Anticipatory Resource Allocation for Wireless Media Streaming

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Motivation

- Predict poor channel state and schedule resources to fill user's play-out buffer in advance.
- At poor channel state, the user satisfies QoE requirements from buffer and radio resources can be allocated to other users with better channel.
- Exploit multi-user diversity at larger time scale and turn memory into spectral efficiency and QoE with fluent streaming.

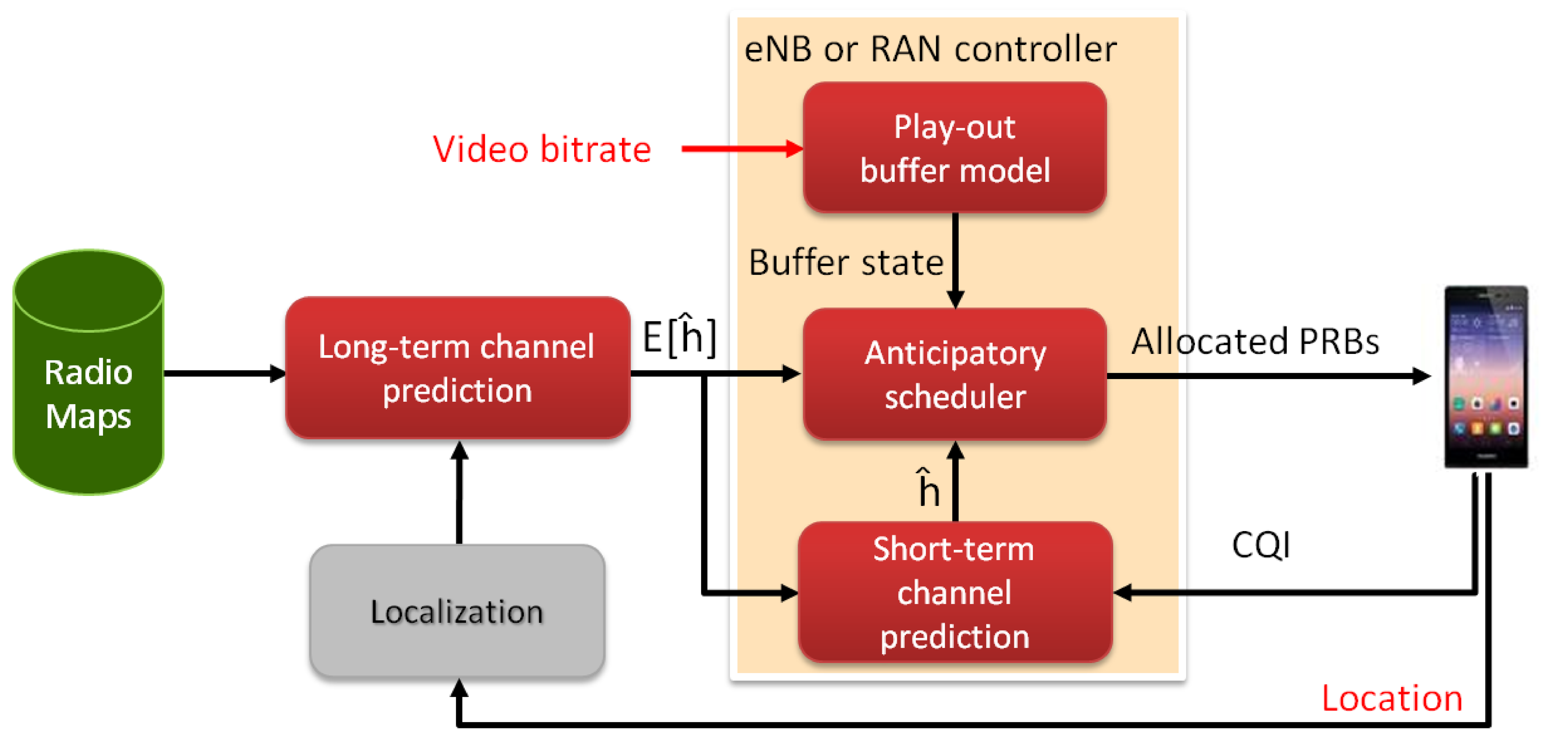
User's buffer model integrated into a network controller

- Runs a linear buffer model to be aware of the user's buffer state.

$$z_{k,t} = \max(\omega_{k,t} S_{k,t} + z_{k,t-1} - V^d_{k,t}, 0)\ \forall k \in \mathcal{K}, \forall t \in \mathcal{T}.$$

- Solves a Linear Programming (LP) problem in real time, in order to allocate the optimal resources to K users by exploiting a prediction horizon of T time slots.

System architecture



Anticipatory Scheduler

$$\min_{\omega,z,\ell} \sum_{k\in\mathcal{K}} \sum_{t\in\mathcal{T}} (\omega_{k,t} + \gamma \ell_{k,t})$$

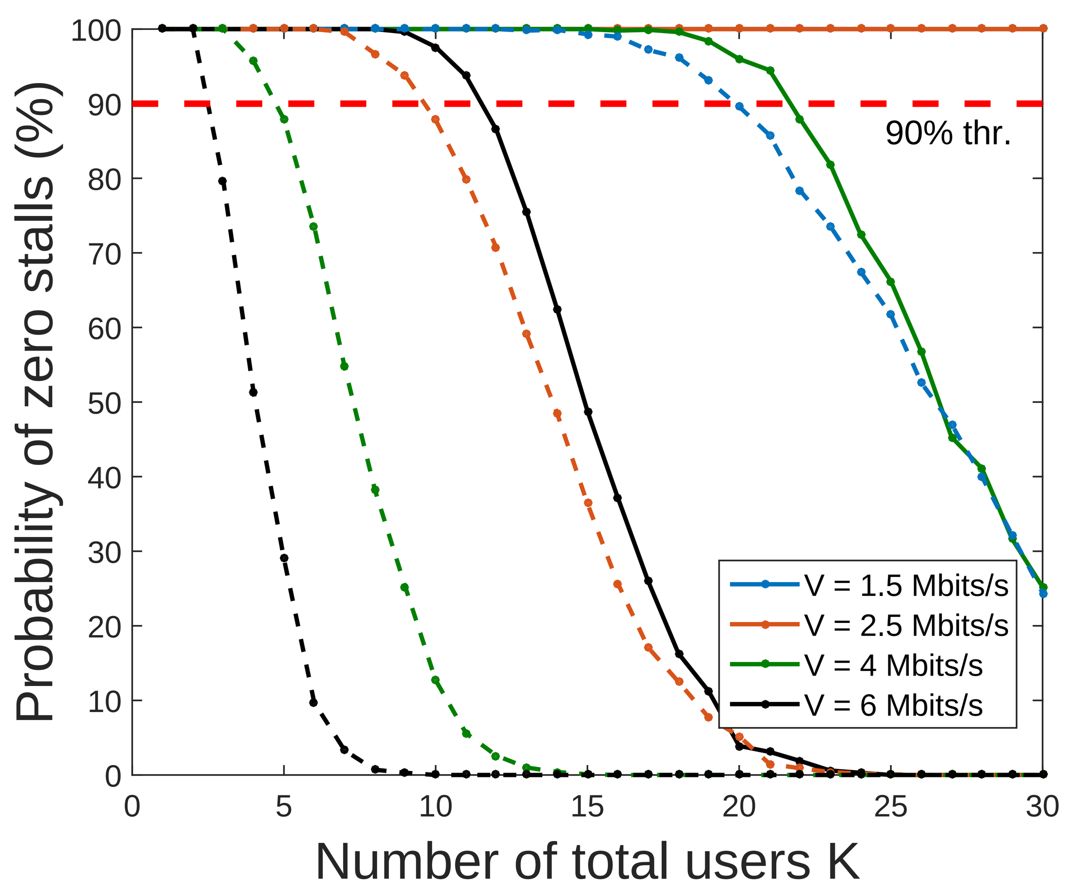
s.t.

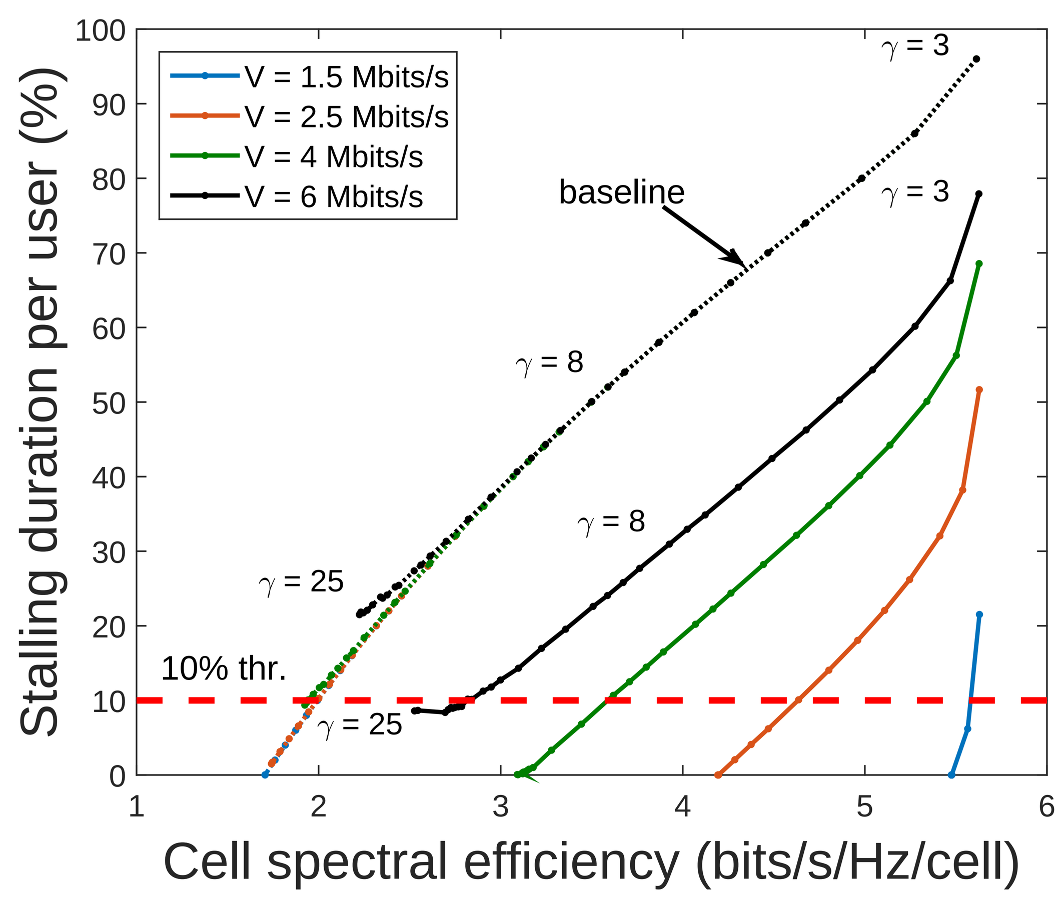
$$\begin{aligned}
z_{k,0} &= \zeta_k\ \forall k \in \mathcal{K}, && \text{Non-empty initial buffer.}\\
z_{k,t} &= \max(\omega_{k,t} S_{k,t} + z_{k,t-1} - V^d_{k,t}, 0)\ \forall k \in \mathcal{K}, \forall t \in \mathcal{T}, && \text{Buffer evolution.}\\
\ell_{k,t} &= \frac{1}{V^d_{k,t}} \max(-\omega_{k,t} S_{k,t} - z_{k,t-1} + V^d_{k,t}, 0)\ \forall k \in \mathcal{K}, \forall t \in \mathcal{T}, && \text{Stalling time.}\\
\textstyle\sum_{k\in\mathcal{K}} \omega_{k,t}\, a^m_{k,t} &\le N_m\ \forall t \in \mathcal{T}, \forall m \in \mathcal{M}, && \text{Limited BS resources.}\\
z_{k,t} &\le Z_k\ \forall k \in \mathcal{K}, \forall t \in \mathcal{T}, && \text{Maximum buffer size.}\\
\omega_{k,t}, z_{k,t} &\in \mathbb{R}^+\ \forall k \in \mathcal{K}, \forall t \in \mathcal{T}.
\end{aligned}$$

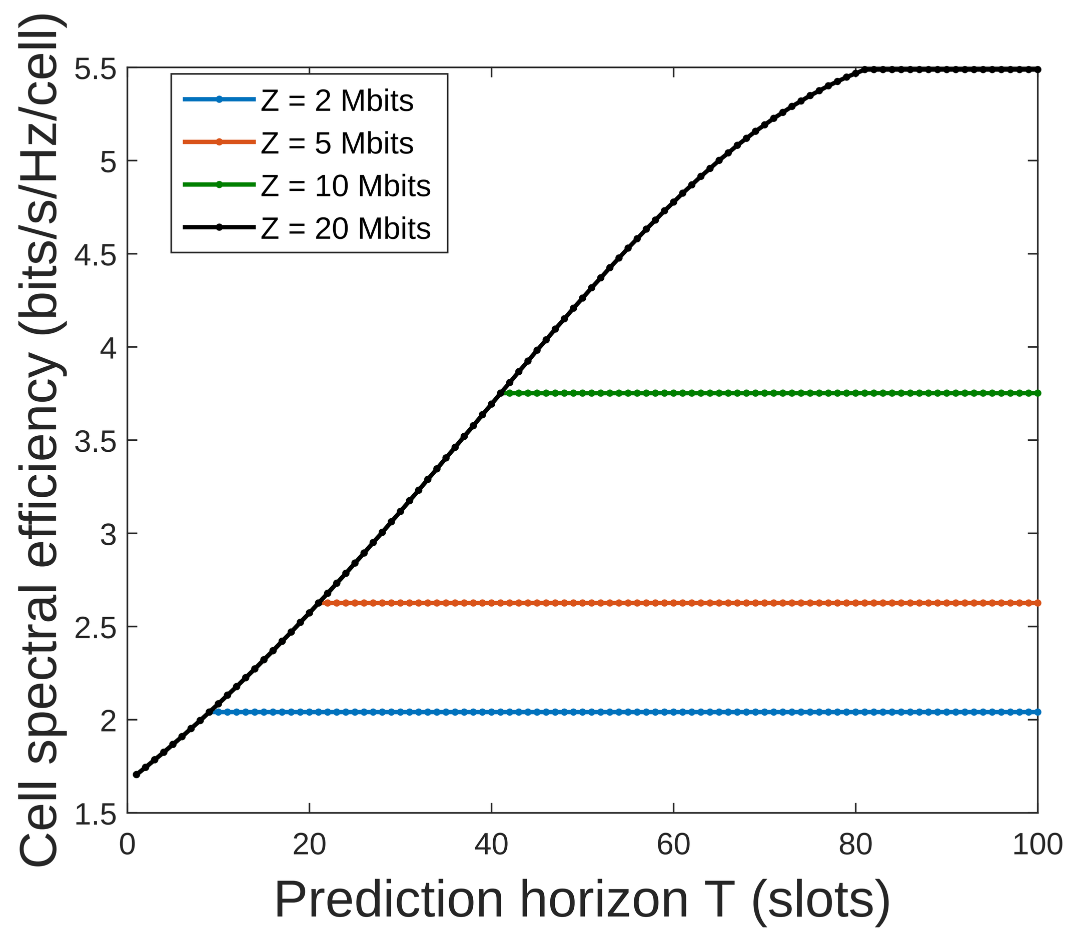
Linearization of constraints for buffer evolution and stalling time leads to an LP formulation.

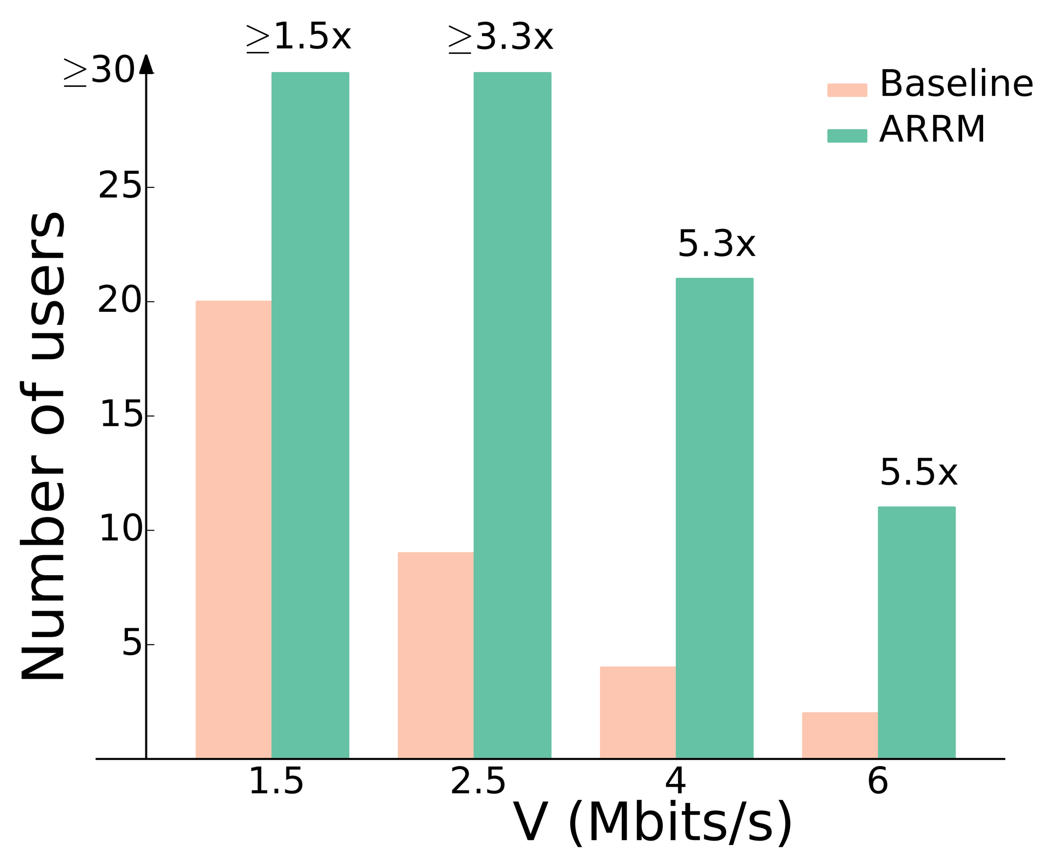
Simulation Results

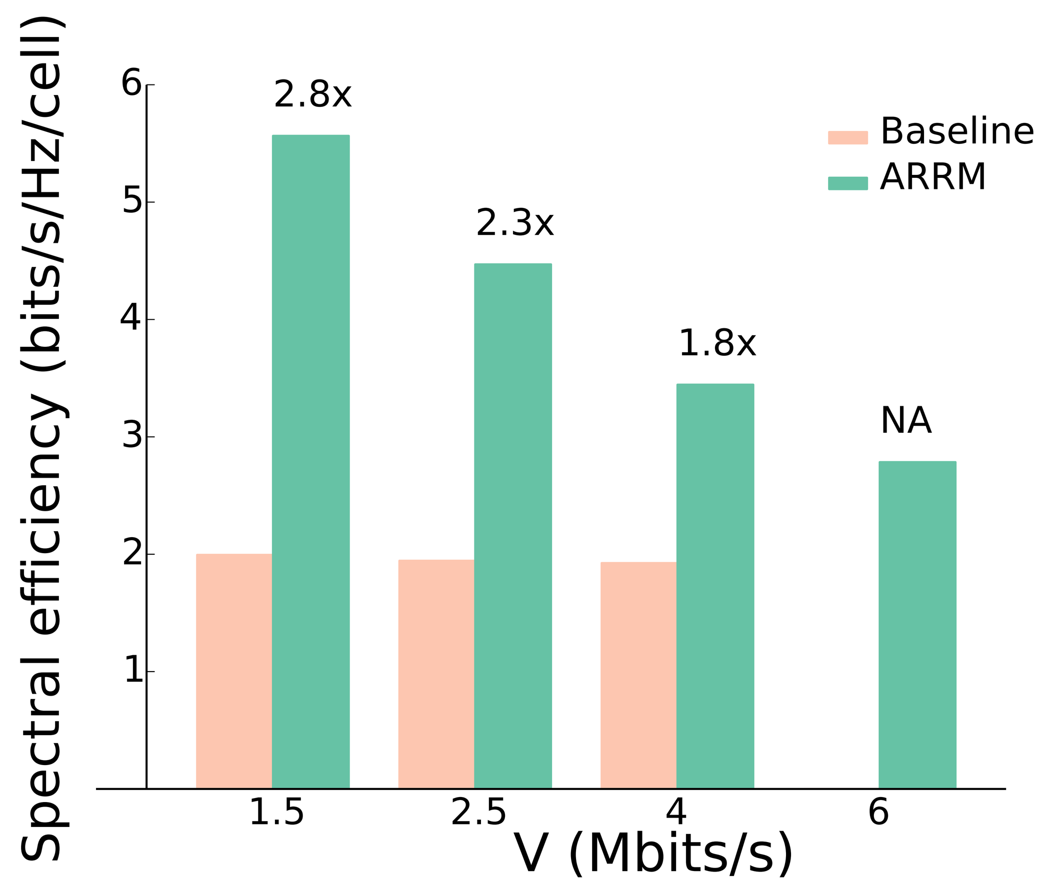
- Perfect channel prediction.
- Multi-user, highway model.
- Cell spectral efficiency vs. prediction horizon.
- Probability of zero stalls vs. number of users.
- Number of supported users with at least 90% probability of zero stalls.
- Cell spectral efficiency vs. stalling duration per user for different values of γ.
- Cell spectral efficiency for 10% average stalling duration.











Conclusions

- Numerical results show an outstanding gain in spectral efficiency, number of supported users and QoE (up to 3 times increase of spectral efficiency and 5 times increase of supported users under the same QoE constraint).
- LP formulation allows real-time implementation: the required computational time is affordable even for large instances of the problem.