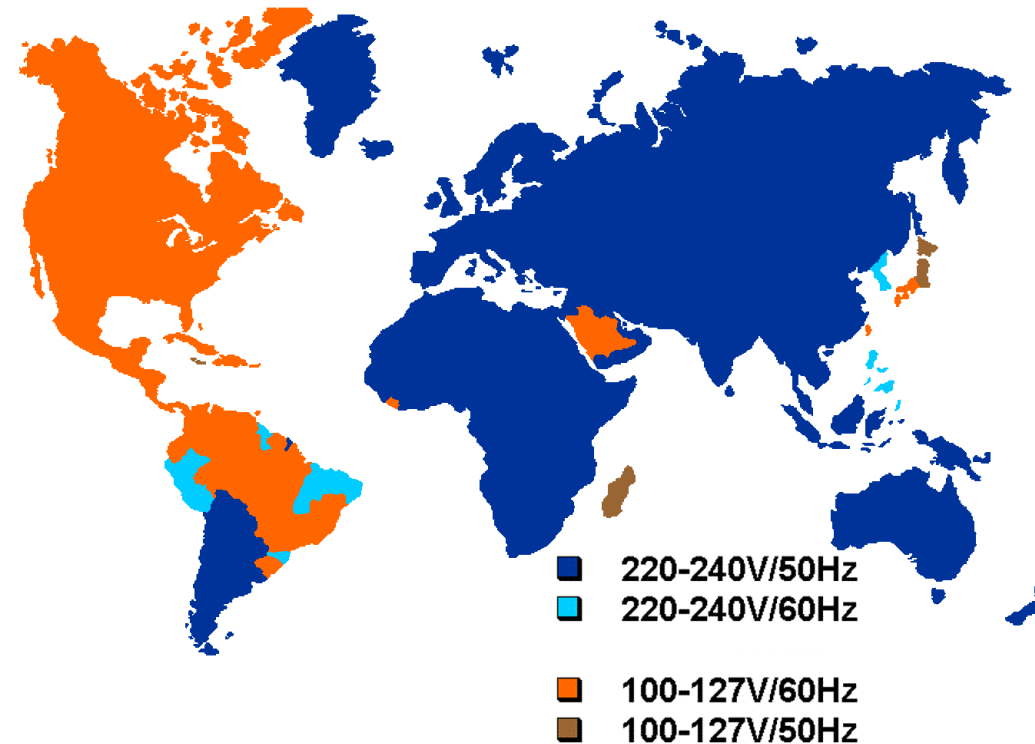
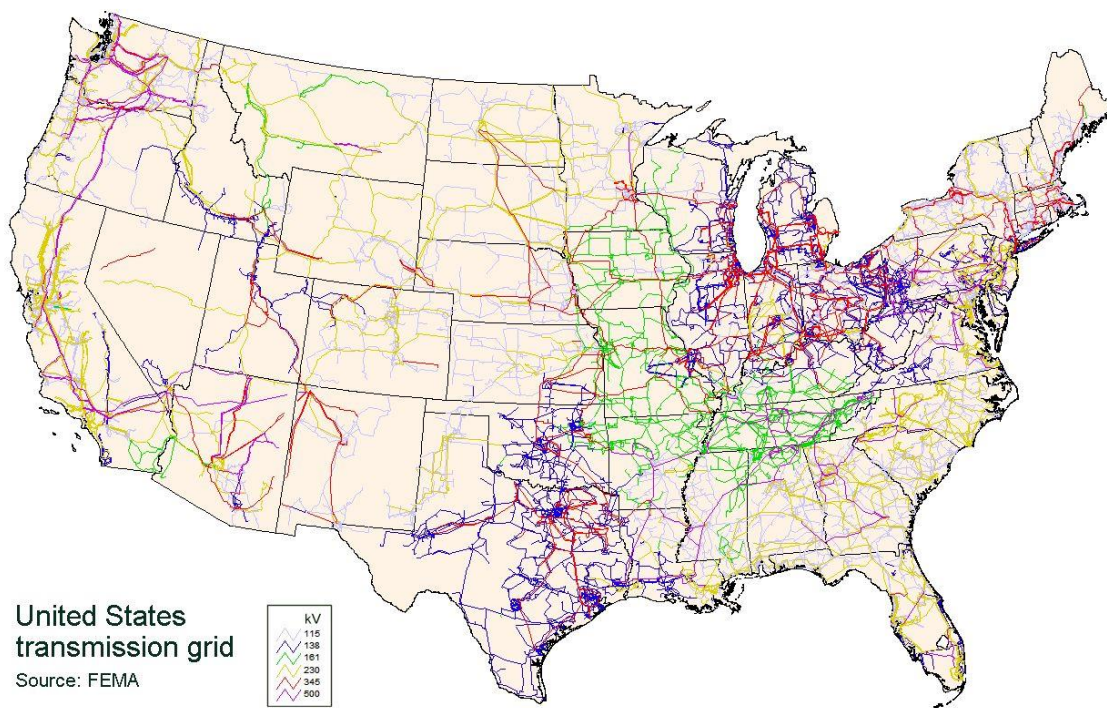


How can we track the user location?



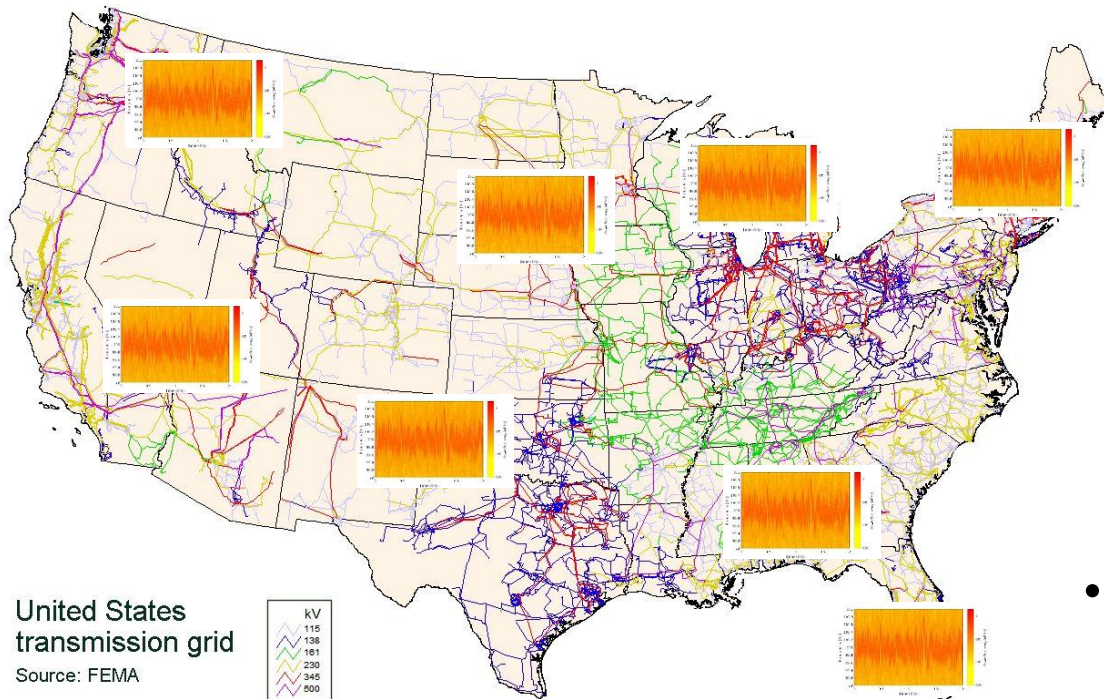
How can we track the user location?

ENF (Electrical Network Frequency)

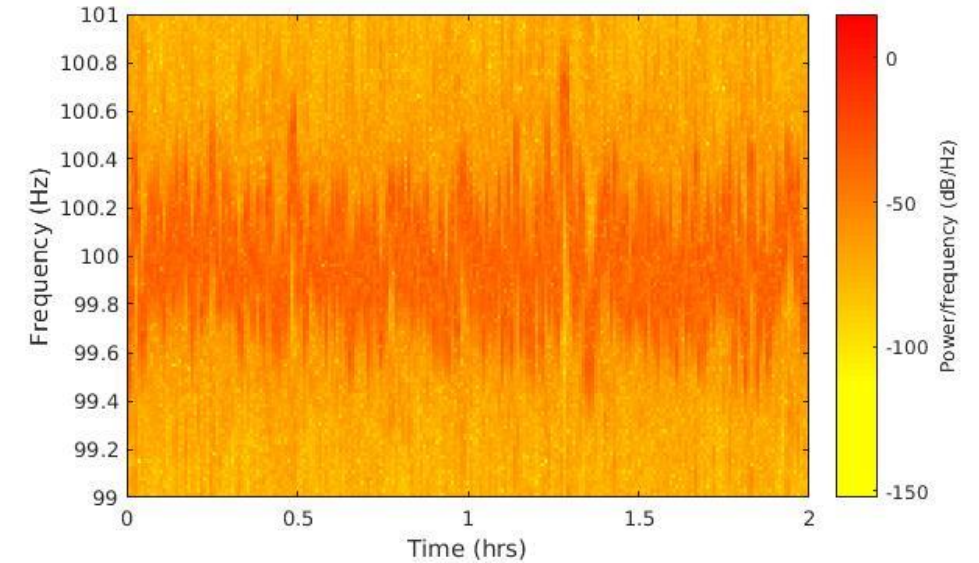


How can we track the user location?

ENF (Electrical Network Frequency)



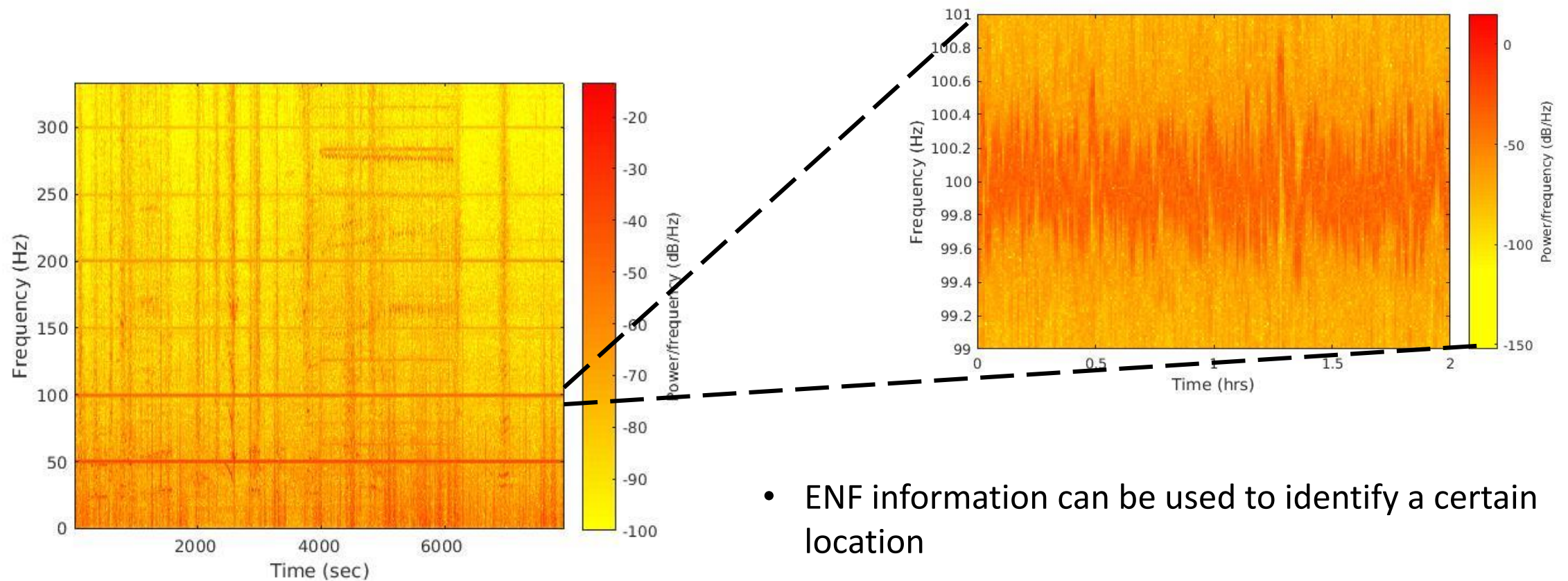
ENF signals



- Mostly captured in a **particular frequency**, either 50Hz or 60Hz
- The patterns of fluctuations of ENF signals are quite **unique** to every region

How can we track the user location?

ENF (Electrical Network Frequency)

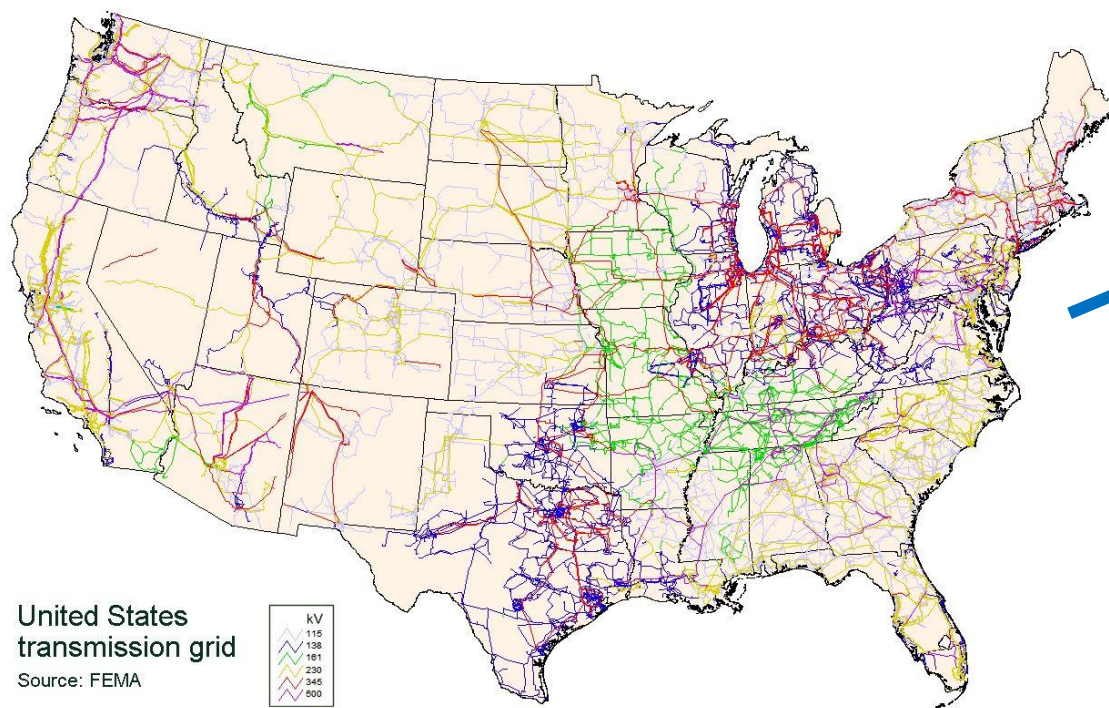


Audio spectrogram of user's voice

- ENF information can be used to identify a certain location

How can we track the user location?

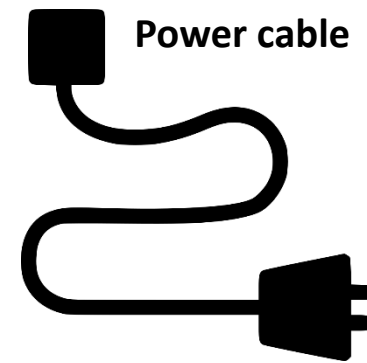
ENF (Electrical Network Frequency)



AC Current



Electrical circuit

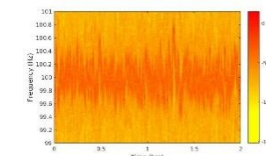


Power cable

ENF

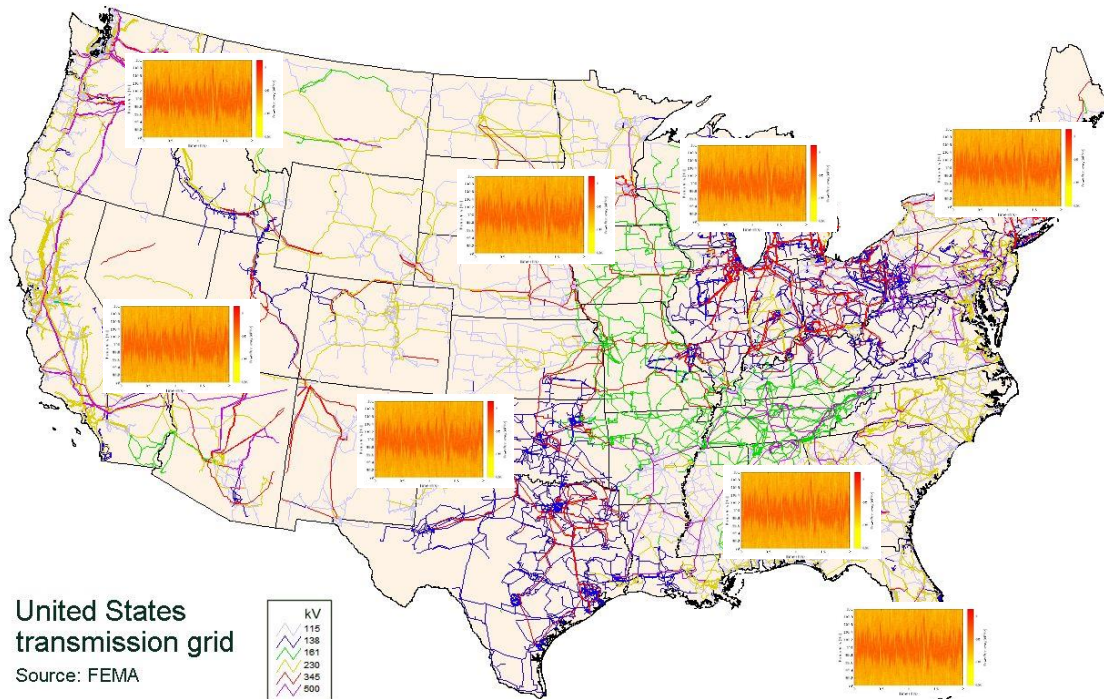


Recording device

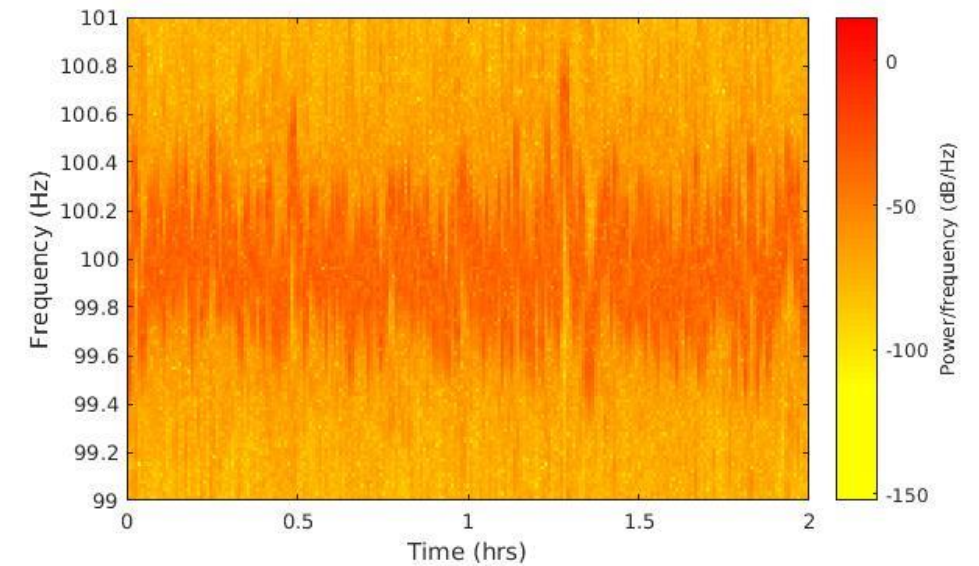


How can we track the user location?

ENF (Electrical Network Frequency)

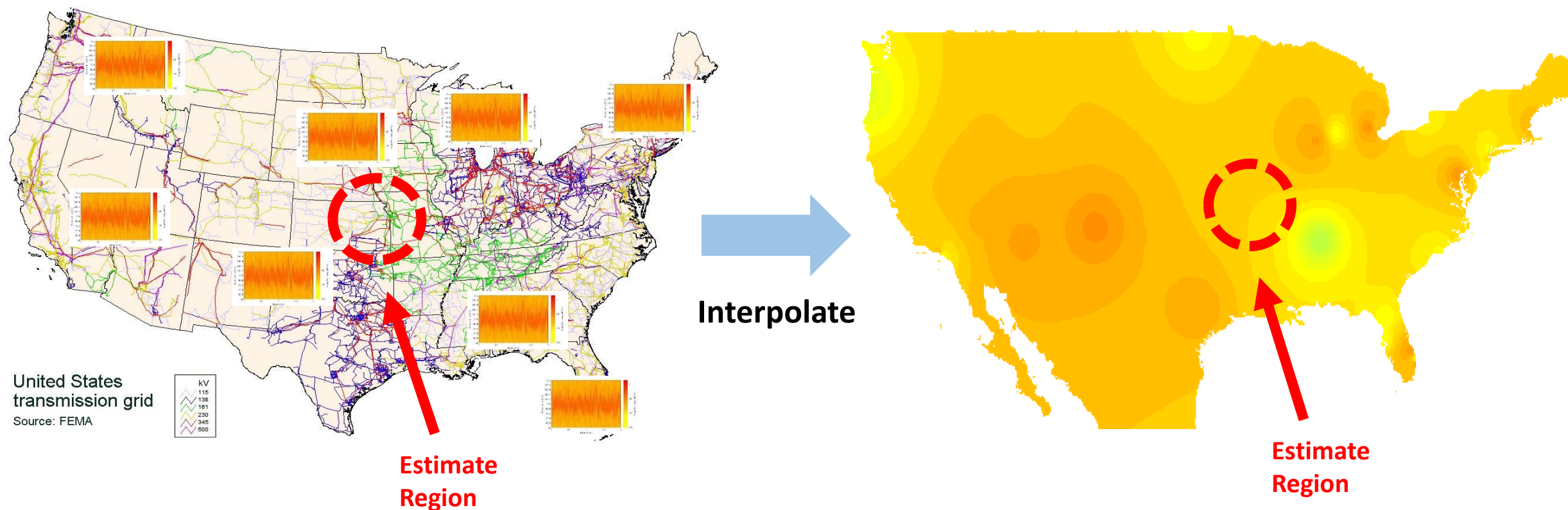


ENF signals



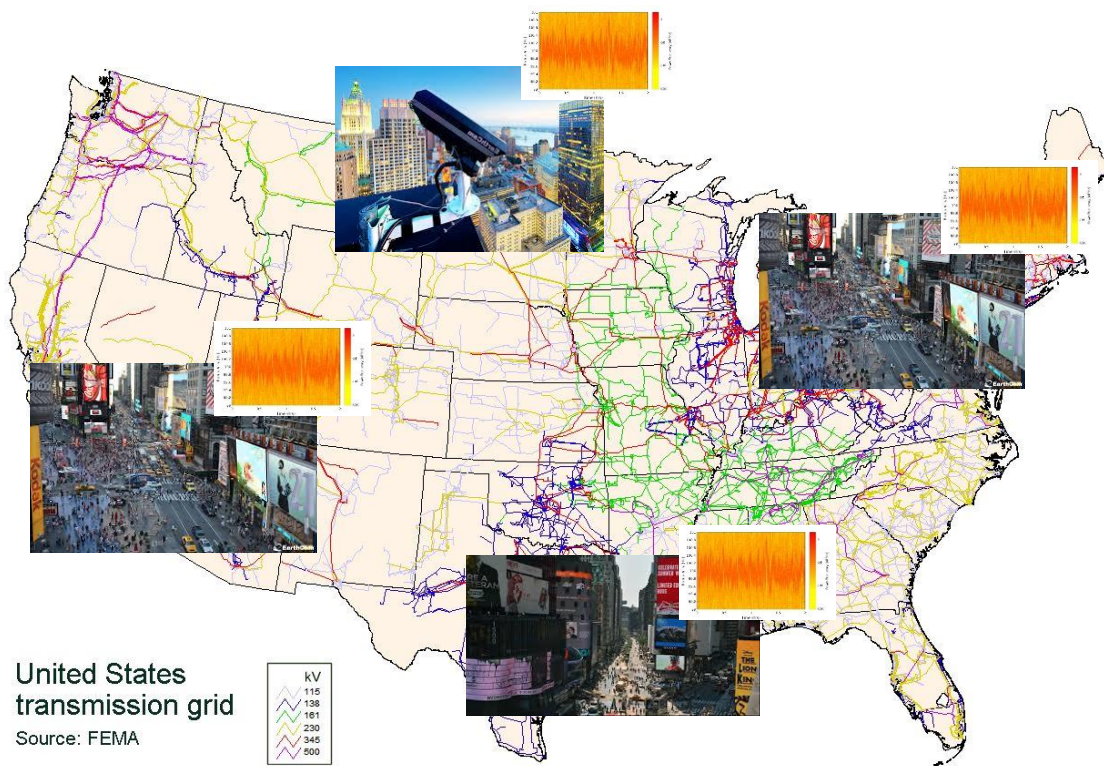
How can we track the user location?

ENF (Electrical Network Frequency)



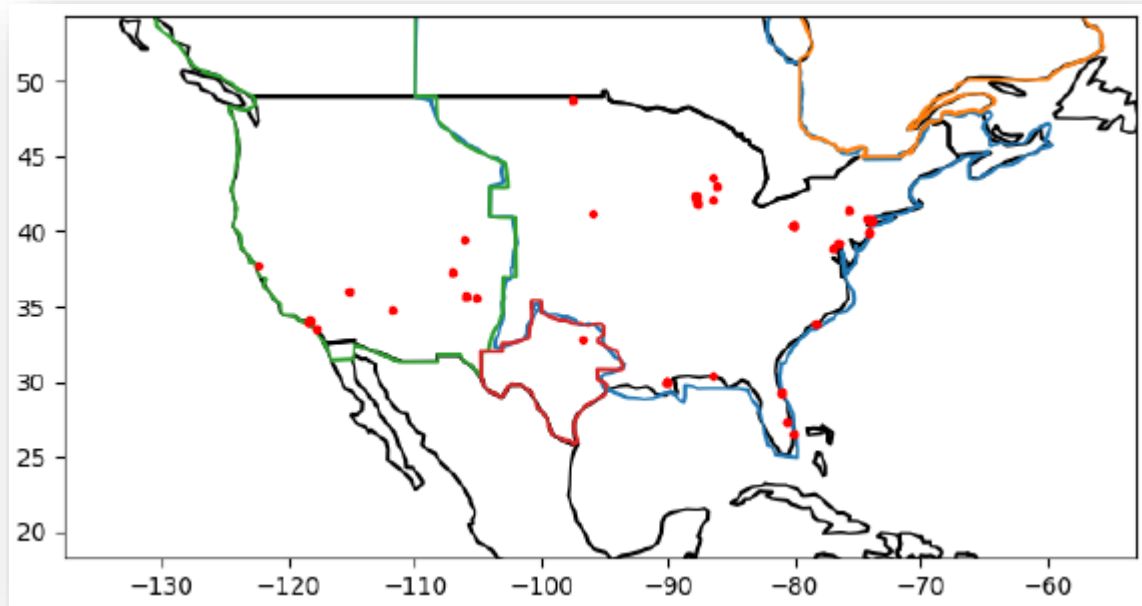
Crawling online multimedia: Reference data

ENF (Electrical Network Frequency)

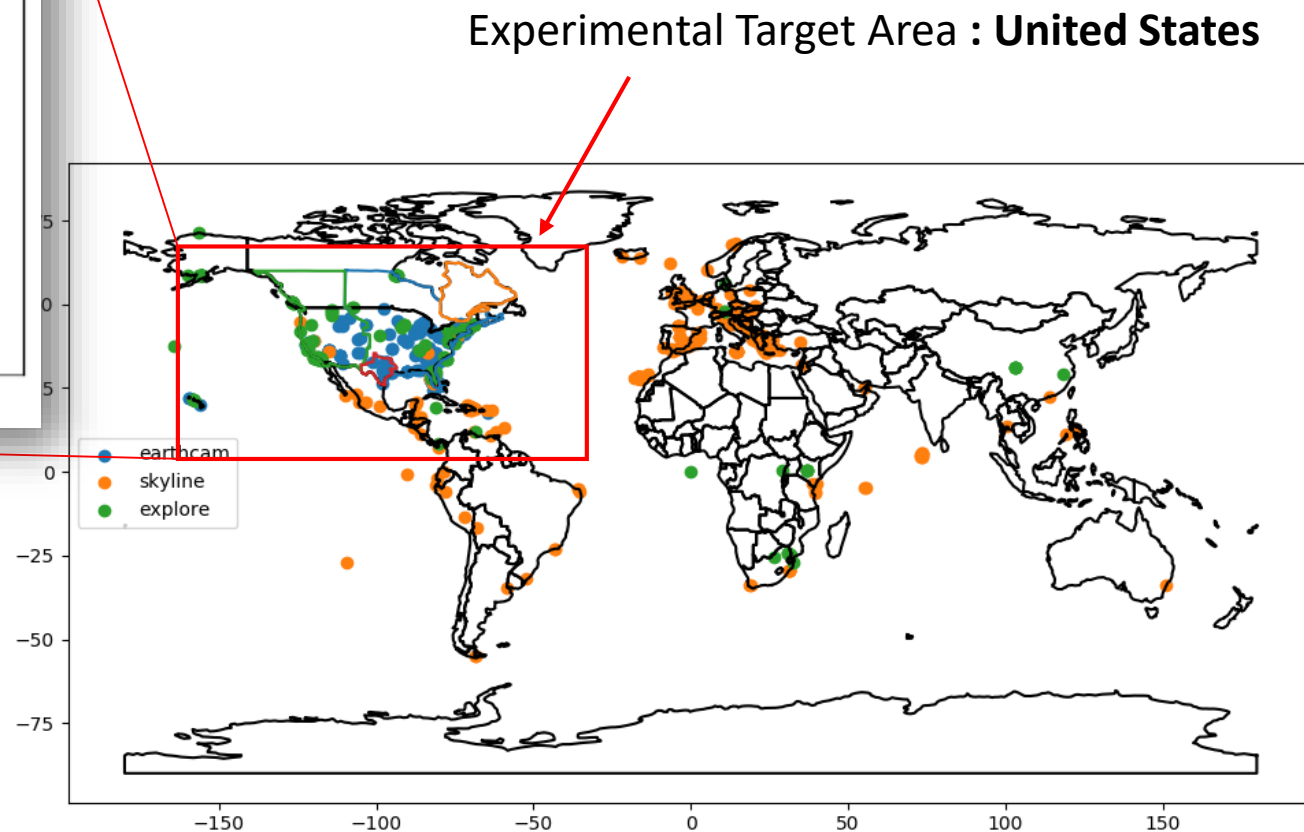


Some online multimedia data can be used to extract ENF signals from the recorded **multimedia**.

Crawling online multimedia: Reference data

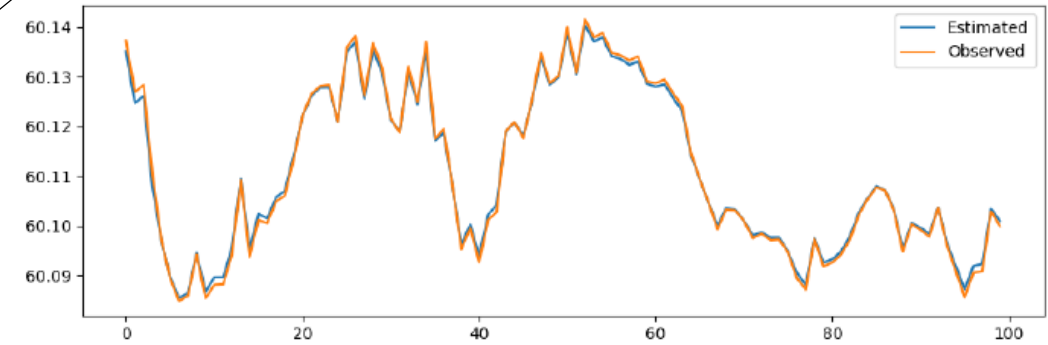
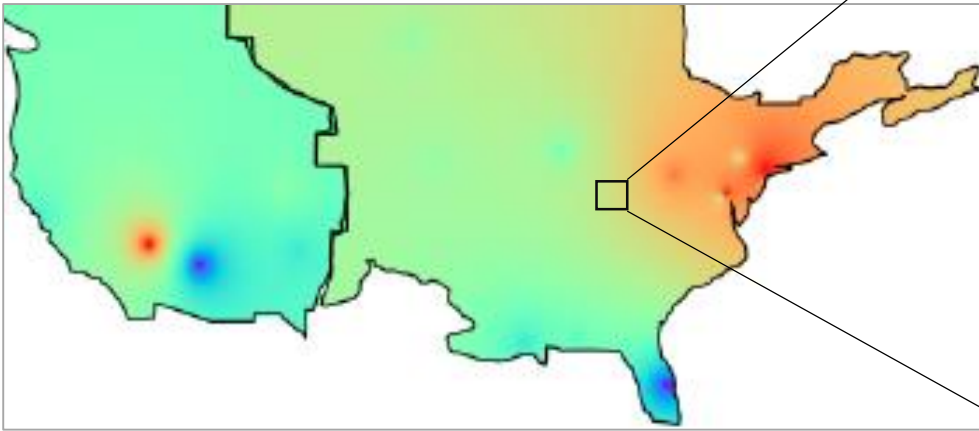


ENFs in the US after filtering

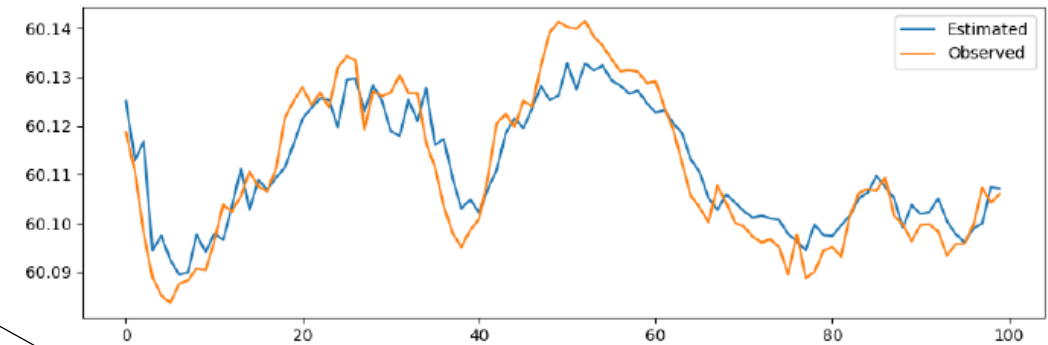


Audio files around the world

Interpolating ENFs to estimate target location value



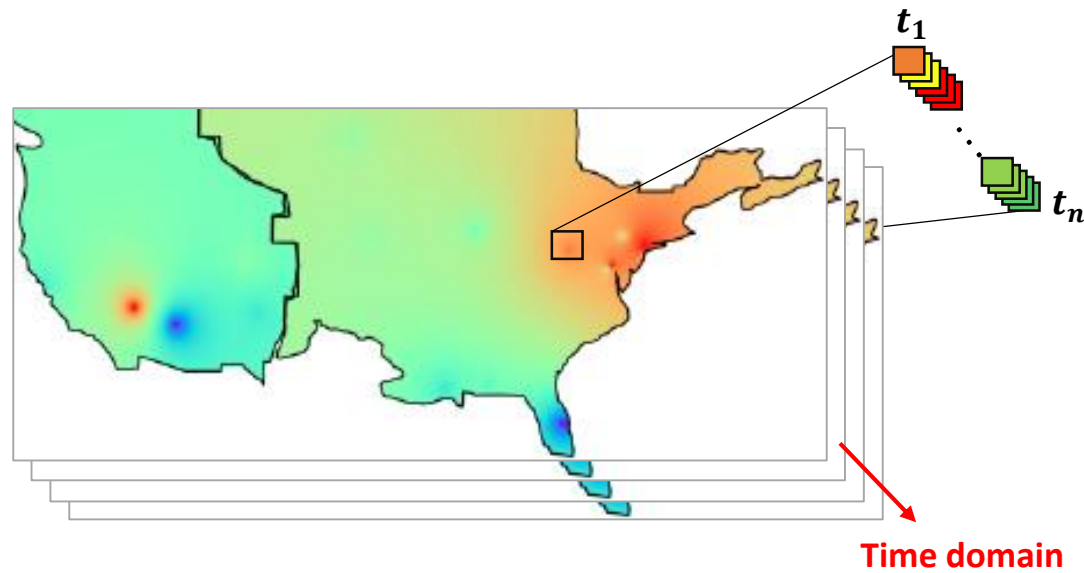
(a)



(b)

Performance of Interpolation Methods

- Calculating RMSE using LOOCV



RMSE of each point n

$$RMSE^{(n)} = \sqrt{\frac{1}{T} \sum_{t=1}^T [Z_t(x_n) - \hat{Z}_t(x_n)]^2}$$

Average RMSE of all points

$$\mathbb{E}[RMSE] = \frac{1}{N} \sum_{n=1}^N RMSE^{(n)}$$

$$\sigma[RMSE] = \sqrt{\frac{1}{N} \sum_{n=1}^N (RMSE^{(n)} - \mathbb{E}[RMSE])^2}$$