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

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December 13, 2021

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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,

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

Hence,

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

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

$$
\begin{aligned}
\int_0^{\mathfrak{f}} \mathbb{E}L^{\pi}_{f,m} df &= \mathbb{E}D_m \\
\mathbb{E}L^{\pi}_{f,m} \int_0^{\mathfrak{f}} df &= \frac{\mathbb{E}D}{\mathfrak{m}} \\
\mathbb{E}L^{\pi}_{f,m}\mathfrak{f} &= \frac{\mathbb{E}D}{\mathfrak{m}} \\
\mathbb{E}L^{\pi}_{f,m} &= \frac{\mathbb{E}D}{\mathfrak{f}\mathfrak{m}} \qquad (2)
\end{aligned}
$$

My Derivation

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

$$\int_0^{\mathfrak{f}} \phi_{f,m} df = \frac{1}{\mathfrak{m}}$$
$$\phi_{f,m} = \frac{1}{\mathfrak{f}\mathfrak{m}} \tag{3}$$

- By equations 2 and 3,

$$\frac{\mathbb{E}L^{\pi}_{f,m}}{\phi_{f,m}} = \mathbb{E}D$$
$$\mathbb{E}L^{\pi}_{f,m} = \phi_{f,m}\mathbb{E}D$$

My Derivation

On the other hand,

$$\mathfrak{f}\mathfrak{t} = 1$$
$$\mathfrak{f}\mathfrak{t}'\mathfrak{m} = 1$$
$$\mathfrak{t}' = \frac{1}{\mathfrak{f}\mathfrak{m}}$$

Furthermore,

$$\zeta_{u,m}^{\pi,s}\mathfrak{t}' = \phi_{u,m}^{\pi,s}$$
$$\zeta_{u,m}^{\pi,s} = \phi_{u,m}^{\pi,s}\mathfrak{f}\mathfrak{m}$$

My Derivation

Thence,

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

Similar derivations for slot give

$$\mathbb{E}L_{u}^{\pi,s} = \phi_{u}^{\pi,s}\mathbb{E}D \tag{5}$$

By equations 1 and 5,

$$\begin{aligned}\mathbb{E}C_u^{\pi,s} &= \mathfrak{c}_u^s\left(\phi_u^{\pi,s} - \phi_u^{\pi,s}\mathbb{E}D\right) \\ &= \mathfrak{c}_u^s\phi_u^{\pi,s}\left(1 - \mathbb{E}D\right) \end{aligned} \tag{6}$$