Utility-based Resource Mangement in Future Mobile Communications Considering QoE

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Utility-based resource allocation

- Resource Allocation (RA): the amount of resources allocated to different users
  - Make the best use of limited resources under time varying channel conditions
  - Fairness, latency reduction, spectral efficiency and system utilization

- Utility-based Resource Allocation
  - Utility reflects actual users‘ perceived performance (QoE)
  - Optimization problem: Maximize the aggregated utility, subject to limited resources

QoE examples

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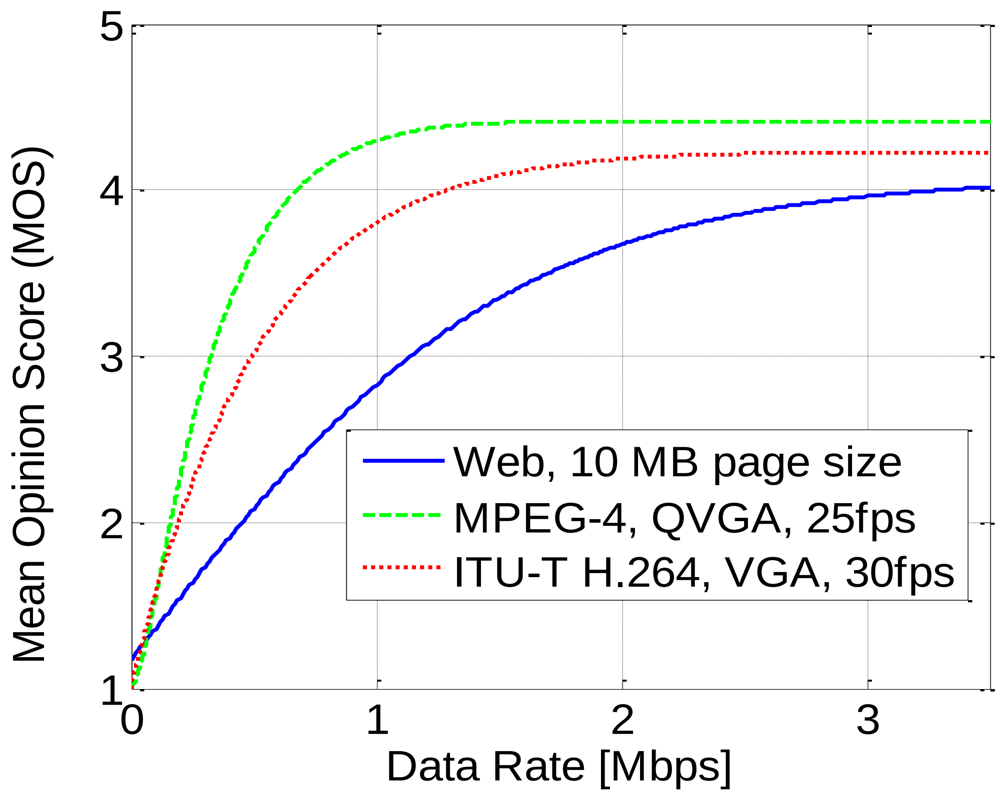
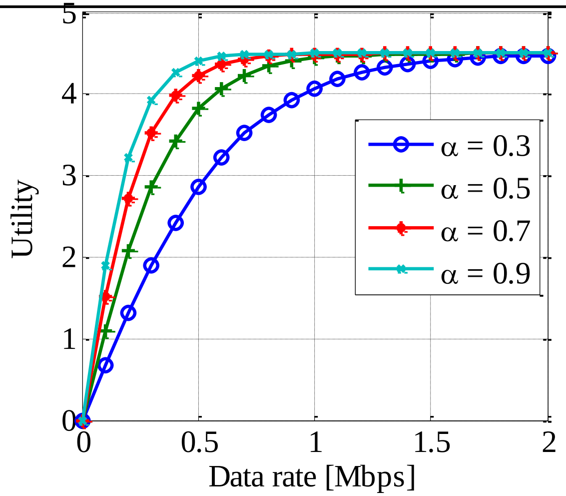


Figure: MOS over data rate [1][2]

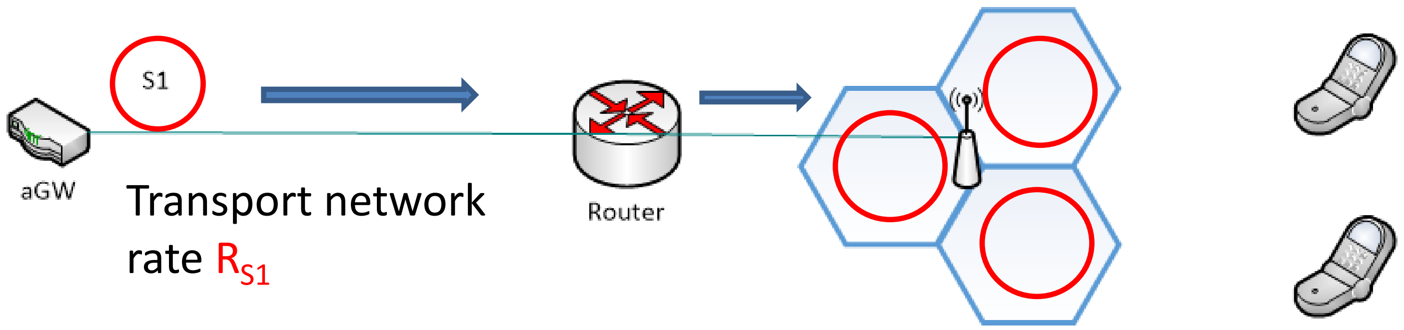
Utility functions

Applications	**Elastic traffics; Video with transcoding**
Properties	QoE monotonically increases with the data rate; Marginal QoE monotonically decreases with the data rate
Function Type	Sigmoid Function (Concave part)
Utility function	$u(r) = \frac{A}{1+e^{-\alpha \cdot r}} + B$
Utility curves	 *with A=9, B=-4.5

General overview

Goal: $\max\left\{U=\sum_{c}\sum_{i}u_{i,c}\left(b_{i,c}\right)\right\}$

Cell bandwidth B_c



Transport network rate R_{S1}

$$\sum_{c}\sum_{i}r_{i,c}=\sum_{c}\sum_{i}b_{i,c}\cdot\sigma_{i,c}\leq R_{S1}$$

$$\sum_{i}b_{i,c}\leq B_c \quad \forall c$$

Case	aGW traffic shaping	Radio scheduler
No S1 bottleneck	-	Optimal algorithm
Only S1 bottleneck	Lagrangian relaxation solved by bisection search	Two heuristics (Centralized/Coordinated MAC scheduler)
Both S1 and some cells are bottleneck	Lagrangian relaxation sovled by projected subgradient method	

Lagrangian relaxation

- Maximize the aggregated utility in the cell cluster, which can be expressed as:

$$\max \left\{ U = \sum_c \sum_i u_{i,c}\left(b_{i,c}\right) \right\}$$
$$s.t. \quad \sum_i b_{i,c} \le B_c \quad \forall c; \quad \sum_c \sum_i b_{i,c} \cdot \sigma_{i,c} \le R_{S1}$$

- It can be solved optimally using the Lagrangian decomposition method.
  - Hessian matrix positive definite -> Problem is convex
  - Slater's condition fulfilled -> Strong duality holds

$$f = \min_{\{\boldsymbol{\lambda}\}} \left\{ \max_{\{\mathbf{b}\}} \left\{ \sum_c \sum_i u_{i,c}\left(b_{i,c}\right) - \sum_c \lambda_c \left(\sum_i b_{i,c} - B_c \right) - \lambda_0 \left(\sum_c \sum_i b_{i,c} \cdot \sigma_{i,c} - R_{S1} \right) \right\} \right\}$$
$$= \min_{\{\boldsymbol{\lambda}\}} \left\{ \sum_c \sum_i \max_{\{\mathbf{b}\}} \left\{ \overbrace{u_{i,c}\left(b_{i,c}\right) - \left(\lambda_c + \lambda_0 \cdot \sigma_{i,c}\right) b_{i,c}}^{L_{i,c}} \right\} + \sum_c \lambda_c \cdot B_c + \lambda_0 \cdot R_{S1} \right\}$$
$$= \min_{\{\boldsymbol{\lambda}\}} \left\{ \sum_c \sum_i L^*_{i,c} + \sum_c \lambda_c \cdot B_c + \lambda_0 \cdot R_{S1} \right\}$$

- Subgradient projection method is applied
  - with modified Polyak's step size

Extensions

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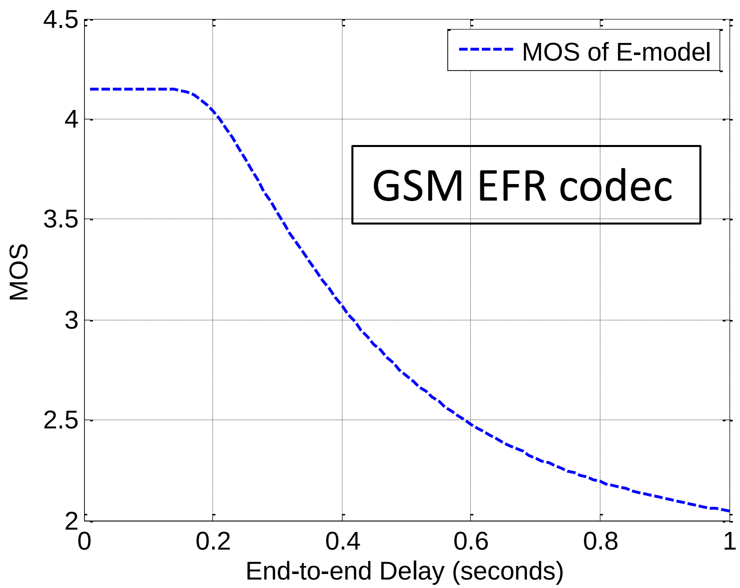
$$\max \left\{ U = \sum_c \sum_i w_{i,c} \cdot u_{i,c}\left(r_{i,c}\right) \right\}$$

Traffic Type	Delay sensitive traffics (Real-time)	Rate sensitive traffics (Non Real-time)
Utility Functions	$u_{i,c}\left(r_{i,c}\right) = \frac{\left\|u'\left(d_{i,c}\right)\right\|}{\lambda_{i,c}} \cdot r_{i,c}$	$u_{i,c}\left(r_{i,c}\right) = \frac{A}{1+e^{-\alpha_{i,c} \cdot r_{i,c}}} \cdot r_{i,c} + B$
Optimatizon Model	Linear Programming	Concave Optimatization



References

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1. ITU-T recommendation G.1070: Opinion model for videotelephony applications (04/2007)
2. ITU-T, G.1030: Estimating end-to-end performance in IP networks for data applications, 2005.

Thanks and Any Questions?

Freunde Förderer ComNets

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