

Report: Joint Scheduling of URLCC and eMBB Traffic in 5G Wireless Networks

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Without URLLC superposition/puncturing,

$$C_u^{\pi,s} = \mathfrak{c}_u^s \phi_u^{\pi,s}$$

With URLLC superposition/puncturing,

$$\begin{aligned} C_u^{\pi,s} &= \mathfrak{c}_u^s \phi_u^{\pi,s} - \mathfrak{c}_u^s \phi_u^{\pi,s} h \left[\frac{L_u^{\pi,s}}{\phi_u^{\pi,s}} \right] \\ &= \mathfrak{c}_u^s \phi_u^{\pi,s} \left(1 - h \left[\frac{L_u^{\pi,s}}{\phi_u^{\pi,s}} \right] \right) \end{aligned}$$

With linear URLLC superposition/puncturing,

$$h \left[\frac{L_u^{\pi,s}}{\phi_u^{\pi,s}} \right] = \frac{L_u^{\pi,s}}{\phi_u^{\pi,s}}$$

That is,

$$\begin{aligned} C_u^{\pi,s} &= \mathfrak{c}_u^s \phi_u^{\pi,s} \left(1 - \frac{L_u^{\pi,s}}{\phi_u^{\pi,s}} \right) \\ &= \mathfrak{c}_u^s (\phi_u^{\pi,s} - L_u^{\pi,s}) \end{aligned}$$

Hence,

$$\mathbb{E} C_u^{\pi,s} = \mathfrak{c}_u^s (\phi_u^{\pi,s} - \mathbb{E} L_u^{\pi,s}) \quad (1)$$

- We assume linear URLLC superposition/puncturing.
- We place URLLC loads uniformly over frequency bandwidth across minislots.
- I assume $\phi_{u,m}^{\pi,s}$ is fixed for a given set of (s, u, m) , for $\mathbb{E}L_{u,m}^{\pi,s}$ in equation 4 to be a proper constant.
- However, I note that such assumption is incorrect because the model aims to modify $\phi_{u,m}^{\pi,s}$ over time.

My Derivation

- Each minislot has an URLLC demand of $\mathbb{E}D_m = \frac{\mathbb{E}D}{m}$.
- Each frequency f in a minislot has an URLLC load of $\mathbb{E}L_{f,m}^\pi$.

$$\int_0^f \mathbb{E}L_{f,m}^\pi df = \mathbb{E}D_m$$

$$\mathbb{E}L_{f,m}^\pi \int_0^f df = \frac{\mathbb{E}D}{m}$$

$$\mathbb{E}L_{f,m}^\pi f = \frac{\mathbb{E}D}{m}$$

$$\mathbb{E}L_{f,m}^\pi = \frac{\mathbb{E}D}{fm} \quad (2)$$

My Derivation

- Each frequency f in a minislot has a resource of $\phi_{f,m}$.

$$\begin{aligned}\int_0^f \phi_{f,m} df &= \frac{1}{m} \\ \phi_{f,m} &= \frac{1}{fm}\end{aligned}\tag{3}$$

- By equations 2 and 3,

$$\begin{aligned}\frac{\mathbb{E}L_{f,m}^\pi}{\phi_{f,m}} &= \mathbb{E}D \\ \mathbb{E}L_{f,m}^\pi &= \phi_{f,m}\mathbb{E}D\end{aligned}$$

My Derivation

On the other hand,

$$\begin{aligned} f t &= 1 \\ f t' m &= 1 \\ t' &= \frac{1}{f m} \end{aligned}$$

Furthermore,

$$\begin{aligned} f_{u,m}^{\pi,s} t' &= \phi_{u,m}^{\pi,s} \\ f_{u,m}^{\pi,s} &= \phi_{u,m}^{\pi,s} f m \end{aligned}$$

My Derivation

Thence,

$$\begin{aligned}
 \mathbb{E}L_{u,m}^{\pi,s} &= \int_0^{f_{u,m}^{\pi,s}} \mathbb{E}L_{f,m}^{\pi} df \\
 &= \int_0^{\phi_{u,m}^{\pi,s} fm} \phi_{f,m} \mathbb{E}D df \\
 &= \mathbb{E}D \int_0^{\phi_{u,m}^{\pi,s} fm} \phi_{f,m} df \\
 &= \mathbb{E}D \phi_{u,m}^{\pi,s}
 \end{aligned} \tag{4}$$

Similar derivations for slot give

$$\mathbb{E}L_u^{\pi,s} = \mathbb{E}D \phi_u^{\pi,s} \tag{5}$$

By equations 1 and 5,

$$\mathbb{E}C_u^{\pi,s} = \mathfrak{c}_u^s (\phi_u^{\pi,s} - \phi_u^{\pi,s} \mathbb{E}D) \quad (6)$$

$$= \mathfrak{c}_u^s \phi_u^{\pi,s} (1 - \mathbb{E}D) \quad (7)$$