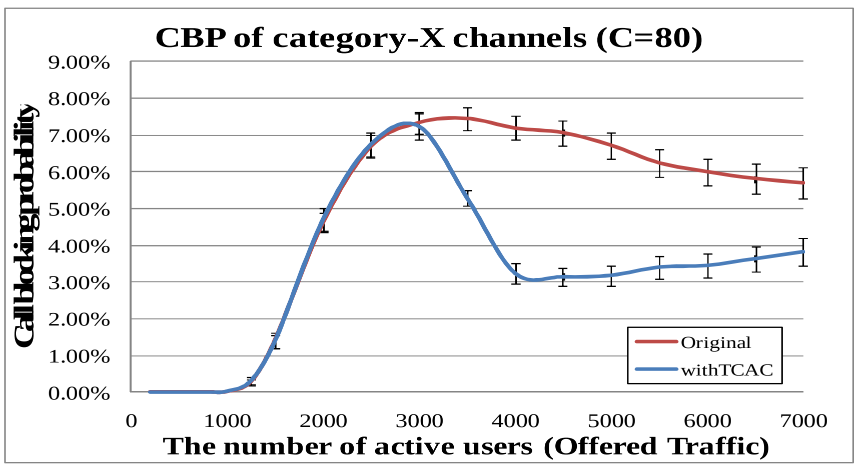
Assumptions

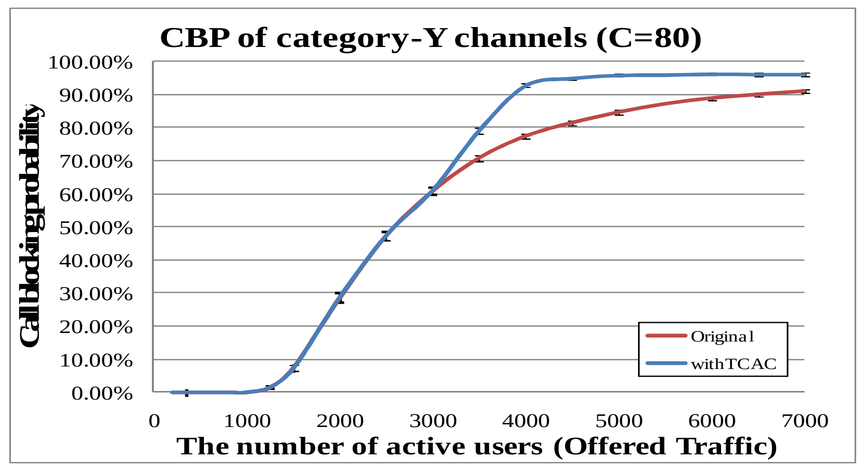
- N = 120 (channels provided)
- BW = 80 (bandwidth capacity of considered PB-link)
- Class-based distribution scheme for channel watching probabilities, cf. Example of channel classes presented earlier (with classes A, B, C and D):
  - A, B, C → Non-blocking,
  - D → High priority &
  - E → Low priority Category
- TCAC applied in 1-BW-scarce-periods.

Simulation Results









Outline

I. Prologue: Motivation and Overview on IPTV Systems

- IPTV System Structure
- Overview of Access Networks (e.g., DSL, WiMAX)

II. Research Challenges and Proposed Solutions

II.1 Comparison between Multicast and Unicast : Multicast Gain

II.2 Modeling the Behavior of IPTV Users

II.3 Reduction of TV Channel Blocking Probability

II.4 How to treat Heavily Zapping Users ?

III. Epilogue: Additional Research Challenges, Lessons Learned, Outlook

How to Treat Heavily Zapping Users ?

Let's "punish" heavy zappers !

Impact of (Heavy) Zappers on IPTV

Problem I: Zapping during high load situations

- Heavy zappers can „kill“ an IPTV system:
  - frequent leave/join operations (→ changes of multicast trees)
  - short-term usage of unpopular channels (→ bottlenecks)
- Sequential switching (during zapping) even much more “dangerous” than targeted switching
- Frequent zapping events could result in denial-of-service (DoS) attacks for IPTV systems

Problem II: Zapping during low load situations

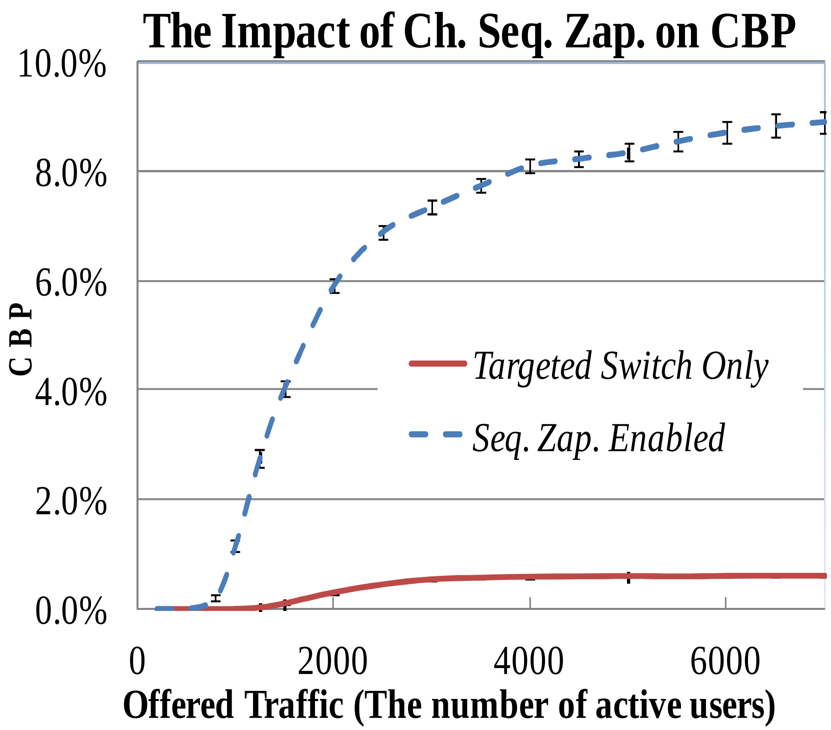
- ***On the other hand:*** It is desirable to reduce the zapping delay if an IPTV system is not in a high-load situation

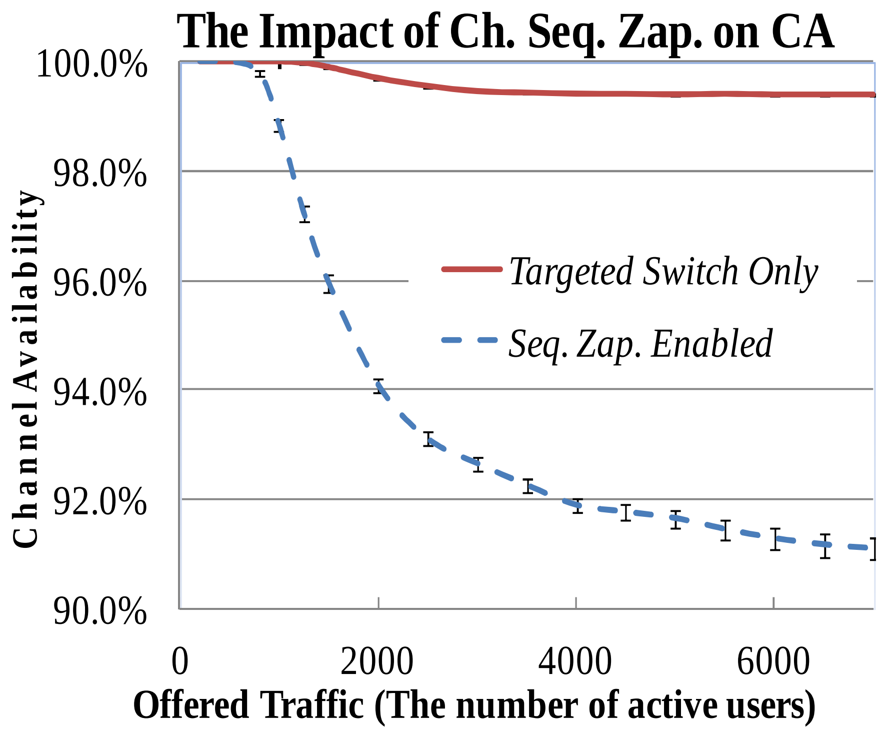
Solution I for Critical Treatment of Zappers

Intentional Switching Delay Method, cf. [Lai & Wolfinger → WWIC 2012, Int. J. of Commun. Netw. & Distr. Syst. 2014]

- **Goal**: Reduce the risk of bottlenecks as a consequence of heavy zapping during system overload situations
- Usage of layered encoding to transmit the TV channels in IPTV: *base* layer & *enhancement* layer
- Always transmit base layer for all channels
- Let zappers wait Δt [s] before serving new channel requests, i.e. offering of enhancement layer → trade-off between quality (QoE) and system availability (CBP)

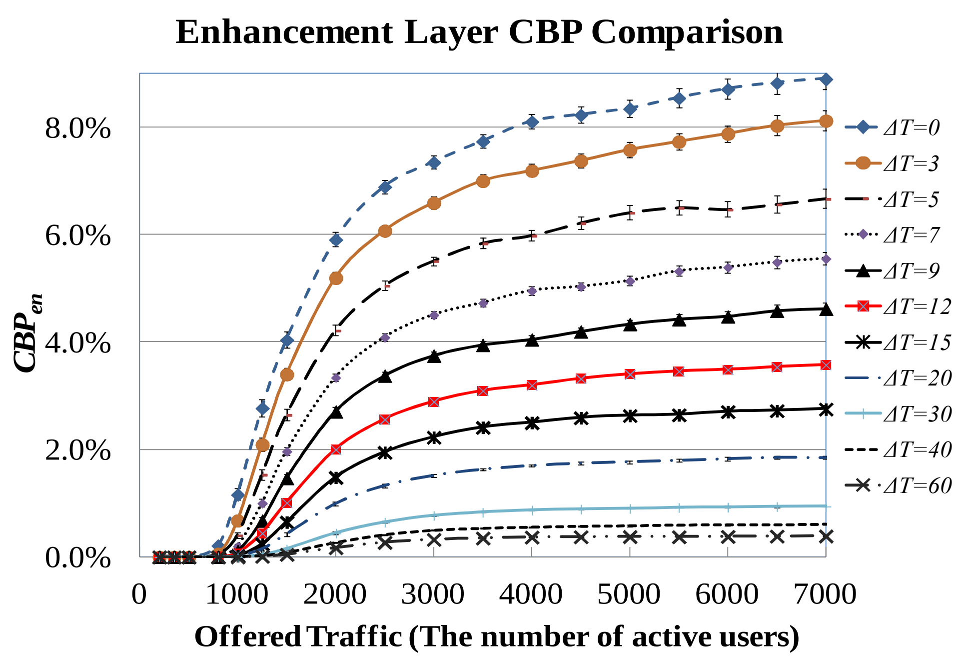
The Negative Impact of Sequential Zapping

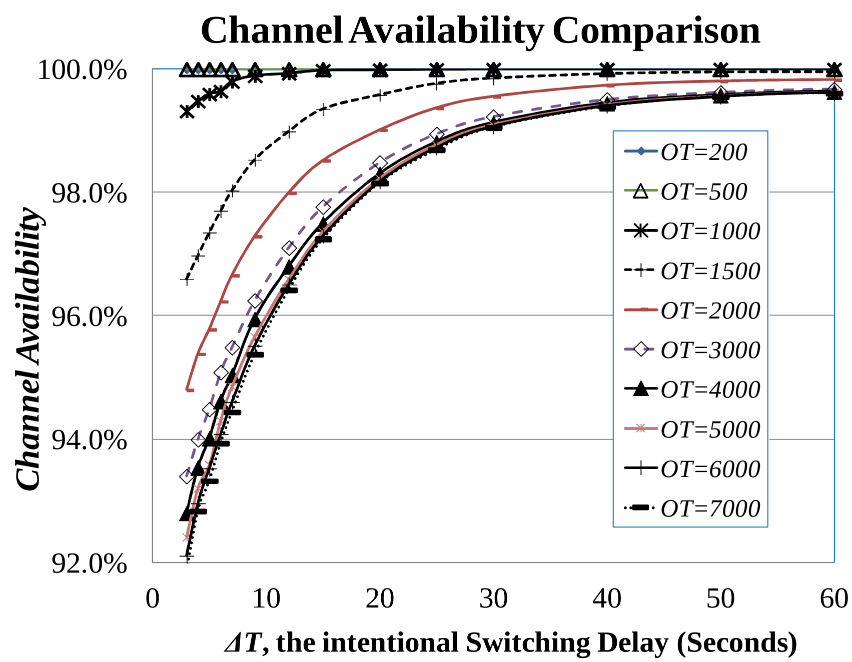




Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Influence of Different Intentional Delays on Channel Availability & CBP_{en} (CBP for enhancement layer)





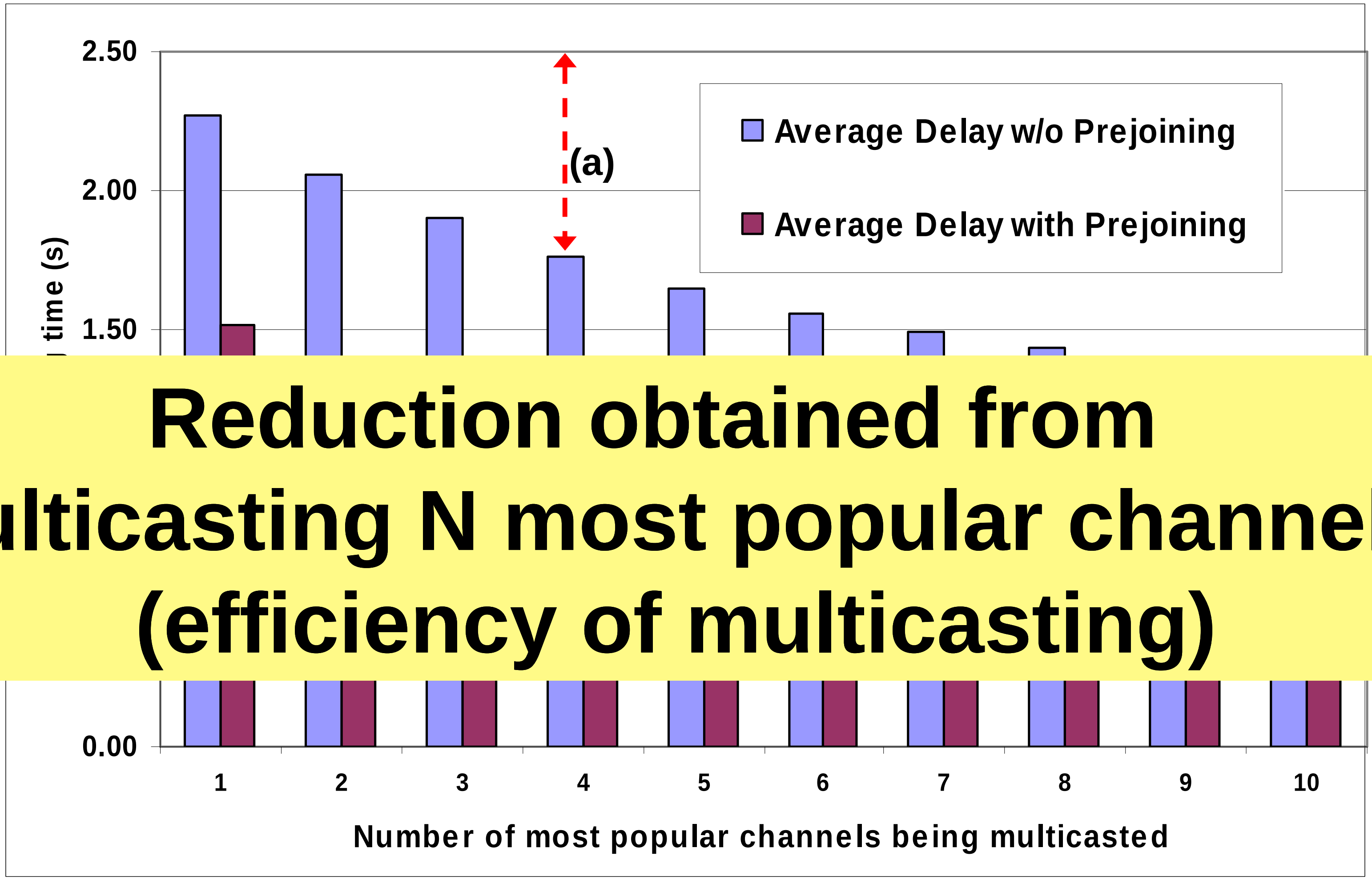
[***OT***: Offered Traffic]

Solution II for Favorable Treatment of Zappers

Prediction-based Prejoin Method, cf. [Abdollahpouri & Wolfinger → MMB & DFT 2012]

- **Assumption**: WiMAX based network with negligible CBP
- **Goal**: Reduce zapping delay in situations w/o system bottlenecks
- Usage of realistic TV user behavior model to predict the channels probably being required next & prejoining those (1 or 2) channels
  → significant reductions of zapping delay as opposed to methods w/o prejoin

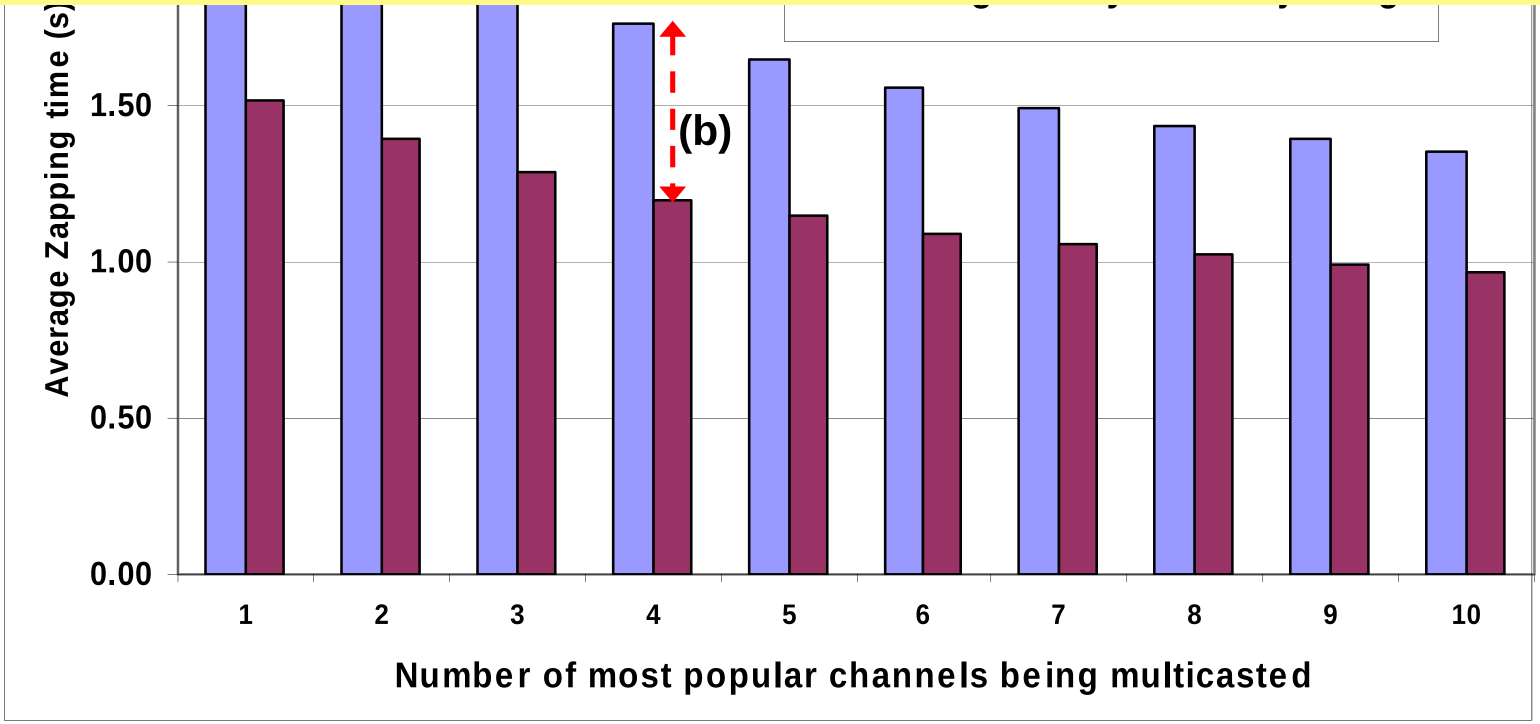
Factors Involved in Delay Reduction



Reduction obtained from multicasting N most popular channels (efficiency of multicasting)

Factors Involved in Delay Reduction

Reduction obtained from Prejoining mechanism (efficiency of prejoining)



Outline

I. Prologue: Motivation and Overview on IPTV Systems

- IPTV System Structure
- Overview of Access Networks (e.g., DSL, WiMAX)

II. Research Challenges and Proposed Solutions

II.1 Comparison between Multicast and Unicast : Multicast Gain

II.2 Modeling the Behavior of IPTV Users

II.3 Reduction of TV Channel Blocking Probability

II.4 How to treat Heavily Zapping Users ?

III. Epilogue: Additional Research Challenges, Lessons Learned, Outlook

Lessons Learned

- Unicast sometimes outperforms multicast
- CBP can be significantly reduced by clever TCAC scheme
- Heavy zappers can “kill” an IPTV system
- Analyses of peak hour scenarios are indispensable (stationary analyses often by far too optimistic !)
- Unlike traditional TV broadcast services, realistic user behavior models are indispensable in IPTV systems

Outlook

Our planned future work, e.g.,

- Measurement of (future) user behavior
  $\rightarrow$ behavior will certainly change (perhaps quite strongly)
- IPTV Service improvement thanks to scalable video coding
- Investigations for different types of access networks (e.g., in VANETs)
- Elaboration of mechanisms to reduce channel access / switching delays
- Studies for emerging new IPTV system architectures

Additional Future Research Challenges in IPTV

Trends to be expected:

- Strong changes in the way future IPTV services will be offered → e.g. more often non-real-time (TV on Demand), feed-back channel for viewers, …
  ⇒ user behavior will strongly change, too !
- Speed and throughput of future (IP based) networks will continue to strongly increase, BUT: networks also much more heavily loaded (e.g., by video traffic)
- "Anytime & anywhere access" will be demanded for IPTV services

Resulting research challenges, e.g.:

- ✓ New user behavior models required
- ✓ Analyses of bottlenecks and new mechanisms for their avoidance (in particular, within access networks)
- ✓ IPTV to be provided for highly different end-systems
- ✓ Security problems (e.g., sniffing of pay-TV channels)
- ✓ How to treat heavy zappers? (→ distr. denial of service attacks)


Questions ?


Questions ?

Cisco-Study "Global IP traffic forecast and methodology; Entering the Zettabyte Era";

White paper series (June 1, 2011); *cf.: www.cisco.com*

Global IP Traffic

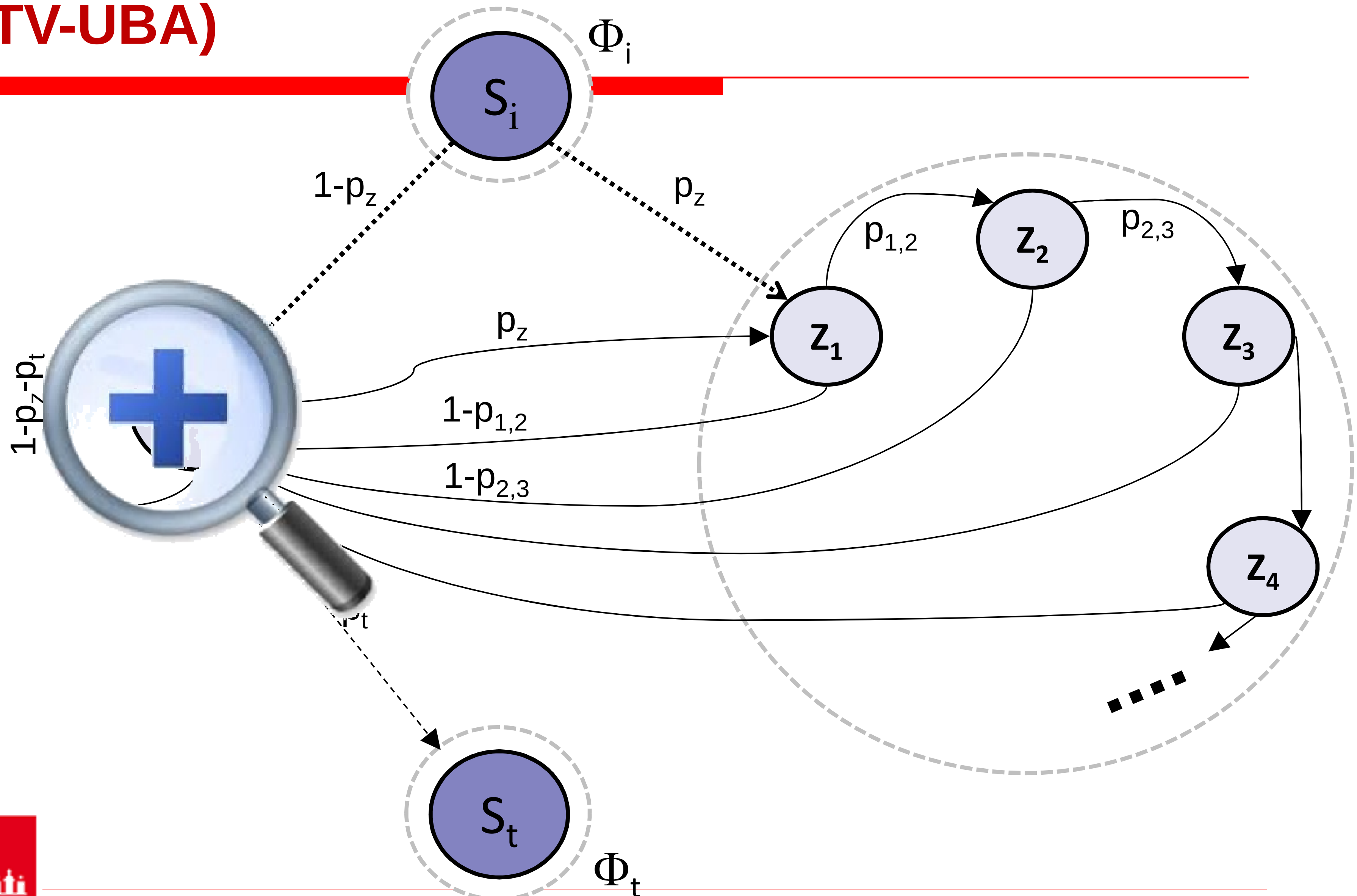
- ***By the end of 2015:*** **Annual global IP traffic will reach the zettabyte*) threshold** (966 exabytes or nearly 1 zettabyte).
- **Global IP traffic has increased eightfold *over the past 5 years*, it will increase fourfold *over the next 5 years***.
- ***In 2015:*** **gigabyte equivalent of all movies ever made will cross global IP networks every 5 minutes**.

Video Highlights

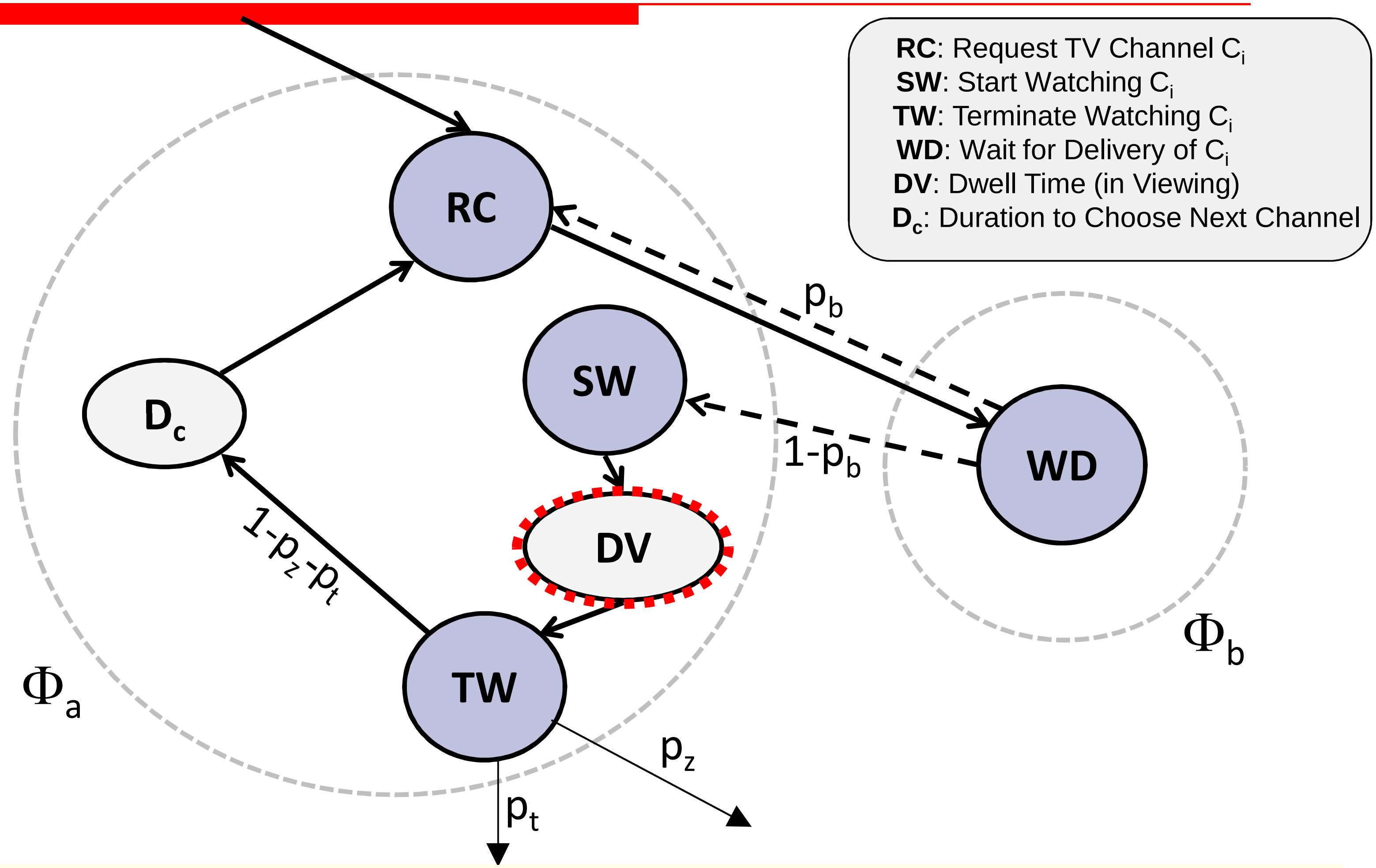
- ***In 2010:*** **Global Internet video traffic surpassed peer-to-peer (P2P) traffic.**
- **It would take over 5 years to watch the amount of video that will cross global IP networks every second *in 2015***.
- ***Now (6/2011):*** **Internet video is 40 percent of consumer Internet traffic, it will reach 62 percent *by the end of 2015*. The sum of all forms of video** (TV, VoD, Internet, and P2P) will continue to be **approximately 90 percent of global consumer traffic *by 2015***.
- ***By the end of 2011:*** **High-definition VoD will surpass standard definition.**

*) ***Zettabyte (for short: ZB) = 10^{21} Byte = 1,000,000,000,000,000,000,000 Byte = 1000^7 Byte***

Proposed Model: TV User Behavior Automaton (TV-UBA)

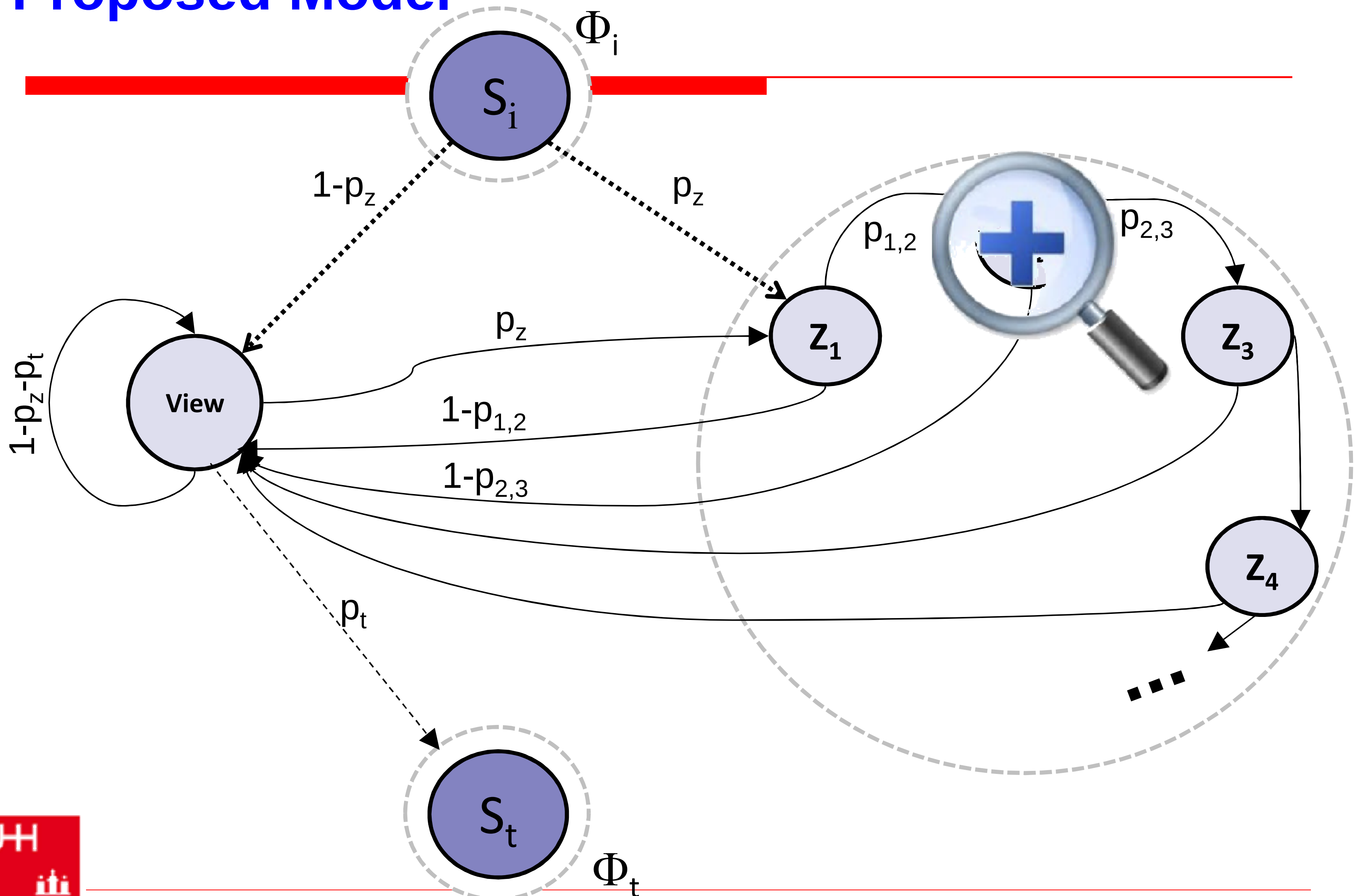


Viewing Mode

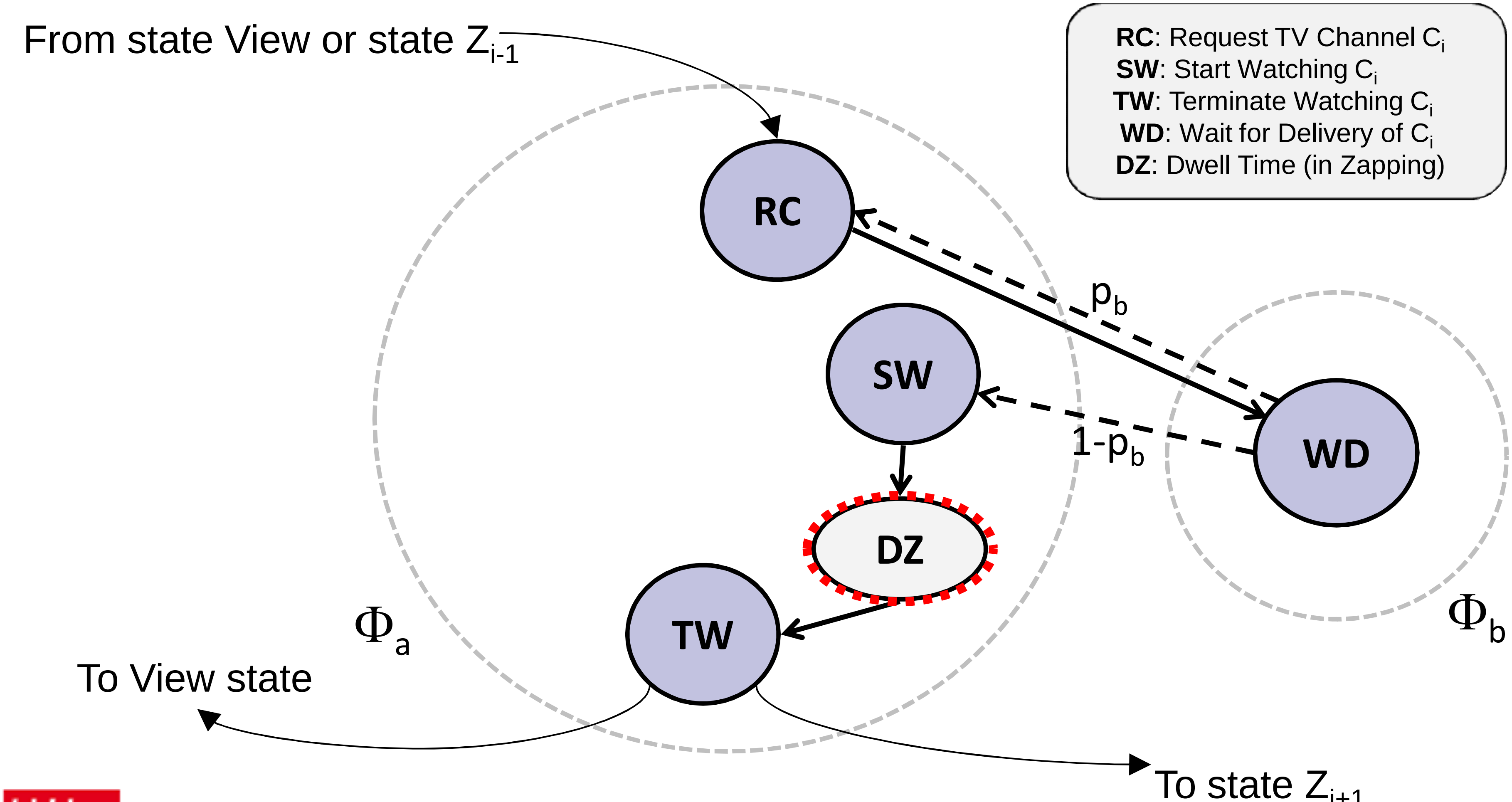


Viewing dwell time (DV): Gamma distribution (mean=10 min)

Proposed Model



Zapping State (Z_i)



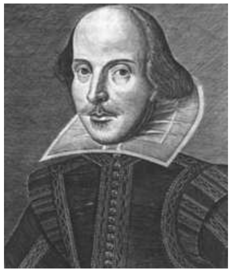
zapping dwell time (DZ): lognormal or Burr distribution (mean=10 sec)

Basic Principles Underlying our TCAC Scheme: *The Basic Idea*

The basic idea:

At instants when remaining resources (i.e., the unoccupied link bandwidth available) become scarce:

$\Rightarrow$ it could be a good idea to deny (block) the demand *D* for a channel *i* (of low priority category-Y, *and* currently not yet available on the link considered).



So:

To b(lock) or not to b(lock) that is the question !!!

Important for TCAC decision:

- *What do we lose if we block D ? (i.e. what is expected loss L ?)*
- *What do we win if we block D ? (i.e. what is expected gain G ?)*

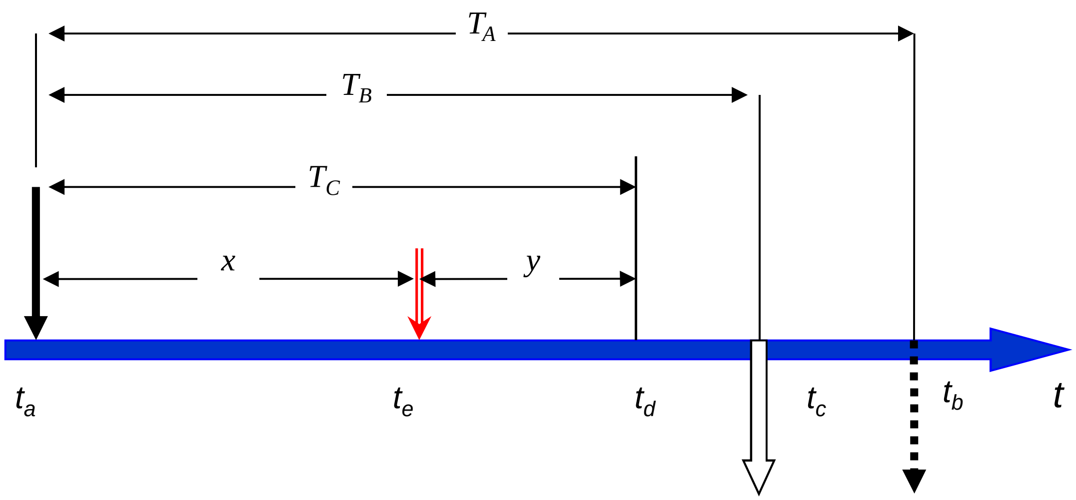
Our TCAC scheme:

Block (reject) a low prio channel request iff. $G^* \geq L^*$,

where G^* is a pessimistic estimate of the gain G to be expected and L^* is an upper bound for the loss to be expected.
Note: $G^* \geq L^*$ implies $G \geq L$ because of $G \geq G^* \geq L^* \geq L$.

TCAC Scheme : Scenario with 1 High and 1 Low Priority Class

Request Arrival & Departure Process



Arrival of a user request for a category-X channel j

Arrival of a user request for a category-Y channel i

Departure of the user which arrived at t_a (if user not blocked)

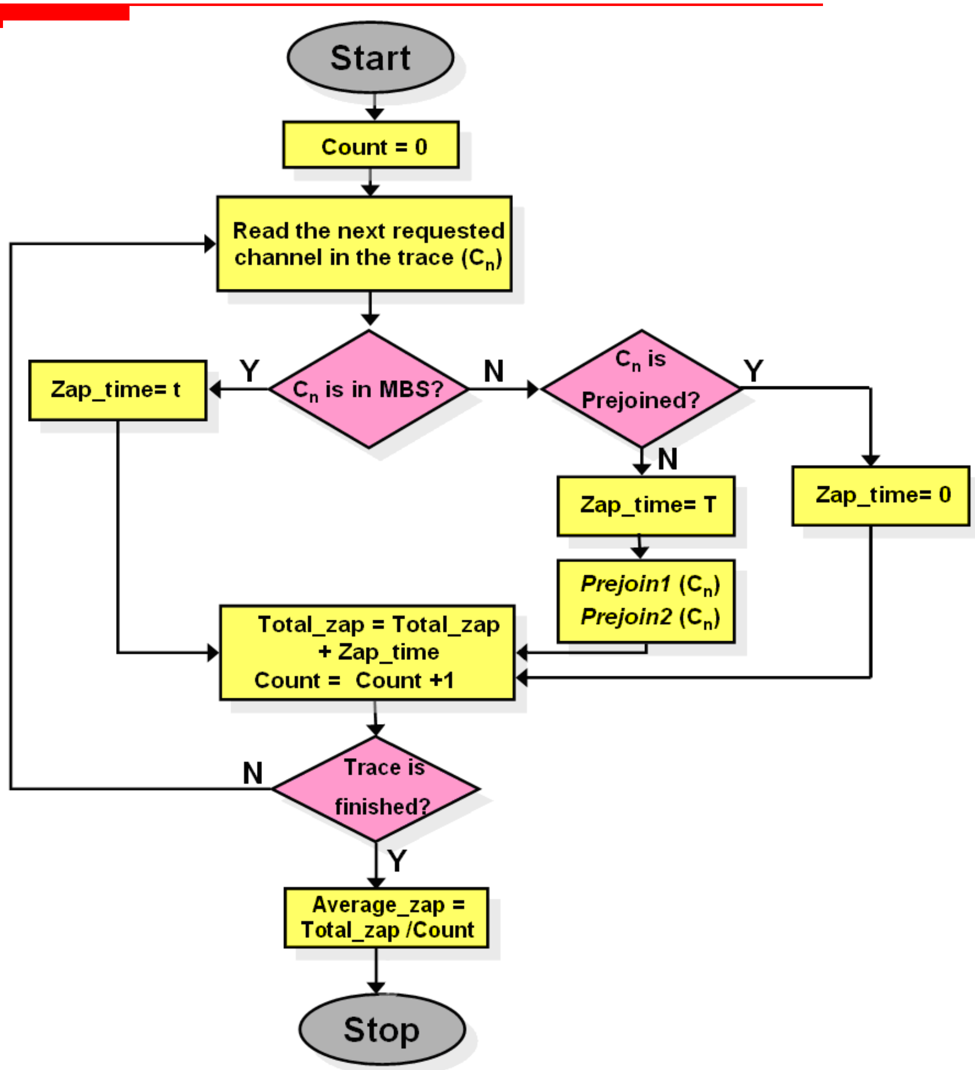
Departure of a user and release of a channel

Expected Gain in a 1-BW-Scarce-Period:

$$G = \frac{\lambda \cdot p_X \cdot N_X(t_a) \cdot (1/T + \lambda_r + \lambda \cdot p_X)}{(1/T + \lambda_r + \lambda \cdot p_X \cdot N_X(t_a)) \cdot (1/T + \lambda_r)}$$

Trace-driven simulation

- A prediction-based prejoin mechanism to join one or two TV channels → cf. *Prejoin1* (C_n) and *Prejoin2* (C_n) (which are likely to be selected next) based on the behavior of IPTV users
- The trace of user behavior is obtained from TV-UBA
- For the channels which are transmitted by means of multicast, switching delay (t [s]) is considerably lower than in case of unicast → switching delay (T [s])
- If the requested channel is correctly predicted and prejoined, the switching delay is virtually zero



Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG