Audio-WiFi: Augmented WiFi Network with Audio Channel for Smart Devices

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Motivation

➔WiFi is a common communication interface for smart devices.

➔ WiFi still has some perturbation such as:

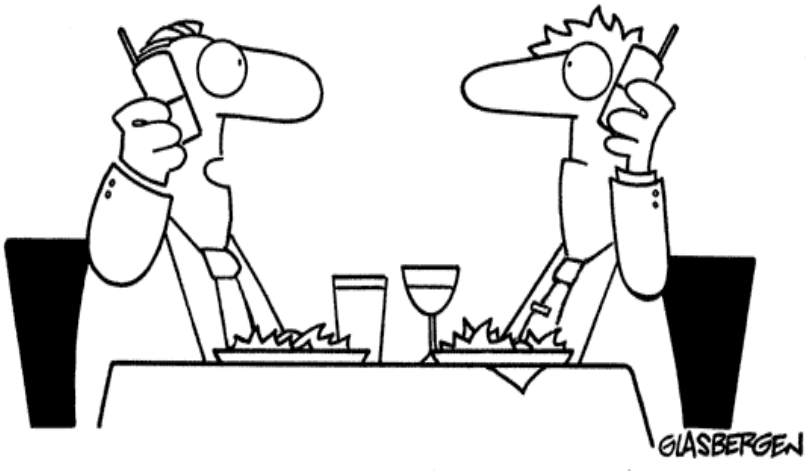
- Poor utilization of wireless channel.
- Energy consumption during idle state.
- Unfairness issue due to capture effect.

Motivation

- ➔Additional channel can be utilized to enhance the performance of WiFi.
- ➔Targeted devices are smart devices like smart phone, palm, tablet etc.
- ➔Smart devices can have following interfaces as additional channel:
  - ➔WiFi
  - ➔Bluetooth
  - ➔Zigbee
  - ➔Light/Camera
  - ➔Audio [Can we utilize this interface]

Proposed Idea

Utilize audio channel as an augmented channel to enhance WiFi performance.



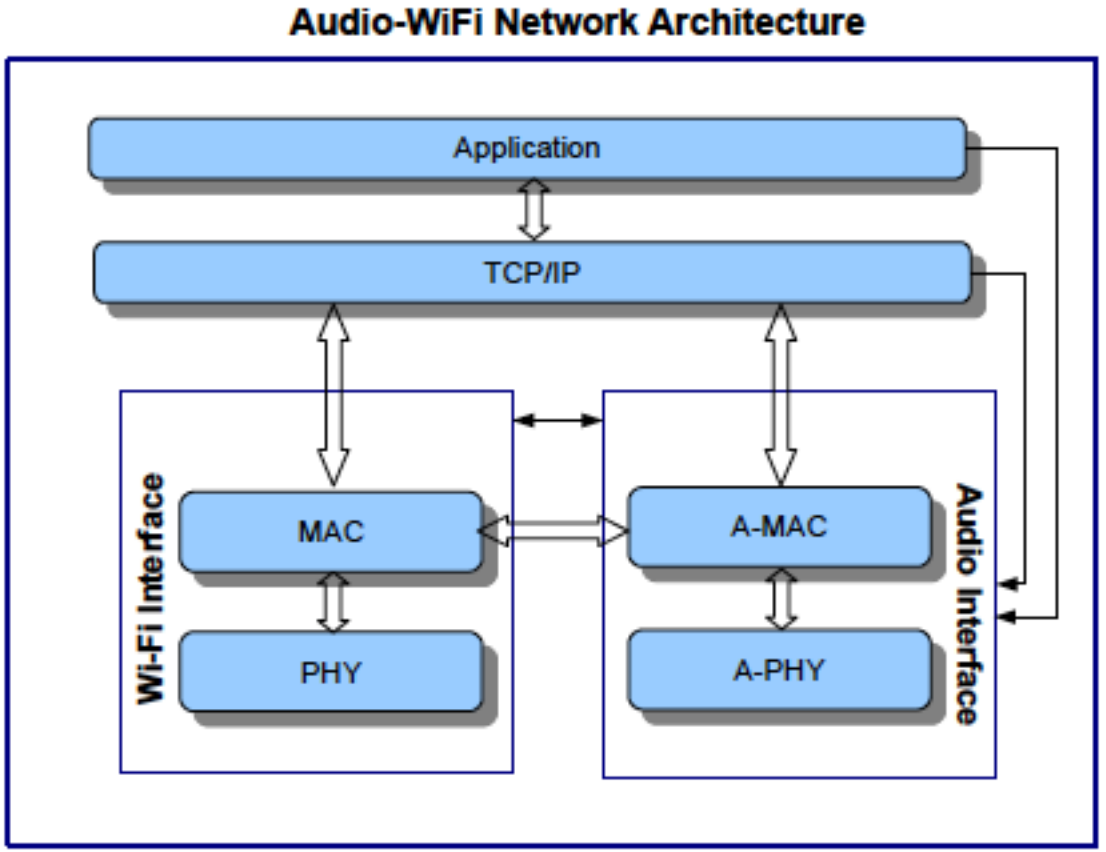
We like to exploit audio frequency beyond human ear perception as a parallel communication channel with WiFi.

Why Audio?

- It is non-interferential with radio network.
- No additional bandwidth required from WiFi.
- Speakers/Microphones are very common hardware component in smart devices.
- Smart devices are capable of generating and discerning audio beyond human ear.

Audio-WiFi Network

Preliminary Architecture of proposed Audio-WiFi Network



***A-MAC**: Can be utilized by MAC and TCP/IP layer to send small size data packet over audio channel.*

***A-PHY**: responsible for signal processing and sending/receiving signal using ,mic/speaker*

TCP/IP and MAC has control path with A-MAC.

Preliminary Evaluation work

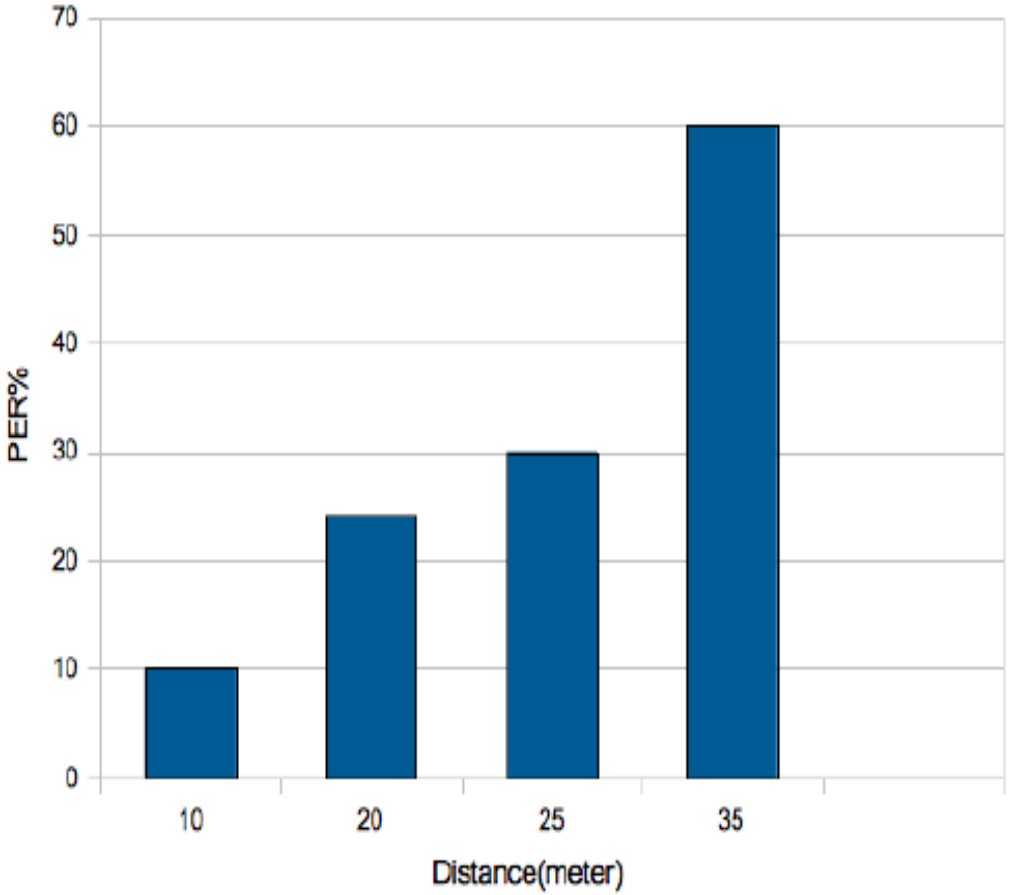
Sending/receiving data frames over audio channel

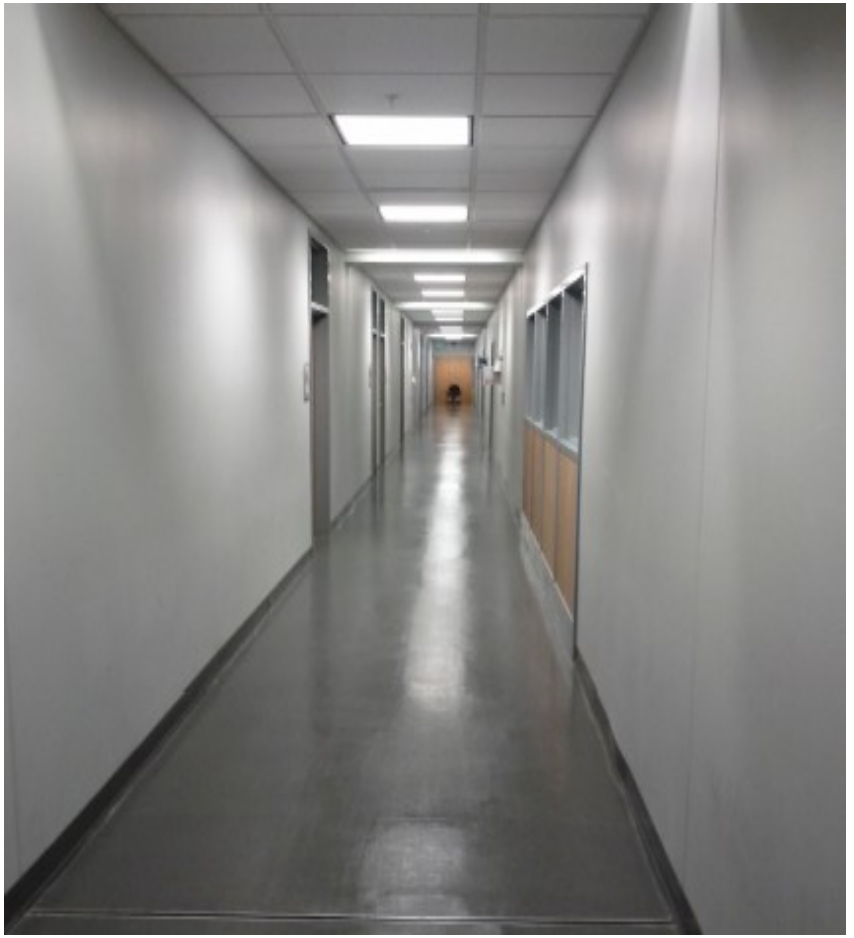
- M-array FSK modulation/demodulation.
- We use 16 frequencies for our modulation/demodulation.
- Each frequency represents a symbol of 4 bit.
- Frequency range from 18000-21200Hz.
- Equal frequency spacing.
- 30bps as data transmission rate.
- Packet size is 25byte.

$$s_m(t) = a\sin(2\pi f_m t) \quad t \in [0, T]$$

T is the Symbol Duration

Preliminary Evaluation Result

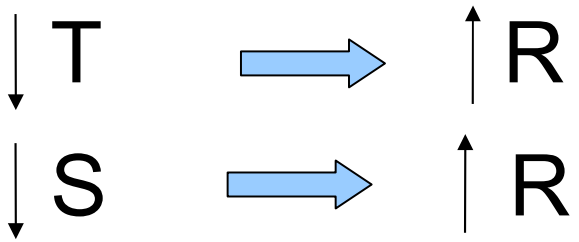




Packet Error Rate(PER) over different distance

Challenges for Audio (1)

- Data rates (R) Depends on Symbol duration(T) and Frequency spacing(S).



According to Nyquist–Shannon theorem Symbol duration is lower bounded by the bandwidth.

$$T > \frac{1}{2B}$$

B is the Channel Bandwidth

Bandwidth (B) is limited to 2-3KHz Beyond humar ear perception in Smart phones

Challenges for Audio (2)

Doppler effect impose constraint over Frequency Spacing (S).

$$\pm 2 f_0 \frac{v}{s}$$

s = Sound velocity
v = Receiver velocity
f0 = Actual frequency

Sound Speed, s << radio propagation speed

Reverberation impose constraint over duration of symbol(T).

Audio-WiFi Challenges

Challenge1: Audio channels suffer from low data rate.

Possible Solution:

- *Use audio channel to transmit only small control frames.*
- *Use different audio tones instead of actual bits for control frames.*

Challenge2: Frame-level synchronization between WiFi and audio.

Possible Solution:

- *Use single audio frame for aggregated WiFi frames.*

Ongoing Work

- Evaluation of the limitations and the characteristics of audio channel in indoor environment.
  - Energy consumption of audio hardware.
- Development of Audio-WiFi schemes that utilize audio channel to enhance Wi-Fi network performance.
  - *Switching on/off the Wi-Fi interface using audio channel during.*
  - *Using audio channel as an control channel for sending ACK frames while WiFi is sending data frames.*
  - *Utilizing audio channel for coordinating between node to reduce the collision.*

Thank you

Questions?

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