Emulating GFSK Modulation for Wi-Fi-to-BLE Multicast Communication

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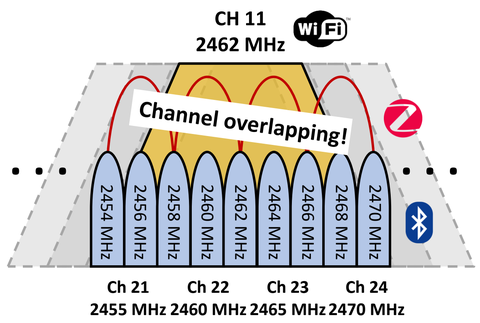
Introduction to CTC between Wi-Fi and BLE

Necessity of Cross Technology Communication (CTC)

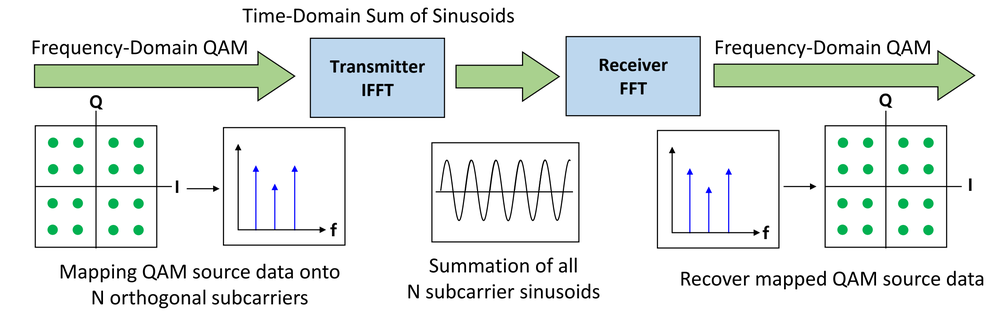
- The 2.4 GHz ISM band's dense population of heterogeneous devices leads to severe cross technology interference, hindering network scalability and spectrum efficiency.
- For example, Bluetooth LE Audio can provide content about exhibits in places like museums, stadiums, and tourist attractions.
- However, in larger venues, more Bluetooth devices are required, which can lead to increased operational and maintenance costs.



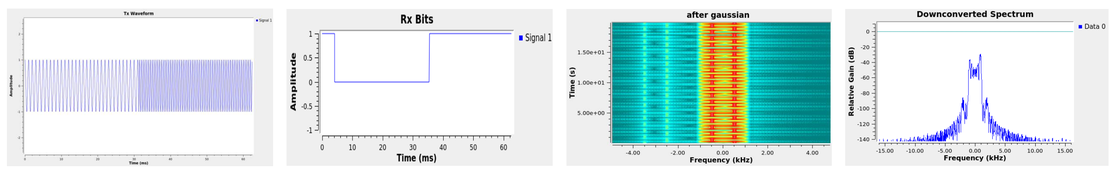
➔ Repurposing Wi-Fi hardware for Bluetooth functionality can leverage its wider coverage to deliver **different content** to **different Bluetooth devices**, thereby enhancing interoperability.

Wi-Fi and Bluetooth Low Energy (BLE)

- Wi-Fi uses **Orthogonal Frequency Division Multiplexing (OFDM)** and **Quadrature Amplitude Modulation (QAM)**, enabling high data speeds and broad coverage.



- BLE uses **Gaussian Frequency Shift Keying (GFSK)** modulation, which reduces the signal spectrum width through a Gaussian filter, thereby minimizing interference between adjacent channels.

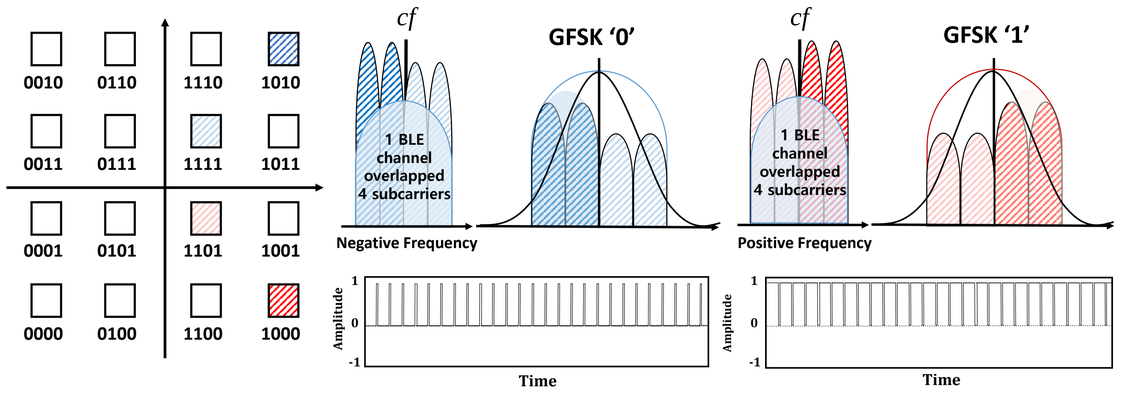


<Time domain> <Frequency domain>

WBMC: Wi-Fi-to-BLE Multicast Communication

One-to-One Communication

- WBMC's key technique is the ***subcarrier manipulation***, which utilizes changes in ***signal strength based on the geographics of QAM symbol coordinates*** to emulate the frequency deviation of GFSK.



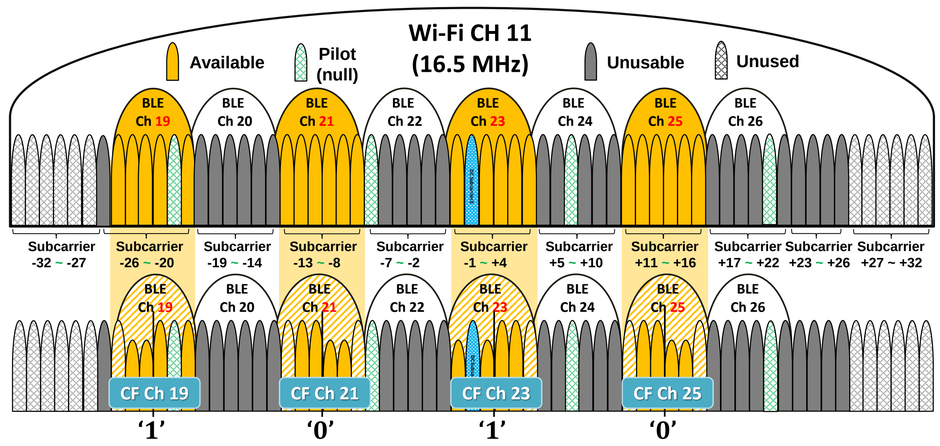
- WBMC transmits by placing ***external symbols (ES)*** on subcarriers with ***higher frequencies*** relative to the center frequency of BLE, and ***internal symbol (IS)*** on subcarriers with ***lower frequency***.

  ➔ Receiving this emulated signal, BLE detects is as a frequency deviation of GFSK and decodes it as a '0' (vice versa).

Multicast Communication

- To expand from one-to-one communication to multicast communication, WBMC employs a second key technique: adding a ***band pass filter***.

➔ The primary goal is to enable **independent data transmission** across **different BLE channels** by applying the band pass filter.

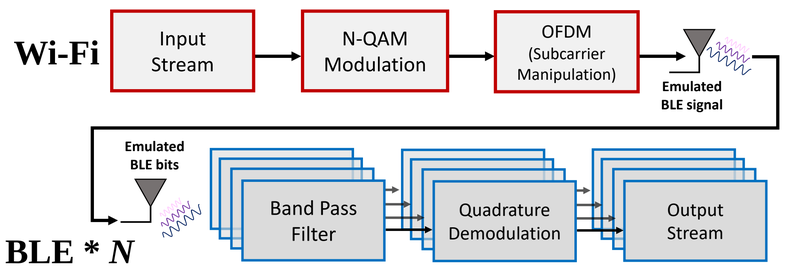


- All subcarriers ambiguously overlap on the BLE channel.
- To avoid interference from Wi-Fi subcarriers that overlap with adjacent BLE channels, we choose 4 nonadjacent channels (19, 21, 23 and 25).

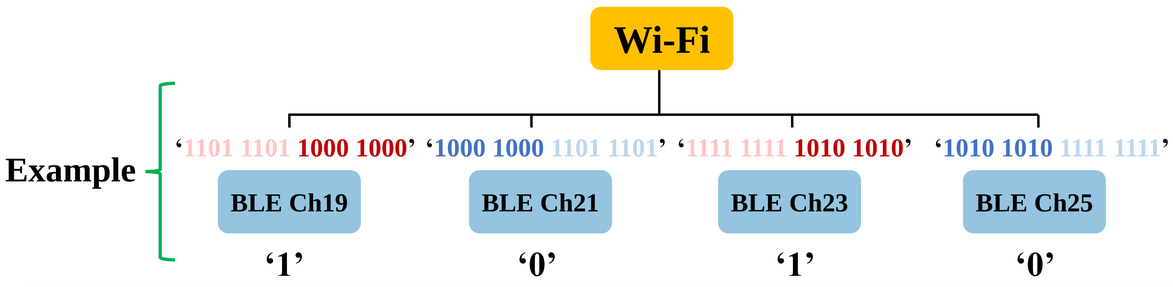
Evaluation

Implementation

- We assess the potential applicability of WBMC and evaluate its performance by implementing the PHY layers of Wi-Fi (based on IEEE 802.11g) and Bluetooth 5.4 in GNURadio.

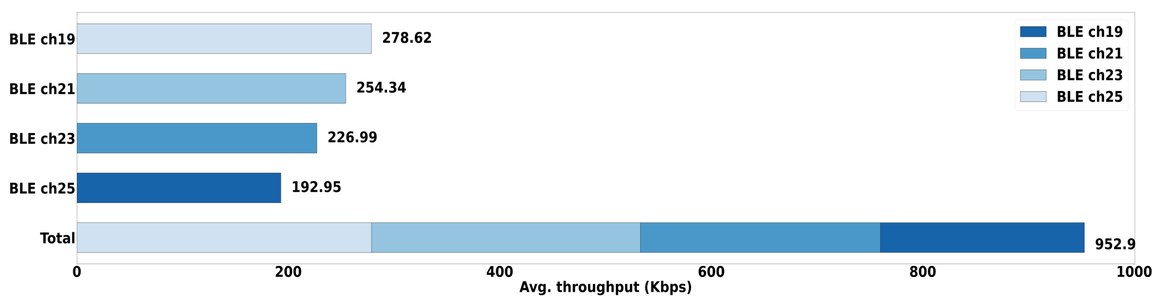


- The data used in the experiment is generated based on subcarrier manipulation and is conducted over a duration of 60 seconds.



Preliminary Results

- BLE channels 19, 21, 23, and 25 achieve average throughputs of 278.62 Kbps, 254.34 Kbps, 226.99 Kbps, and 192.95 Kbps, respectively.
- Furthermore, WBMC enables parallel simultaneous transmissions, resulting in an aggregate throughput of **952.9 Kbps** across all BLE channels, which is close to the 1 Mbps throughput of the BLE 1M PHY.



Future Work

- To enable efficient CTC when multiple BLE devices interact with the same Wi-Fi, WBMC plans to add channel hopping and enhance the study by applying deep learning with SDR and commercial BLE devices in real environments, conducting comparative experiments with previous studies.

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