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WINLAB | Wireless Information Network Laboratory

Digital Twin for Network Energy Consumption

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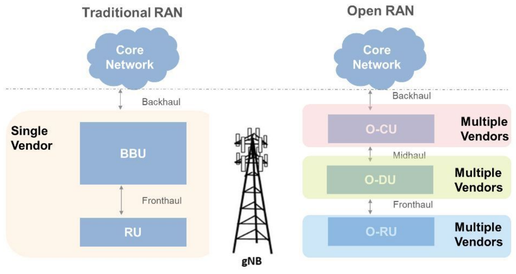
Overview

- Rising demand for 5G and 6G in cellular networks has led to increased energy consumption and operating expenses (OPEX)
- Creating a **digital twin** model will simulate network traffic to identify low-traffic periods
- Energy saving actions include implementing sleep mode strategy on **Open Radio Access Network (O-RAN)** components

O- RAN Architecture

- Main components of the O-RAN system includes the Radio Unit (RU), Distributed Unit (DU), Centralized Unit (CU)
- RU, DU, and CU desegregation allows for tracking of individual components to monitor energy usage



Comparison between a Traditional RAN to an Open RAN network https://www.mathworks.com/discovery/o-ran.html

Equations

- **RU Power Ranges (Watts):**

P_micro_0 = 59-110W, P_macro_0 = 197-531W

- **Basic RU Power Model:**

ru_power = round(min_p + (max_p - min_p) * ru_load,2)

- **Algorithm for Micro RU's:**

Algorithm 1 Number of Micro RU needed Algorithm

```
rangeAboveThreshold ← maxTraffic − threshold
trafficRange ← traffic − threshold
percentageOfMicroRU ← trafficRange/rangeAboveThreshold
neededMicro ← percentageOfMicro · numberOfMicros
```

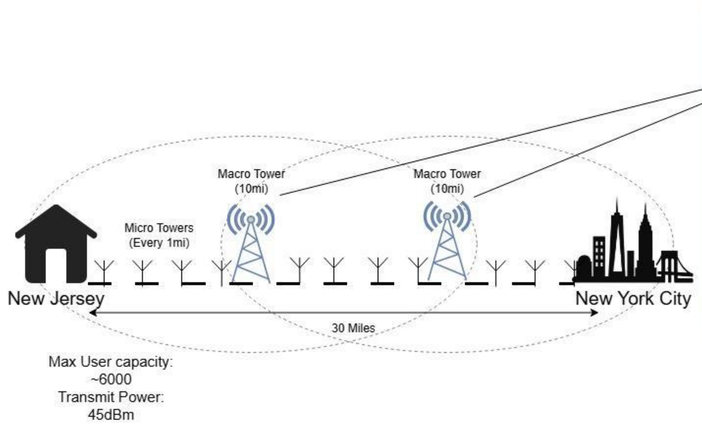
- **3GPP Defined Energy Efficiency Formula**

$$EE = \frac{Data\ Volume(DV)}{Energy\ Consumed(EC)}$$

Highway Traffic Dataset

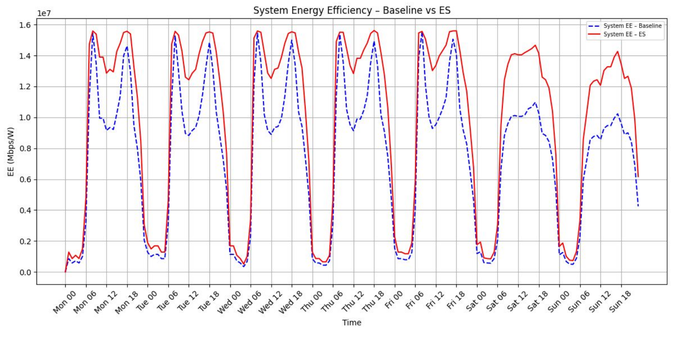
- We were able to reverse engineer our own data set of cellular network traffic on a highway from a reference paper
- This is over a 7 day period measuring bytes over each hour

Highway Scenario



(Real Life Example of Macro Cell Tower)

Energy Efficiency



This graph accurately depicts the energy efficiency of our simulation using the energy efficiency equation. The Y-axis measure the EE in mbps/W and it evident our scenario is efficient due to the gap between the red line (ES) and blue line (Baseline). The greater the gap the more efficient

References

F. Xu, Y. Li, H. Wang, P. Zhang and D. Jin, "Understanding Mobile Traffic Patterns of Large Scale Cellular Towers in Urban Environment," in *IEEE/ACM Transactions on Networking*, vol. 25, no. 2, pp. 1147-1161, April 2017
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Shankaranarayanan, N. K., Li, Z., Seskar, I., Maddala, P., Puthenpura, S., Stancu, A., & Agarwal, A. (2024, October). POET: A platform for O-RAN energy efficiency testing. In 2024 IEEE 100th Vehicular Technology Conference (VTC2024-Fall) (pp. 1-5). IEEE.

Acknowledgments

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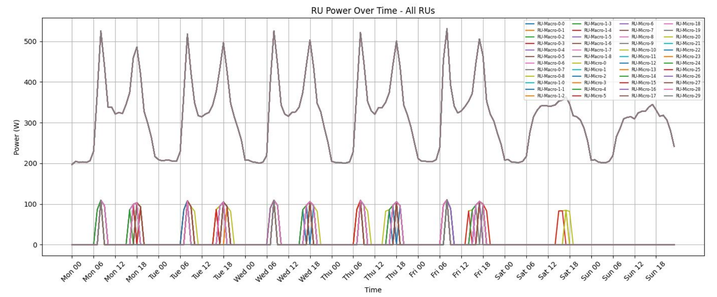
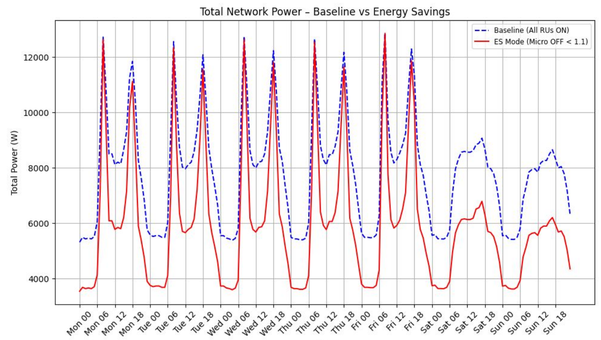
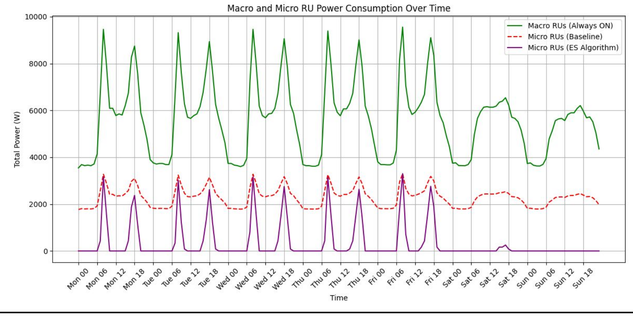
Data Collected/Plots



Our team was able to reflect an accurate power consumption plot using data collected in Shangai. Due to Macros having greater coverage we gave them a higher power range than Micros
We measured it using **18 Macro Radio Units** and the two peaks during commute to and from work/school
We accurately visualized the **30 Micro Radio Units** power consumption while implementing an algorithm to turn them on.
We collectively decided to turn off all Micro RU's if the traffic was below **880 Megabits**
It would be inefficient to turn all 30 RU's on if the traffic was for example 1.2 x 10^8 so we implemented an algorithm to proportaionaly use them based on the traffic load and evenly disperse them along the 30 miles





Plotted accurate visalizations of total power generated by all ORAN components. The first graph depicts the power consumption specifically for both types of RUs and the gap shows the difference in total power if we used ES strategies or not. The second graph depicts when the Macro RUs are always on witht he green line, When the Micro RUs do not implement es actions as the red line and when they do shown in purple

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