Revisiting Unlicensed Channel Access Scheme of 5G New Radio

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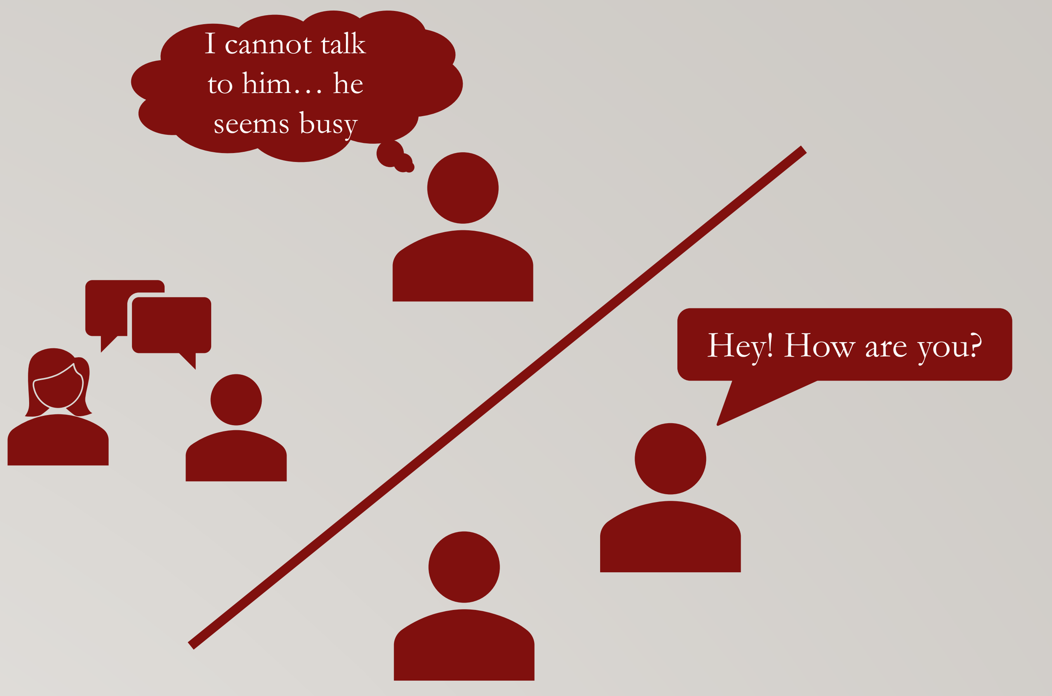
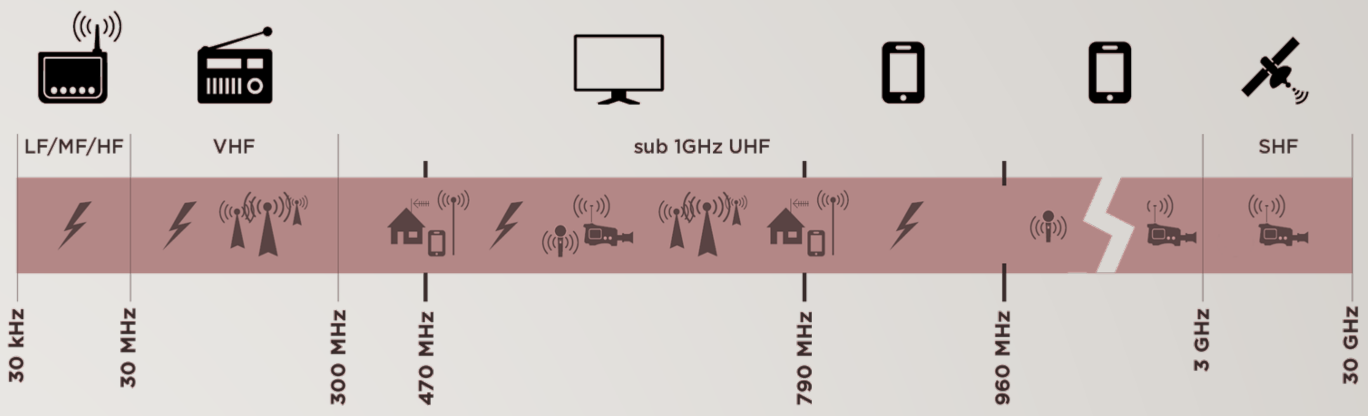
What was the objective?

Listen-Before-Talk (LBT) is a mechanism that allows various wireless devices (e.g., Wi-Fi Access Point, Smartphones, Smart TVs, etc.) to share a frequency channel in an unlicensed spectrum (i.e., 2.4 GHz and 5 GHz). LBT ensures no harm (interference) is caused among coexisting devices, by monitoring the channel before every transmission and making sure it is idle.
The LBT performance was investigated under dense wireless devices deployments and metrics such as efficiency, delay, and fairness were evaluated.



Why is it important?

1) Radio spectrum is a finite and precious natural resource which is already crowded with many technologies.
2) Within the next 2 years, data traffic generated by smartphones is expected to increase 10 times the amount reported in 2016 [1].
3) Next-generation wireless systems (5G New Radio) are being developed to operate in the unlicensed band (2.4 GHz and 5 GHz), which means mobile operators will contend with Wi-Fi and Bluetooth to use the spectrum.



A proper assessment of the LBT mechanism operating in very dense environments – as predicted for 5G NR – is imperative to ensure radio spectrum is being utilized efficiently.

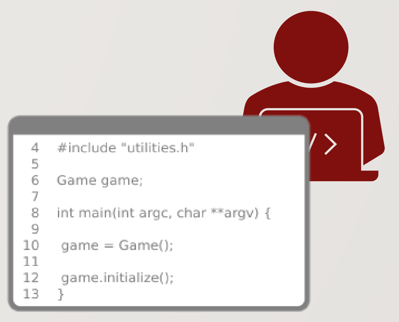
What did we do?

A mathematical model for LBT was developed using a technique called Markov chains

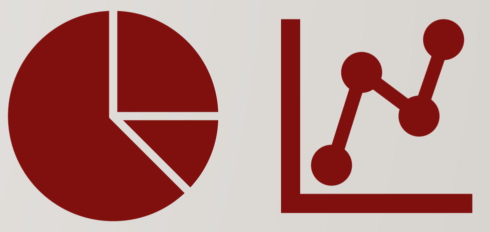
$$\tau_c = \sum_{i=0}^{m_c} \pi(i,0) = \frac{\pi(0,0)}{1-p_c}$$

$$\tau_c = \frac{(1-2p_c)}{(1-2p_c)(W_c+1) + p_c W_c (1-(2p_c)^{m_c})}$$

The model was then validated using computer simulations in C++ programming language

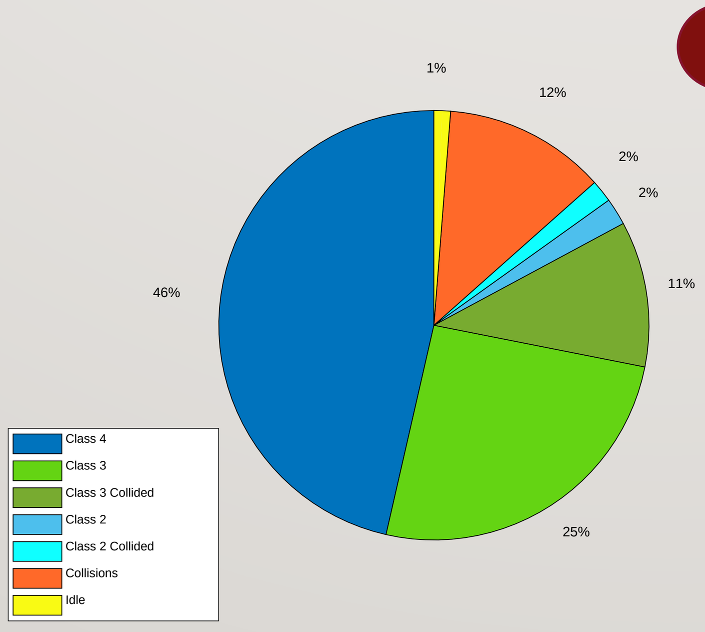


Results were obtained for various settings and scenarios



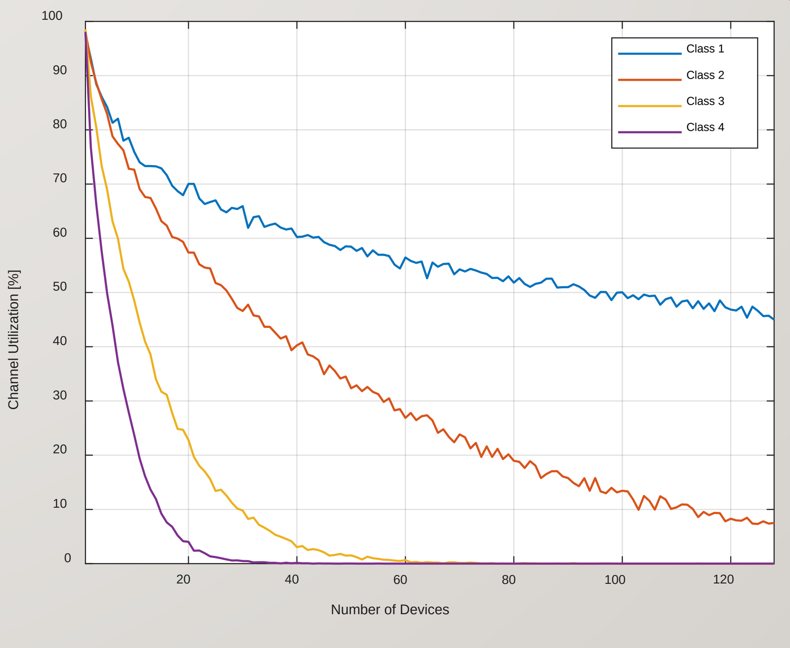
What did we find?

We considered various scenarios where devices were transmitting the following types of data: Audio (Class 4), Video (Class 3), File transfer (Class 2), and Browsing (Class 1), with descending priority.



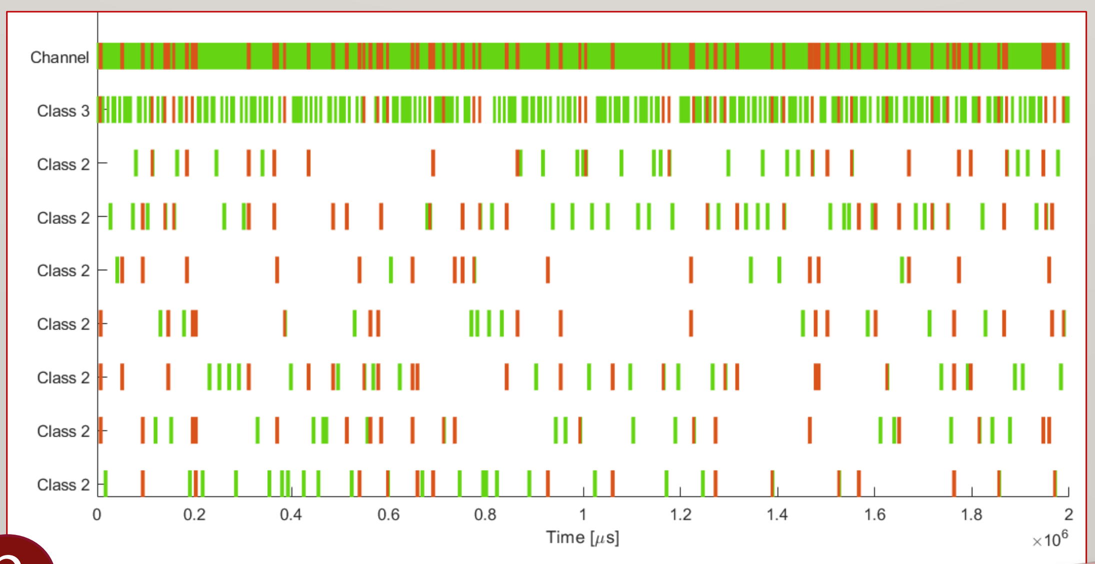
1 When 4 devices share the channel—each representing a single class—they collide 12% of the time rendering the packets corrupt. 1% the channel is idle.

An audio device (Class 4) utilizes nearly half the time, while a device browsing the internet (Class 1) wouldn't be able to access the channel at all.



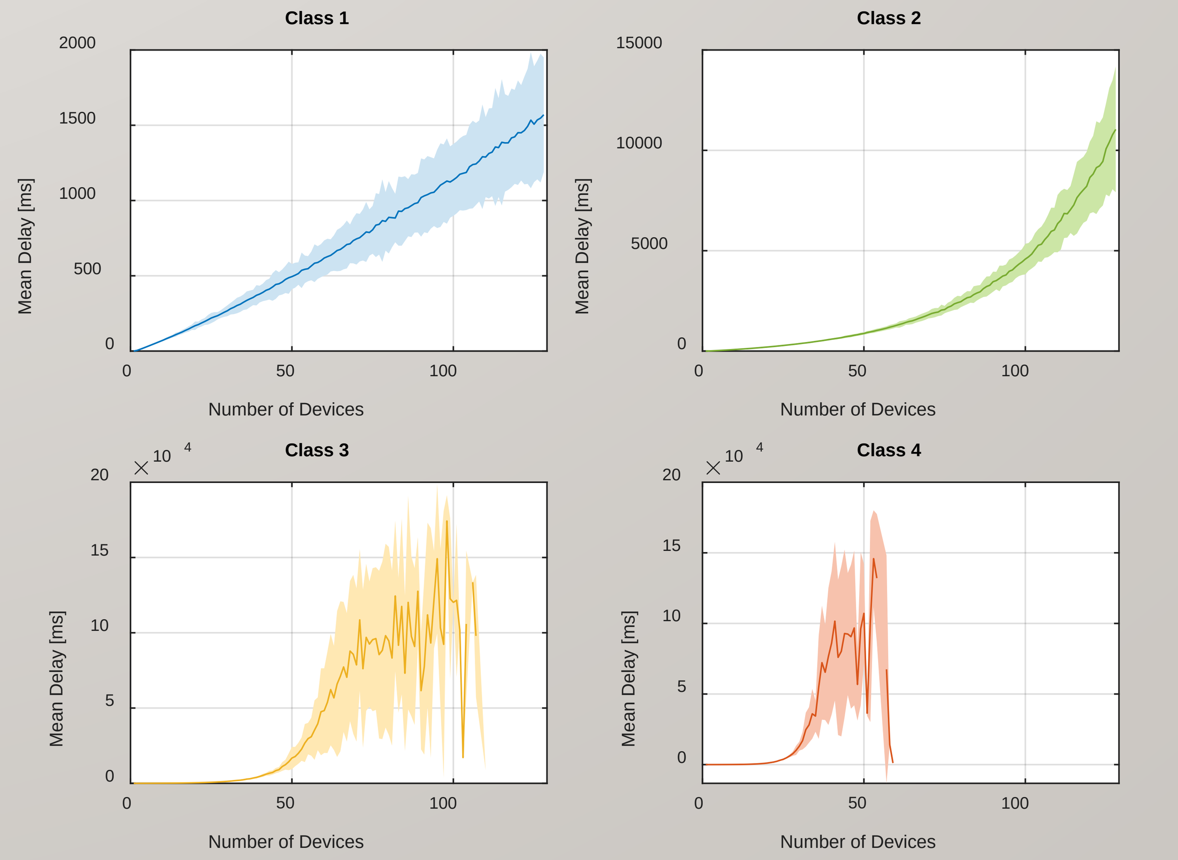
3 Simulating a large number of devices transmitting a single class of data reveals that Class 3 and 4 (Video and Audio) are less efficient compared to Class 1 and 2.

Class 3 and Class 4 waste 80% and 95% of channel time, respectively, at 20 devices sharing the wireless medium.



2 A single device streaming video (Class 3) coexisting with 7 other devices downloading a file (Class 2) takes 42% of channel time, leaving other devices with 34% to share.
This explains why users connected to Wi-Fi in a crowded place (e.g., coffee shop) experience a slow connection and are forced to switch to LTE.

The figure above depicts activity on the channel in time domain: green bars represent successful transmissions, and red bars represent failed ones (collisions).



4 This figure demonstrates the delay each class incurs as a function of the number of devices sharing the channel.

Class 3 and Class 4 incur more delay than Class 1 and 2 by two orders of magnitude!

Conclusion

- Radio spectrum is a priceless natural resource that must not be underutilized, and society is being ever inundated by a staggering number of connected instruments.
- Wireless devices employ a mechanism called LBT to share radio frequency channels. This work examines its performance under future dense deployments.
- Results indicate that LBT does not utilize the spectrum efficiently in dense deployments, and that channel is divided unfairly in mixed-class scenarios.
- This work underlines the importance of improving channel access mechanisms in next-generation wireless systems.

[1] Ericsson, "Future mobile data usage and traffic growth," 2019.