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THINKING OF THE WORLD

Scalable Video Streaming over WiMAX Networks

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18th IEEE International Workshop on Quality of Service
June 18, 2010 • Beijing, China

Rise of Mobile Multimedia

- Mobile Video Multicast/Broadcast
  - Mobile TV users to increase by 55% by 2015 [VisionGain10]
- Competing Technologies
  - DVB-H/FLO ⇒ No return channel
  - LTE MBMS ⇒ Low Bandwidth
- WiMAX Advantage:
  - High Bandwidth + Return Channel
  - 50 million WiMAX users by 2014 [Juni09]

Better Video Quality ⇒ Higher Revenue

Figure: Yota TV

Outline

- Overview of WiMAX and SVC
- Problem description
- Solution Approach
  - Approximation Algorithm SSA
- Evaluation
  - Trace based simulation
- Conclusion and Future Work

WiMAX Frame Structure

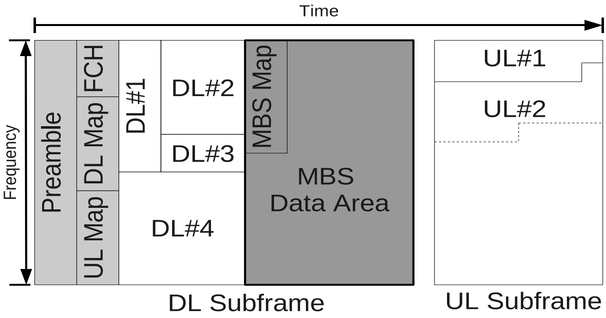

Figure: Example of MBS area in downlink frame

H.264 Scalable Video Coding [Schwarz07]

- Temporal, spatial and *quality* scalability
- In network stream adaptation
- Embedded stream metadata information

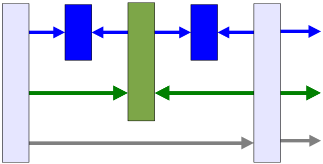

Figure: Scalable Video Frames

Layer	Data Rate (kbps)	Quality (dB)
EL2	589	36.00
EL1	407	34.86
BL	170	32.90

Table: FOREMAN Sequence

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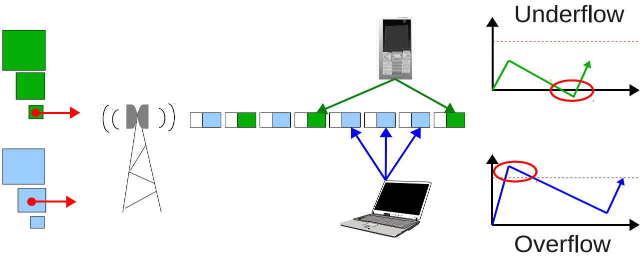
Optimal Substream Selection Problem

Substream : A layer and and all its dependency layers



Objective : Maximize video quality

Challenge 1 : Limited channel bandwidth

Challenge 2 : Limited receiver buffer size

Hardness

Theorem: Optimal substream selection subject to channel capacity constraints and receiver buffer constraints is NP-Complete.

Reduce from the 0/1 Multiple Choice Knapsack Problem

Channel bandwidth	$\Leftrightarrow$	Knapsack size
Streams	$\Leftrightarrow$	Item classes
Substreams	$\Leftrightarrow$	Items
Substream data rate	$\Leftrightarrow$	Item weight
Substream quality	$\Leftrightarrow$	Item profit

$\Rightarrow$ We can NOT optimally solve it in Real Time.

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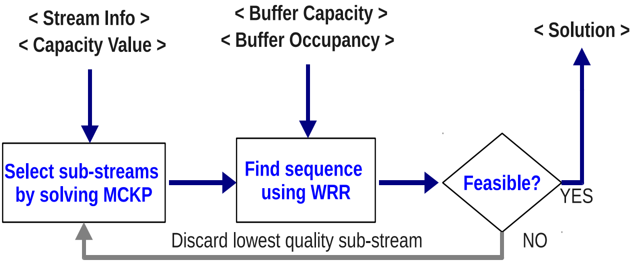
Substream Selection Algorithm (SSA)

- Separate the problem into a *selection* problem and a *scheduling* problem
- Selection problem ⇒ **dynamic programming**
- Scheduling problem ⇒ **weighted round robin**



Approximate Solution using Dynamic Programming

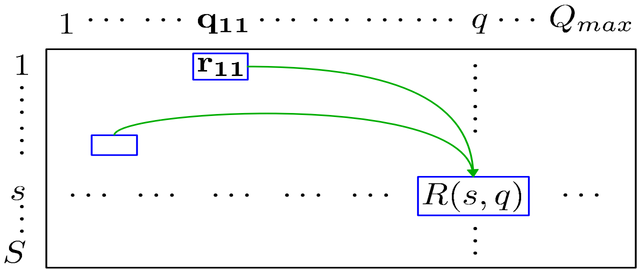


Figure: Simple Dynamic Programming [Martello90]

Drawback : Q_{max} may not be polynomial in S!

Our approach :Scale each quality value to a smaller number

How to find the scaling factor ?

Scaling Factor

- Fact 1 : LP Relaxation gives an upper bound on optimum.
- Fact 2 : In LP solution only two variables are fractional and they belong to same stream [Sinha79].

- Let Q_0 = LP solution after discarding the fractions

  Theorem : $Q_0 \leq Q^* \leq Q_{LP} \leq 2Q_0$
  Proof outline: Follows from Fact 1 and Fact 2.

- Scaling Factor $K = \frac{\epsilon Q_0}{S}$, ϵ=Error parameter
  Scale down quality (i.e. $q \leftarrow \frac{q}{K}$) $\Rightarrow$ Reduce columns to $O(\frac{SL}{\epsilon})$

Weighted Round Robin

- Once the sub-streams are selected, we perform a weighted round robin allocation.
- Weight of the stream is based on the buffer exhaustion time.

- Sorting the streams to arrange them according to buffer exhaustion takes $O(S \log S)$ time.
- Total time complexity of the algorithm: $O\left(\frac{S^2 L}{\epsilon} + PS \log S\right)$

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Evaluation: Number of Streams

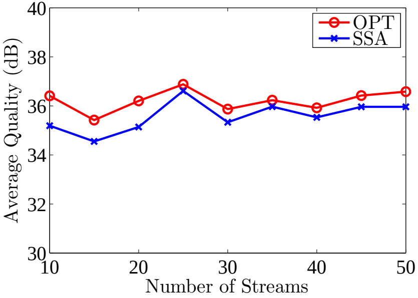


Figure: Average video quality

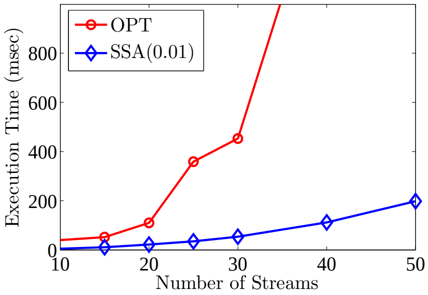


Figure: Execution time efficiency

Evaluation: Scheduling Window Size

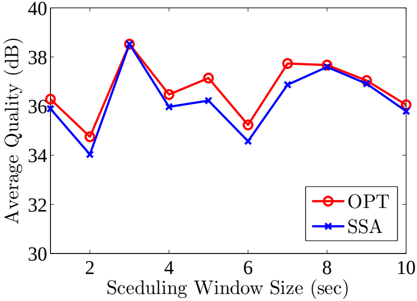


Figure: Average video quality

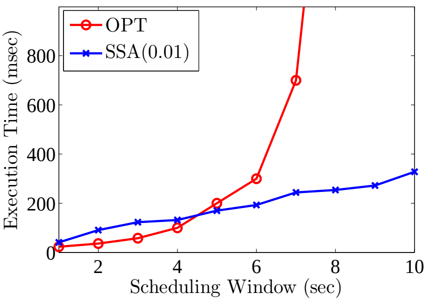


Figure: Execution time efficiency

Evaluation

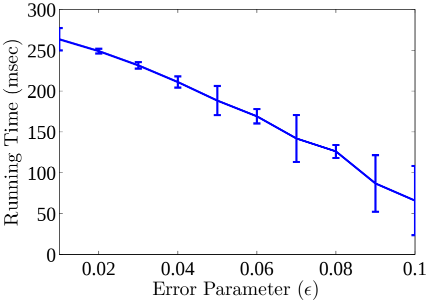


Figure: Approximation Factor

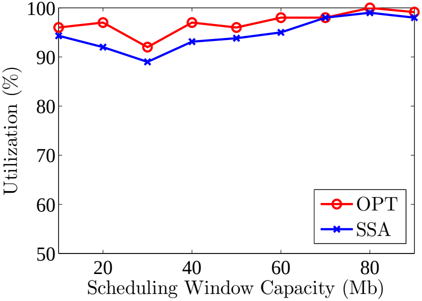


Figure: Capacity utilization

Conclusion

- Broadcasting high quality scalable video streams over WiMAX networks
- A near optimal algorithm for the NP-Complete Optimal Substream Selection problem
- Approximation factor close to 1 for typical network parameters
- **Future Work:**
  - Energy Efficient scheduling
  - Multilayer Multicast

References

[VisionGain10]

http://www.visiongain.com/Report/478/Mobile-TV-Market

[Juni09] http://juniperresearch.com/reports/WiMAX_broadband

[Martello90] S. Martello, and P. Toth, Knapsack Problems: Algorithms and Computer Implementation , pp 77-80, John Wiley and Sons, 1990.

[Schwarz07] H. Schwarz, D. Marpe and T. Wiegand , Overview of the Scalable Video Coding Extension of the H.264/AVC Standard, IEEE Transactions on Circuits and Systems for Video Technology, pp 1103-1120, September 2007.

[Sinha79] A. Sinha and A. Zoltners, The multiple-choice knapsack problem,Operations Research, vol. 27, pp. 503-515, 1979

Thank you

Questions ?

Extra Slides: Table Construction

Table Construction Mechanism:

- $R(*, 0) = 0$, $R(s, q) = \infty$, for all $s \in S, q \geq 1$
- $R(1, q) = \begin{cases} \min_{l}\{r_{sl}\}, & \text{where } l \in L \text{ such that } q_{sl} = q \\ \infty, & \text{otherwise} \end{cases}$
- $R(s, q) =$
$$\begin{cases} \min \left[R(s-1, q), \min_{l \in L_s}\{r_{sl} + R(s-1, q - q_{sl})\} \right], & \text{when } q_{sl} \leq q \\ R(s-1, q), & \text{otherwise} \end{cases}$$

Extra Slides: An Illustrative Example

	r1	q1	r2	q2
S1	187	3398	380	3615
S2	548	3715	824	3845
S3	466	3294	848	3468

$$R(1,q) = \begin{cases} \min_{l}\{r_{sl}\}, & \text{where } l \in L_1 \text{ such that } q_{sl} = q \\ \infty, & \text{otherwise} \end{cases}$$

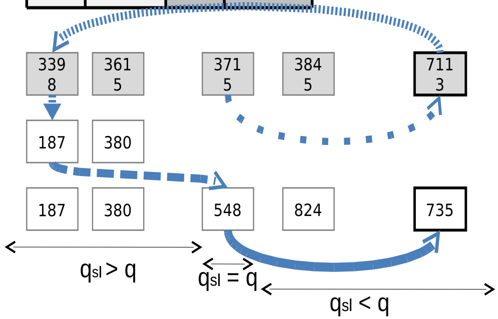
C = 1500

q =	**0**	**- - -**	**3398**	**- - -**	**3615**	**- - -**	**1092 8**
s1	0		187		380		
s2	0						
s3	0						

Extra Slides: DP Example(contd.)

	r=1	q=1	r=2	q=2
1	187	3398	380	3615
2	548	3715	824	3845
3	466	3294	848	3468

$$R(s,q) = \begin{cases} \min\{R(s-1,q), \min\limits_{l \in L_s}\{r_{sl} \\ \quad + R(s-1, q-q_{sl})\}\}, & \text{when } q_{sl} \leq q \\ R(s-1,q), & \text{otherwise} \end{cases}$$



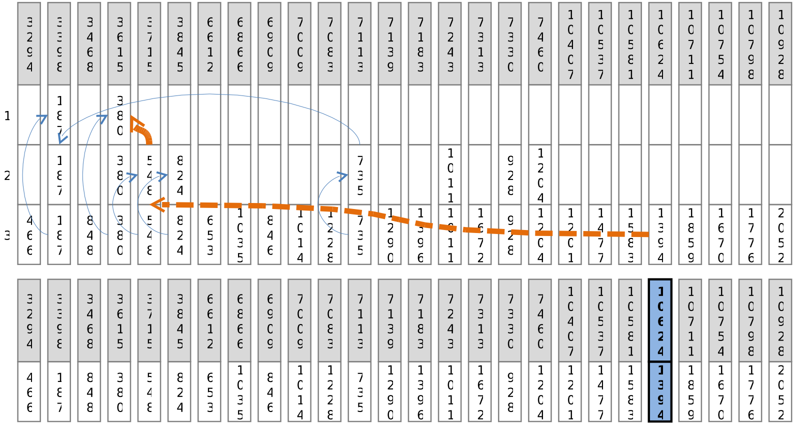
$q = 7113 \quad q_{sl} = 3715$

$q - q_{sl} = 3398$

R(1,3398) = 187

min {rsl+R} = 548+187=735

Extra Slides: DP Example(end)



Optimal Value = 106.24/3 =35.41 dB   Solution Vector = (1,1,2)