“Dimensioning IPTV VoD Services”

- Thesis Defence -

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Introduction (1/2)

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- **IPTV?**
  - **IPTV is system capable of receiving and displaying video stream using IP**
  - **IPTV Service Classification**
    - **Live TV and video on demand (VoD)**
- **Possible contenders:**
  - **AT&T, Verizon, AOL, Apple, Google**
  - **KT (MegaTV), SKT (Broad&TV)**
- **Problem?**
  - **Network dimensioning and deployment of IPTV services with optimum cost and reasonable quality of experience**

Introduction (2/2)

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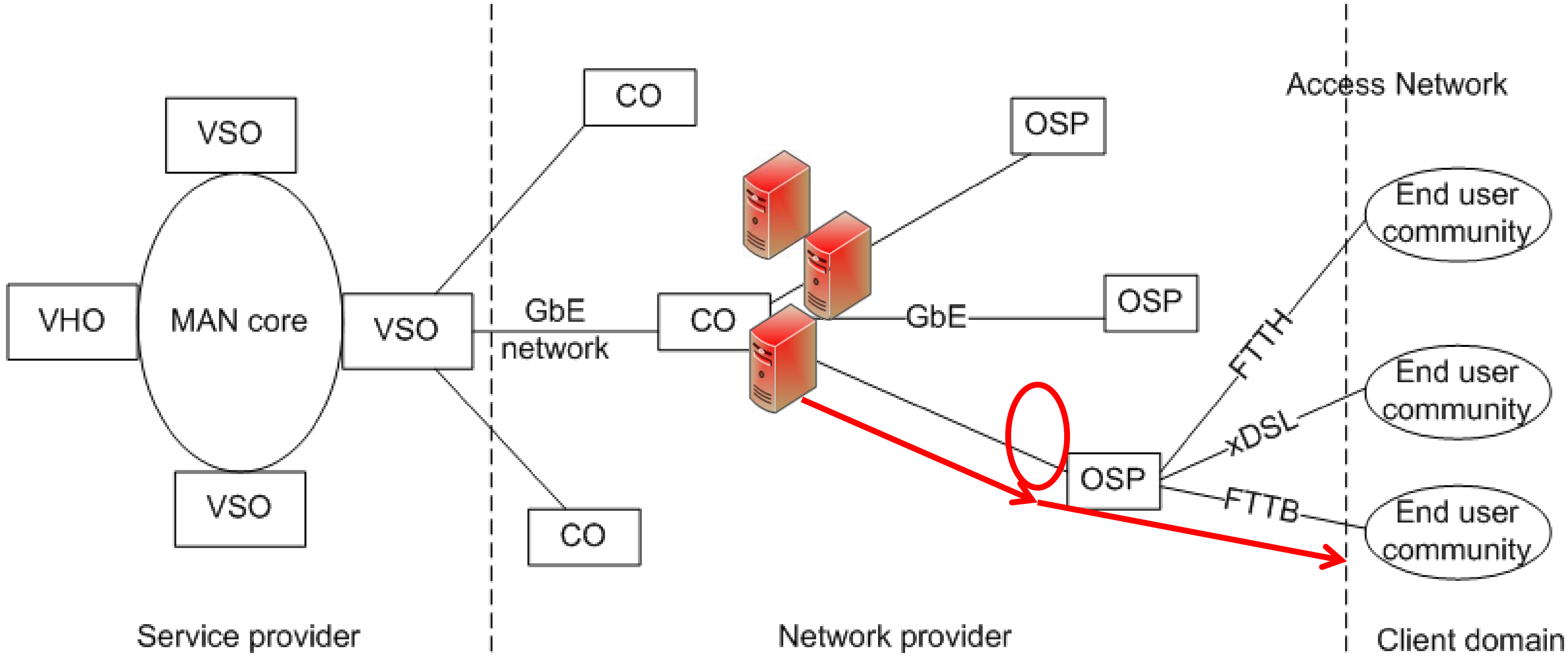

VHO – Video Headend Office
VSO – Video Source Office
CO – Central Office
OSP – Outside Plant

❖ Architecture

- **Server placement at each level of hierarchy**
- **Distance from server to community**
- **Access network bandwidth capacity**

Research Goal

- ❖ **Providing an analysis method for potential IPTV VoD service providers to determine the optimum deployment conditions, such as:**
  - **Optimum server placements (# of servers)**
  - **Access network bandwidth requirement**
  - **Tolerable distance from server to subscribers**
- ❖ **User QoE requirement analysis must be considered**
  - **As well as heterogeneous access networks among IPTV subscribers**

Related Work

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IPTV Service Categories	Unicast VoD	P2P VoD	Multicast VoD	Live TV	Deployment Analysis
Agrawal et al. 2007 [1]	√			√	√
Wauters et al. 2005 [2]	√			√	√
El-Sayed et al. 2006 [3]	√				√
Thouin et al. 2007 [4]	√			√	√
Simsarian et al. 2007 [8]	√				
Han et al. 2008 [16]	√			√	√
Chen et al. 2009 [6]		√			√
Naor et al. 2007 [18]			√		
Ganjam et al. 2005 [19]			√		

Deployment Features	Heterogeneous	Bandwidth Model	Delay Model	Decision	Output Measure
Agrawal et al. 2007 [1]	No	No	Zapping delay	For over provisioned network	QoE
Wauters et al. 2005 [2]	No – Ethernet WDM	No	No	No	Cost of traffic and content distribution
El-Sayed et al. 2006 [3]	No – EoF and EoS	Yes	No	No	Comparison of two AN
Thouin et al. 2007 [4]	No	No	No	No	Hit ratio
Han et al. 2008 [16]	No	No	No	No	Comparison of L1 technology
Chen et al. 2009 [6]	No	Yes – P2P	No	No	P2P traffic benefits

Proposed Method

Proposed Method - Outline

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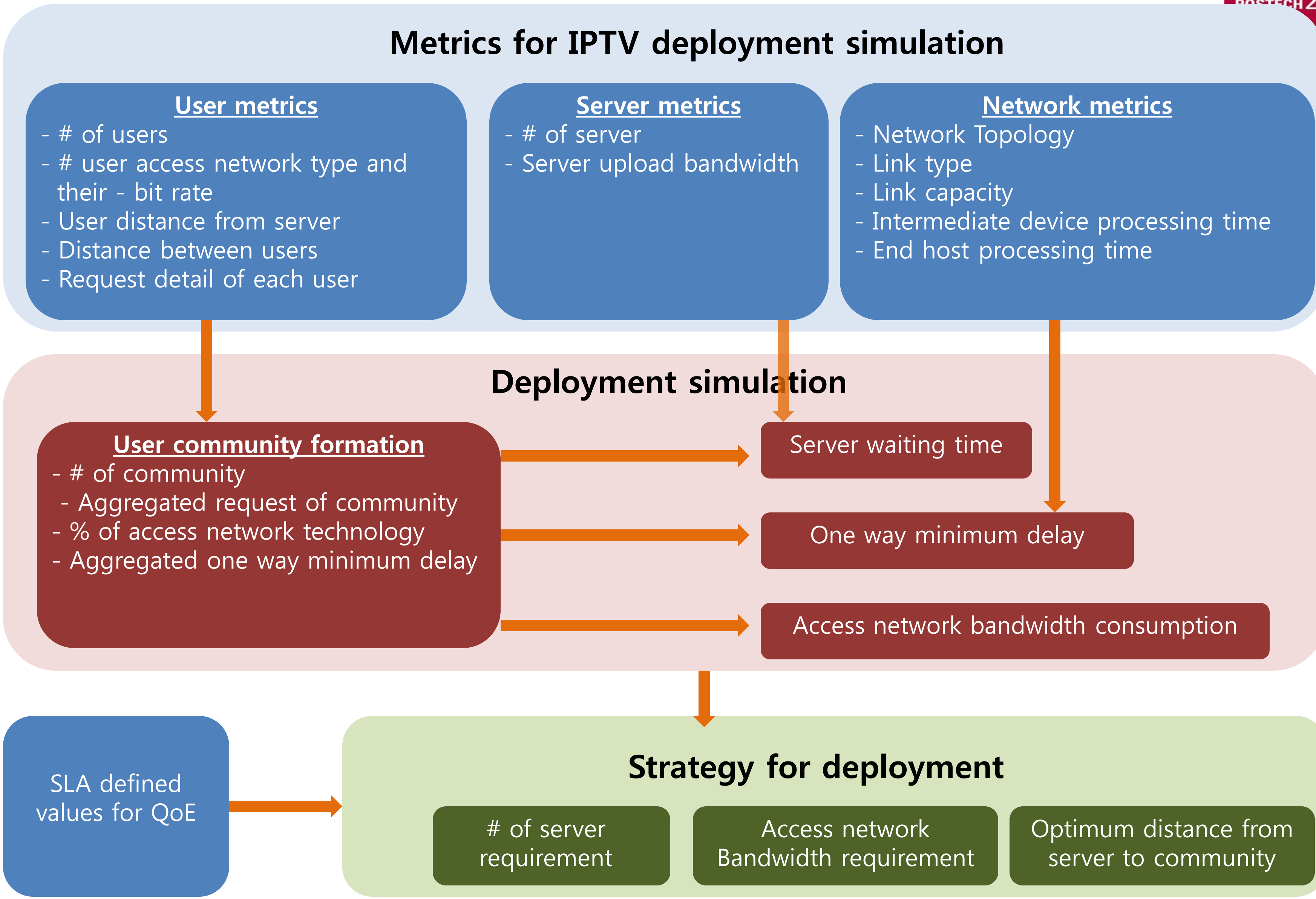
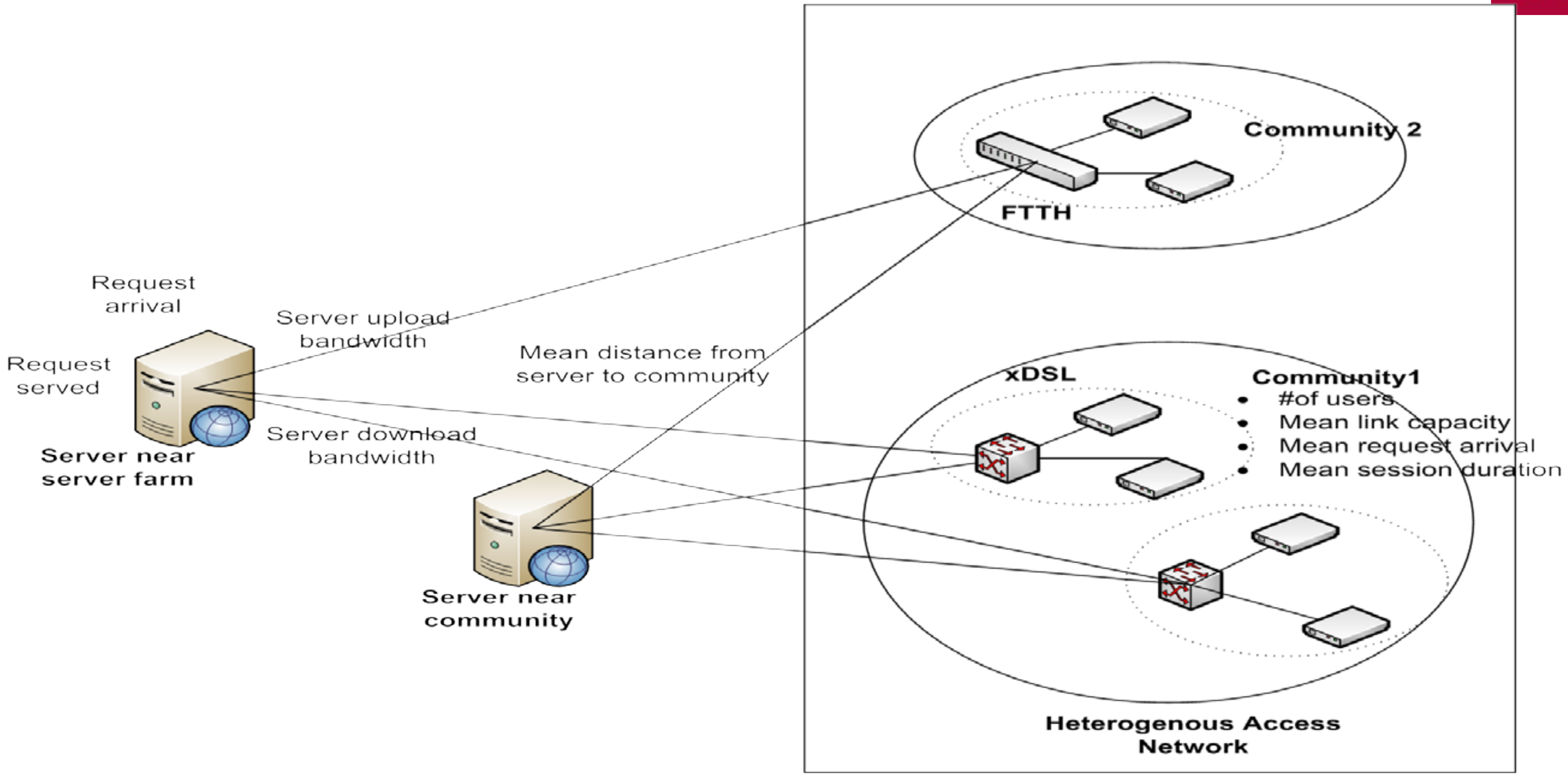
- Define community
- Determine important QoE measures
  - Model for server waiting time
  - Model for one way minimum delay
  - Model for bandwidth consumption
- Deployment decision based on the results produced by the proposed model
  - Simulation & Analysis

Proposed Method - Details



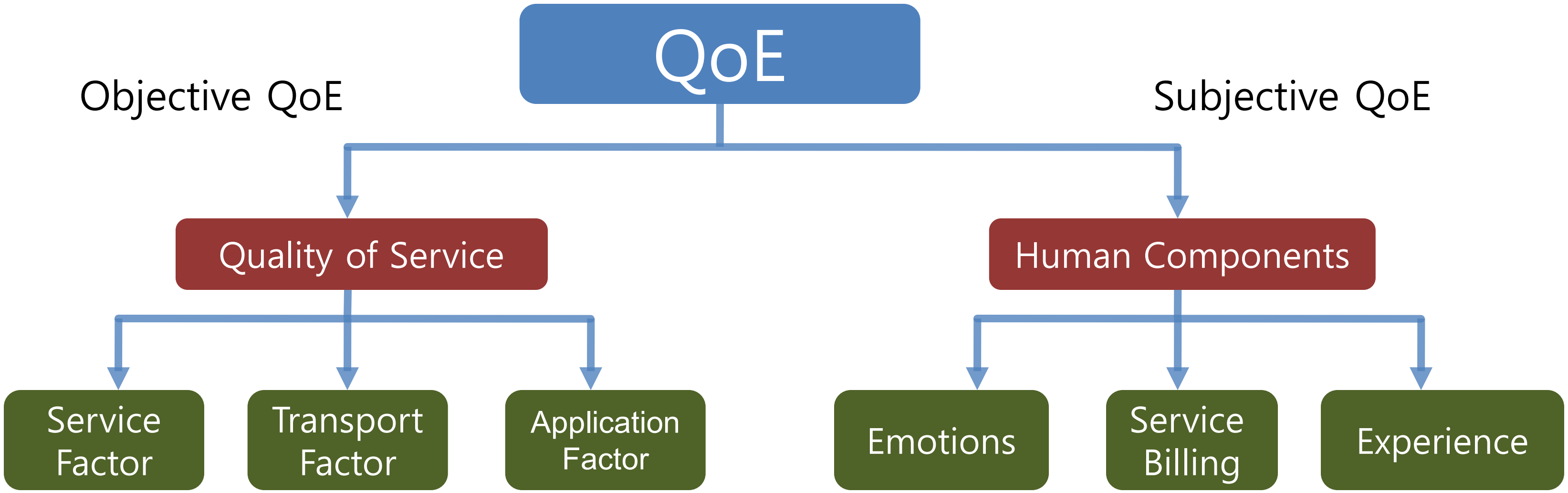
Community



- **Community creation**
  - Physical closeness among subscribers
  - Distance from the IPTV server to subscribers
  - Type of network access technologies
  - User behavior - viewing preferences and patterns

- **Clustering-based algorithm**

QoE Selection



❖ **Subjective QoE**

1. **Emotions**
2. **Linguistic background**
3. **Attitude**
4. **Motivation**

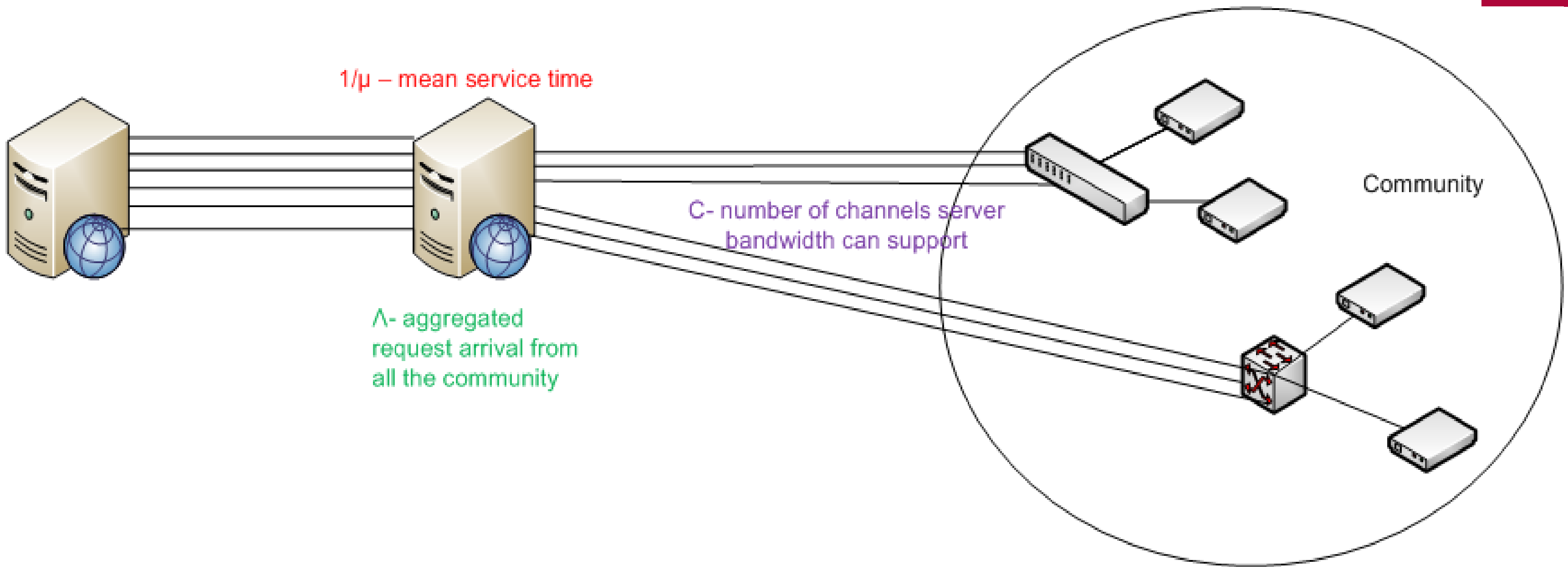
❖ **Objective QoE**

1. **PLR, delay**
2. **Measure of network performance**

❖ **Selected QoE measures**

1. **Server waiting time**
2. **Minimum one way delay**
3. **Bandwidth consumption**

Server Waiting Time Model (1/2)



- **This metric is an important component of overall delay**

- **Required models**
  - **Request arrival follows the Poisson distribution**
  - **Erlang C model**
    - **Requests that cannot be satisfied immediately are delayed until a server is available**

Server Waiting Time Model (2/2)

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Symbol	Description
λ	Mean request arrival from all communities (Poisson distribution)
μ^{-1}	Mean service time from all communities (exponential distribution)
c	Number of parallel identical servers

Output Metrics	Equations
Occupation rate	$\rho = \frac{\lambda}{c\mu} < 1$
Delay probability (Erlang C)	$D_w = \frac{(c\rho)^c}{c!}((1-\rho)\sum_{n=1}^{c-1}\frac{(c\rho)^n}{n!} + \frac{(c\rho)^c}{c!})^{-1}$
Waiting time (Little equation)	$E_w = D_w * \frac{1}{1-\rho} * \frac{1}{c\mu}$

One Way Minimum Delay Model (1/2)

- Behavior of underlying network infrastructure
- One way
  - For VoD only download time is required
- Minimum delay
  - Low traffic hours, avoid congestion
- Heterogeneous network is concern
- Modeling in two ways
  - Relying on RTT
  - Network properties

One Way Minimum Delay Model (2/2)

Symbol	Description
N	Number of hops (intermediate device) to reach each server
D_h	Mean processing delay of each hop
D_e	Processing delay at end host
l	Types of links in the path
d_n	Physical length of link of type n
v_n	Propagation velocity of the link type n
RTT(s,i)	RTT measured by sender for packet i
RTT(r,i)	RTT measured by receiver of packet i

Output Metrics	Equations
Propagation delay	$D_p = \sum_{n=1}^{l} \frac{d_n}{v_n}$
One way minimum delay (first way)	$D = \sum_{n=1}^{l} \frac{d_n}{v_n} + N * D_h + D_e$
One way minimum delay (second way)	$RTT_{\min(n)} = RTT_{\min(d)} - \sum_{i=1}^{n} [RTT(s,i) - RTT(r,i)]$

Bandwidth Consumption Model

Symbol	Descriptions
λ_a	Request arrival in AN
μ_a	Request leaving in AN
br_l	Bit rate between VOD server and viewer via link l. the link can be any heterogeneous network such as xDSL, Cable, FTTH, FTTB
p_l	% of generated traffic from different type of access link network l, such as xDSL, Cable, FTTH, FTTB
k	Number of AN type
B	Total outgoing bandwidth from AN to server

Output Metrics	Equations
Bandwidth demand	$T(t) = \lambda_a(\sum_{l=1}^{k} br_l * p_l) - \mu_a(\sum_{l=1}^{k} br_l * p_l)$
Bandwidth consumption	$B_{consump(t)} = \lambda_a(\sum_{l=1}^{k} br_l * p_l) - \mu_a(\sum_{l=1}^{k} br_l * p_l) / B$

Simulation

Simulation Scenario - Assumptions

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- Probability of having content on server is 1
- Request arrival – Poisson
- Request served – Exponential
- Video format – HDTV (10 Mbps)
- Each CO will have multiple VoD servers
- Half of the network resource are reserved for other services

Assumptions for server waiting time	
Mean request arrival time (l)	3600 to 10800 users/hour (total request)
Mean session duration (m)	20 min
Simultaneous requests per server (c)	50 to 500 (1 to 10 GbE)
Assumptions for one way minimum delay	
Intermediate device processing time (D_h)	224 ms
End host processing time (D_e)	155 ms
Type of links (d_n) and propagation delay (v_n)	coaxial(0.195 km/μs), fiber(0.198 km/μs)
Assumptions for access network bandwidth consumption	
Penetration of xDSL, FTTH, Cable type in AN (p_l)	xDSL(60%), FTTH(20%), Cable(20%)
Bit rate of xDSL, FTTH, Cable type in AN (b_{rl})	xDSL(6), FTTH(11), Cable(7)
Total available bandwidth of AN (B)	100 Mbps to 1 Gbps

Server Waiting Time Analysis (1/3)

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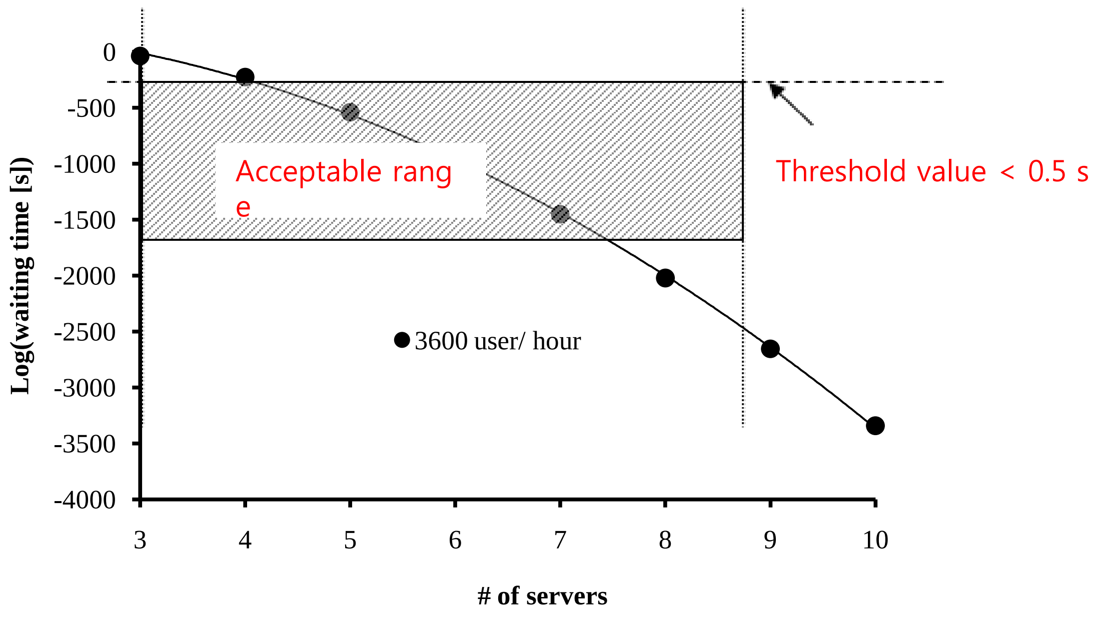

Decrease in log of server waiting time with increase in number of servers.

Server Waiting Time Analysis (2/3)

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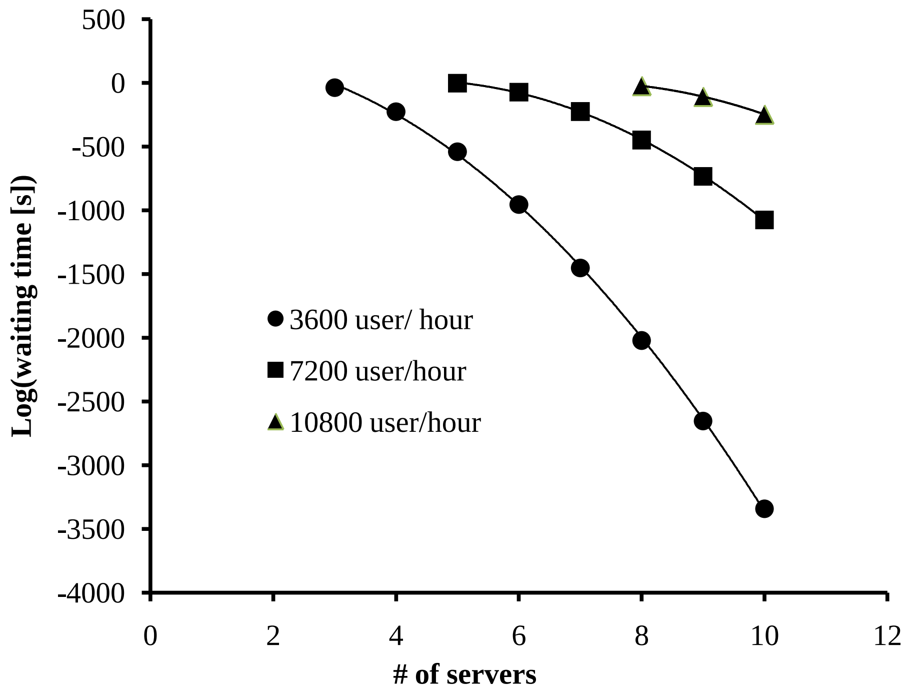
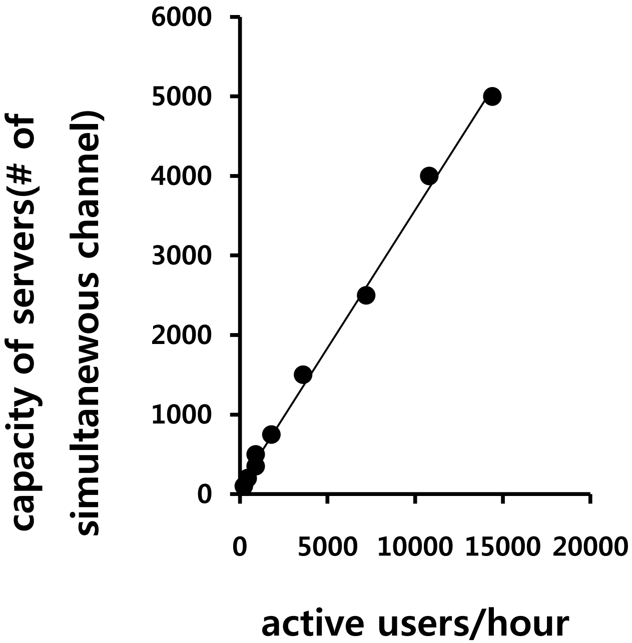


Decrease in log of server waiting time with increase in number of servers for different number of users per hour.

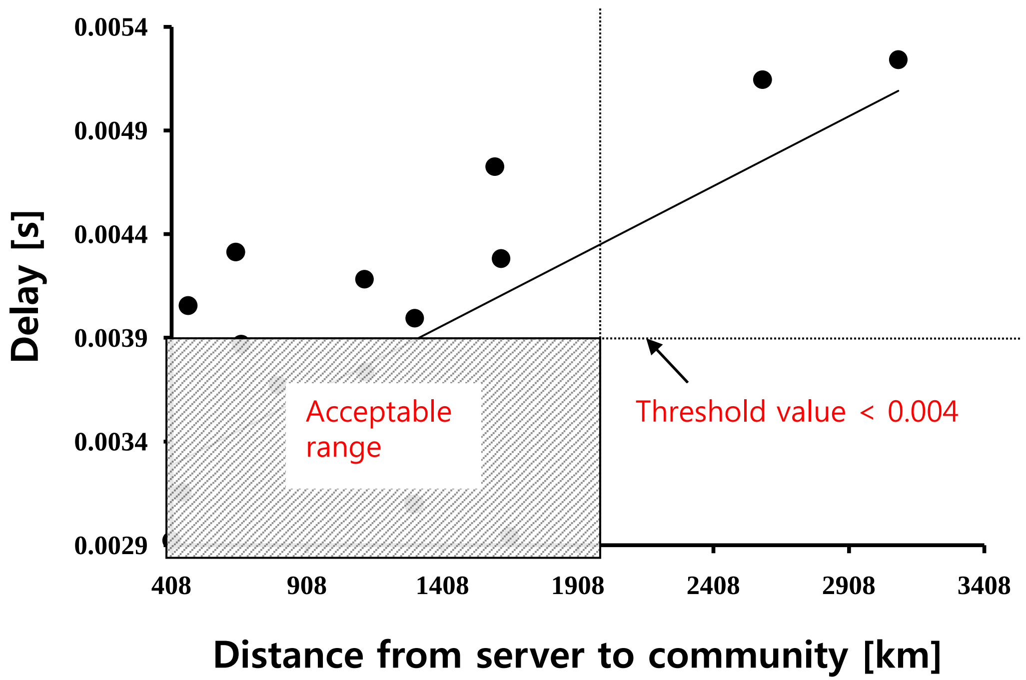
Server Waiting Time Analysis (3/3)



Active users/hour	# of servers	Server capacity	Waiting time (s)	Total server capacity
225	2	50(1 GbE)	1.77×10^{-1}	100
450	4	50(1 GbE)	1.44×10^{-3}	200
900	7	50(1 GbE)	6.88×10^{-2}	350
900	2	250(5 GbE)	2.30×10^{-25}	500
1800	3	250(5 GbE)	1.69×10^{-8}	750
3600	3	500(10 GbE)	1.73×10^{-16}	1500
7200	5	500(10 GbE)	3.05×10^{-1}	2500
10800	8	500(10 GbE)	9.22×10^{-11}	4000
14400	10	500(10 GbE)	1.39×10^{-2}	5000

Linear increase in server capacity with increase in number of users per hour

One Way Minimum Delay Analysis(1/2)

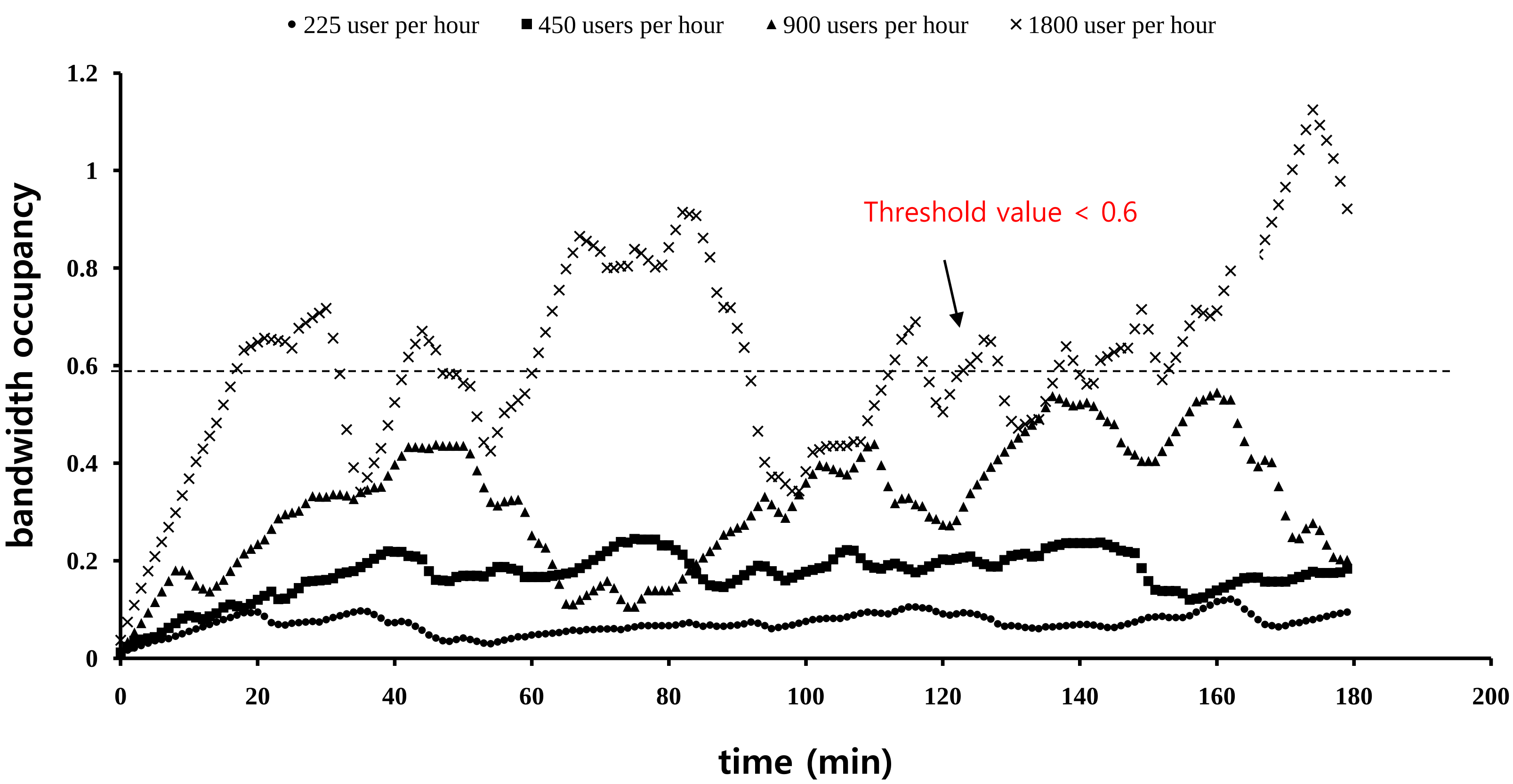


Liner increase in delay with increase in distance from server to community

One Way Minimum Delay Analysis(2/2)

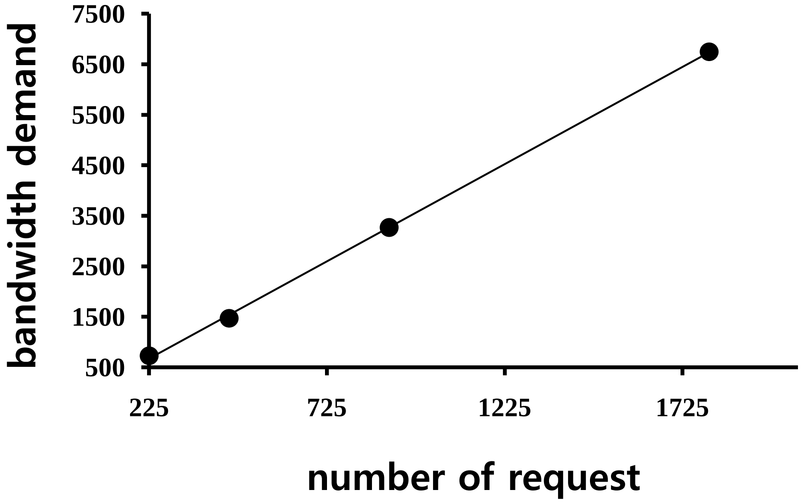
Serial	# of hops	Distance	Ratio of fiber and coaxial cable	Delay (s)
1	12	408	0.6,0.4	0.002923
2	12	408	0.6,0.4	0.002923
3	13	444	0.6,0.4	0.003154
4	13	448	0.5,0.5	0.003155
5	17	469	0.3,0.7	0.004055
6	18	645	0.5,0.5	0.004314
7	16	665	0.6,0.4	0.003869
8	15	800	0.3,0.7	0.003673
9	14	985	0.5,0.5	0.003485
10	17	1120	0.5,0.5	0.004183
11	15	1122	0.6,0.4	0.003735
12	12	1301	0.6,0.4	0.003098
13	16	1305	0.6,0.4	0.003995
14	12	1305	0.5,0.5	0.003099
15	19	1601	0.6,0.4	0.004725
16	17	1624	0.5,0.5	0.004282
17	11	1656	0.5,0.5	0.002944
18	20	2589	0.3,0.7	0.005145
19	20	3090	0.6,0.4	0.005241

Bandwidth Analysis (1/2)



xDSL, FTTH and Cable penetration – 40%, 20%, 20%

Bandwidth Analysis(2/2)



Linear increase in bandwidth demand with increase in users in AN

# of requests per hour	Bandwidth occupancy for 100 Mbps link	Bandwidth demand per hour
225	0.1212	727.2
450	0.2448	1468.8
900	0.5448	3268.8
1800	1.1244	6746.4

Deployment Decision

Metrics provided by network and service providers	QoE measures on mutual agreement of customers and service provider	Deployment decisions made by service providers
• Users – 36,000 • Active users/hour – 10 % • Three AN types (% community in AN) xDSL-60% FTTH-20% Cable-20%	Server waiting time < 0.5 s	Server requirement – 3 servers each capable of handling 500 simultaneous request
	One way delay < 0.004 s	Distance of community from server – 400 to 2000 km with 12 to 15 intermediate device
	Access network bandwidth consumption < 0.6	Access network bandwidth requirement – 100 Mbps or more bandwidth

Summary & Contributions

❖ Summary

- Models considering heterogeneous network technologies
- Important objective QoE selections
- Optimum deployment decision given with respect to the scenario

❖ Contributions

- Survey and categorization of IPTV services
- Models for simulating QoE measures
- Analysis for network deployment decision

Future Work

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- Advanced models for complex VoD services
  - Integration of multiplexing and content popularity models
- Develop models for other IPTV services
  - P2P-assisted VoD
  - Multicast VoD
  - Live TV (unicast live/multicast live/P2P-assisted live)
- Comparison and tradeoff analysis
  - Combinations of IPTV services and delivery mechanisms
  - A guideline to determine the optimum strategy for given scenario


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