UC San Diego
JACOBS SCHOOL OF ENGINEERING
Electrical and Computer Engineering

WCSNG
Wireless Communications Sensing and Networking

Multiple smaller base stations are greener than a single powerful one: Densification of Wireless Cellular Networks

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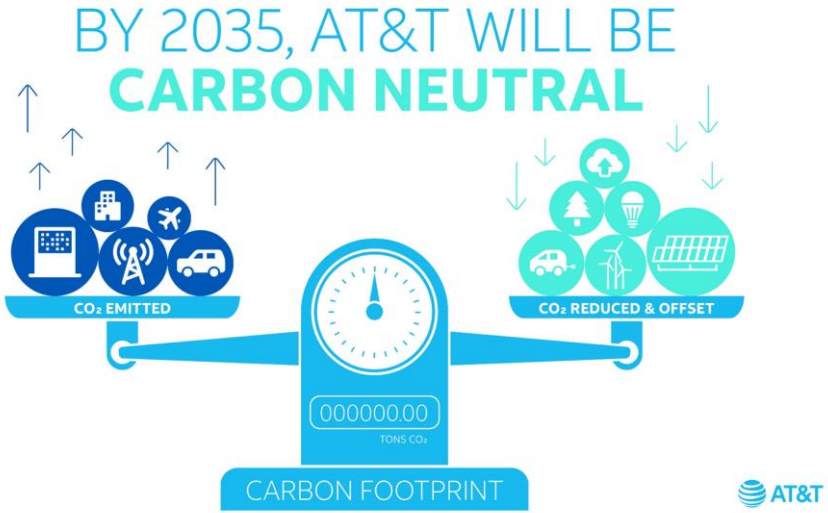
https://wcsng.ucsd.edu/sustainability

LTE: One of humanity’s biggest achievements of 2010’s?

- Always connected to a far-away located base-station
- Plethora of new applications over the past decade: rideshare, video streaming/calls, can’t imagine life w/o LTE

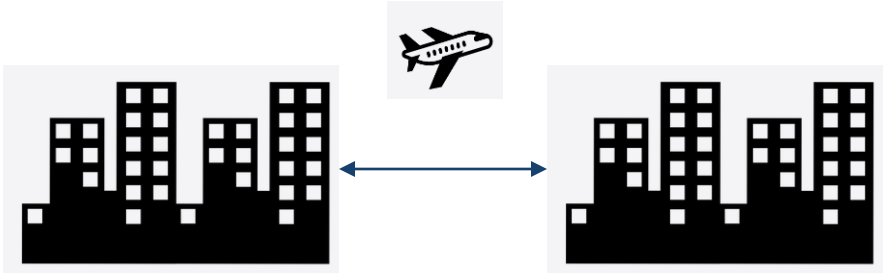
However, this has come at a huge cost to environment

- Carbon footprint of Telecom: 1.6%, comparable to aviation industry [1]
- Telecom Industry under heavy scrutiny to reduce the footprint [2]
- 4G base stations consume about 1 kW power, with 5G this is going to rise to 4 kW [3]



[1]: "**The Wireless Communications Industry and its Carbon Footprint",** AZO CleanTech
[2]: "**AT&T Commits to be Carbon Neutral by 2035**": About AT&T
[3]: "**Energy-efficient 5G for a greener future**", nature electronics

Why telecom carbon footprint comparable to aviation?



City A

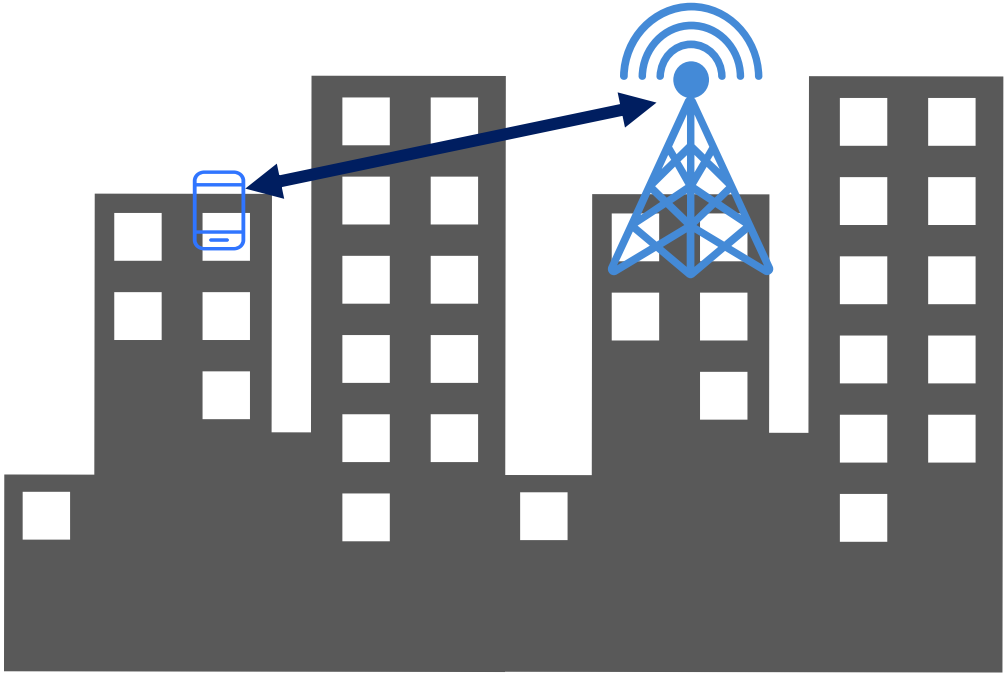
City B

100s of miles away

Data Packets communicated to base stations miles away, >>1,000,000 times a day

Both these industries face the curse of distance

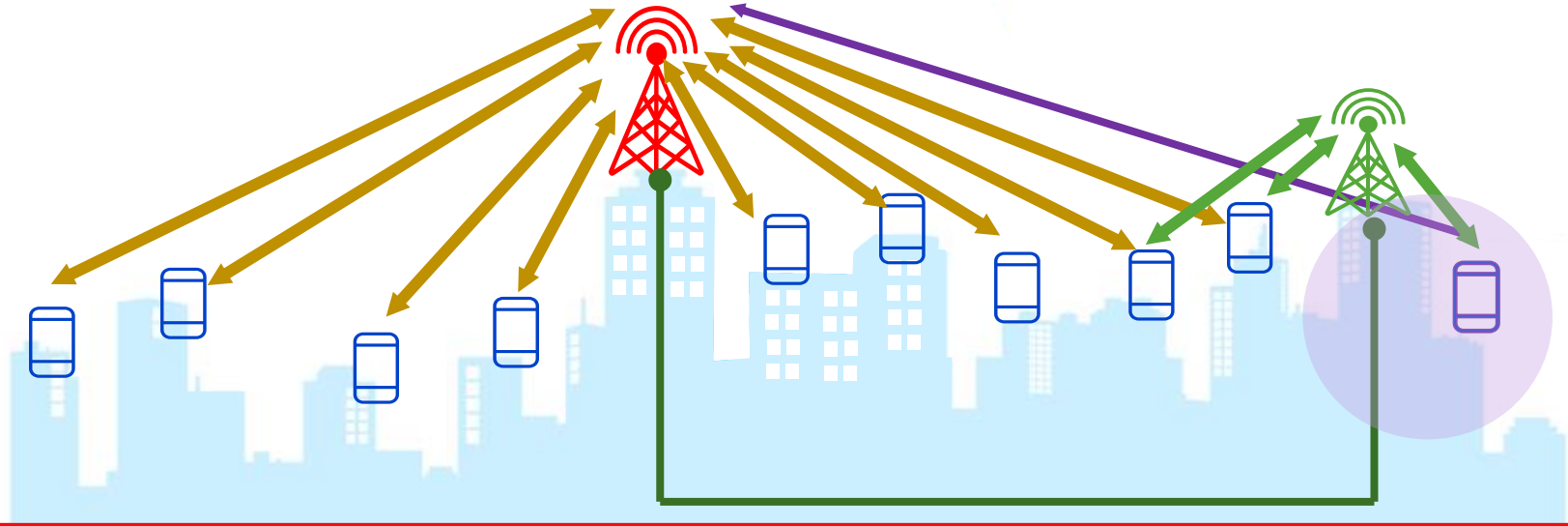
Communicating to far away BS is power consuming



- Communication happens via EM waves, die out due to **high distance**
- BS transmit at very high power to get the required range
- Effort towards making power amplifiers spit high enough power levels

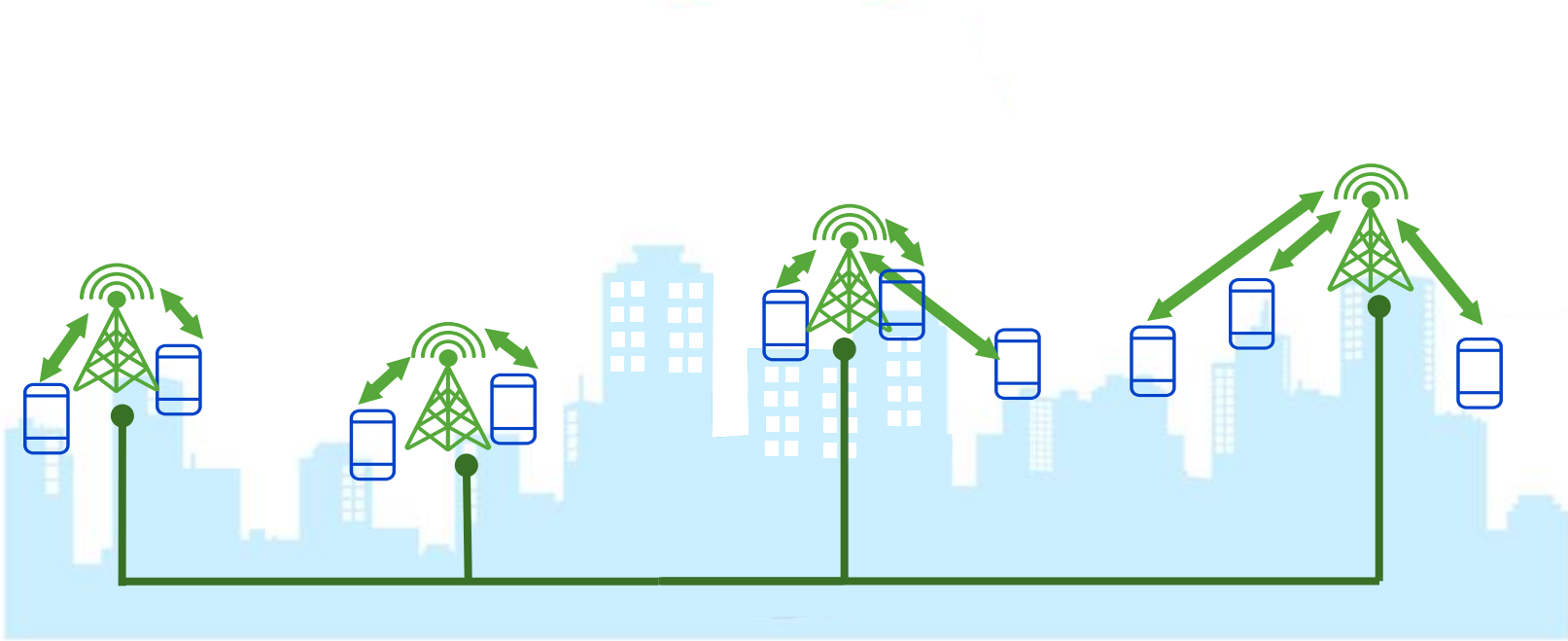
BS designed to maximize range by transmitting high power

Existing deployments, small cells increase capacity



Existing deployments have used smaller base stations as side characters to just address capacity

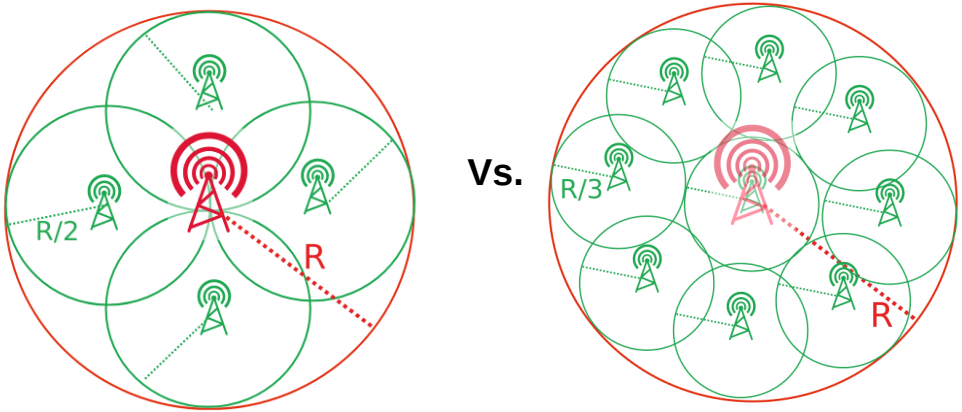
We propose uniform dense deployment for green future



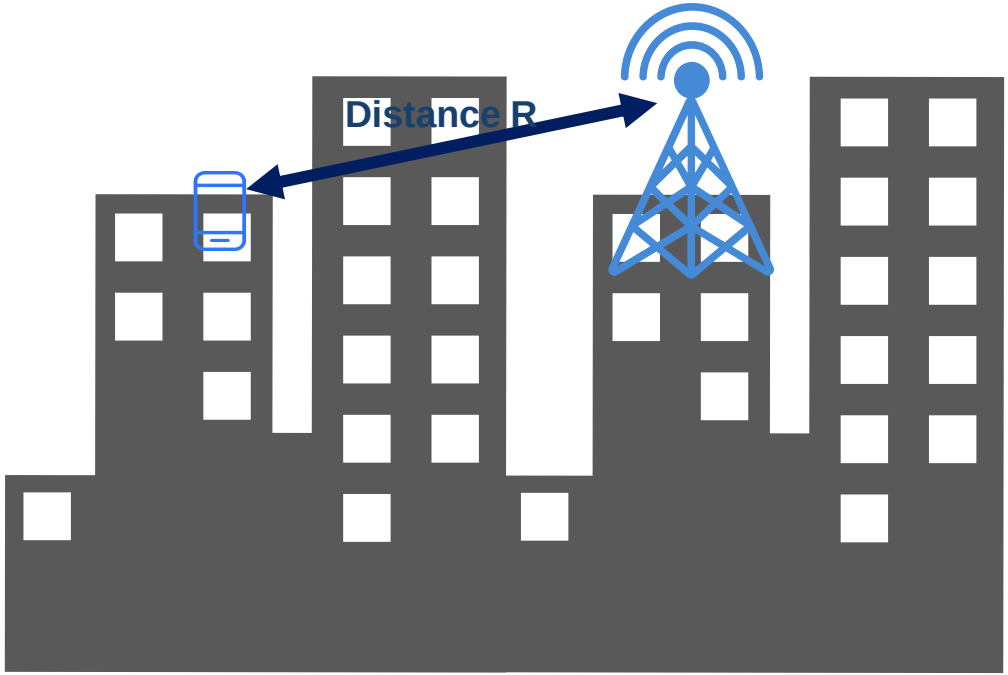
Small base stations become main characters!
Less wireless air travel time -> Tons of power saved

Talk Roadmap

1. Modelling the curse of distance in wireless transmission
2. How uniformly dense deployment breaks the curse of distance
3. LTE case-study, how much to densify?
4. Deployment and Management challenges

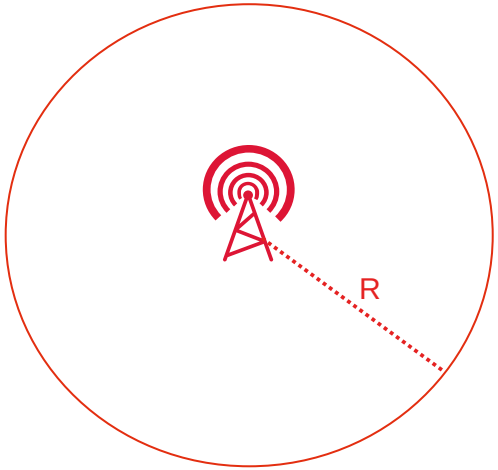


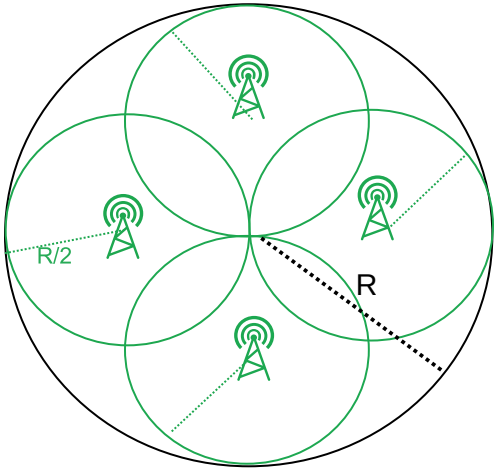
How signals attenuate with distance?



- Mobile device requires signals at level P_R
- Path loss (PL) $\propto (1/R^2)$ over air
- Base station transmits at $P_R*(KR^2)$
- Statistically PL $\propto (1/R^{\gamma})$ urban setting, $\gamma > 2$
- $\gamma \sim 2.5\text{-}3.5$, BTS transmits at $P_R*(KR^3)$

How densification defeats the curse of distance?



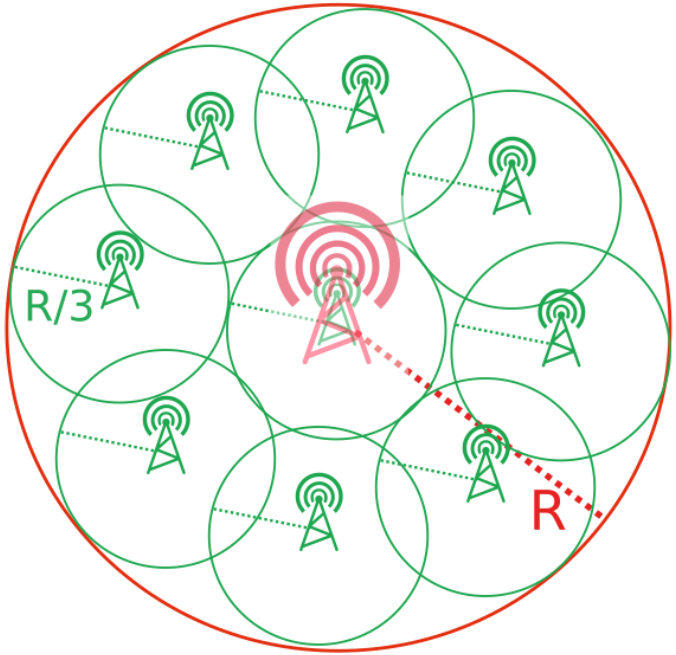


- Single Red BS (existing)
- Red BS transmits $P_R*(KR^3)$
- Total power $P_R*(KR^3)$

- 4 green BS (proposed)
- Each Green BS transmit $P_R*(K(R/2)^3) = P_R*(KR^3)/8$
- Total 4 Green BS power: $4*P_R*(KR^3)/8 = P_R*(KR^3)$**/2**

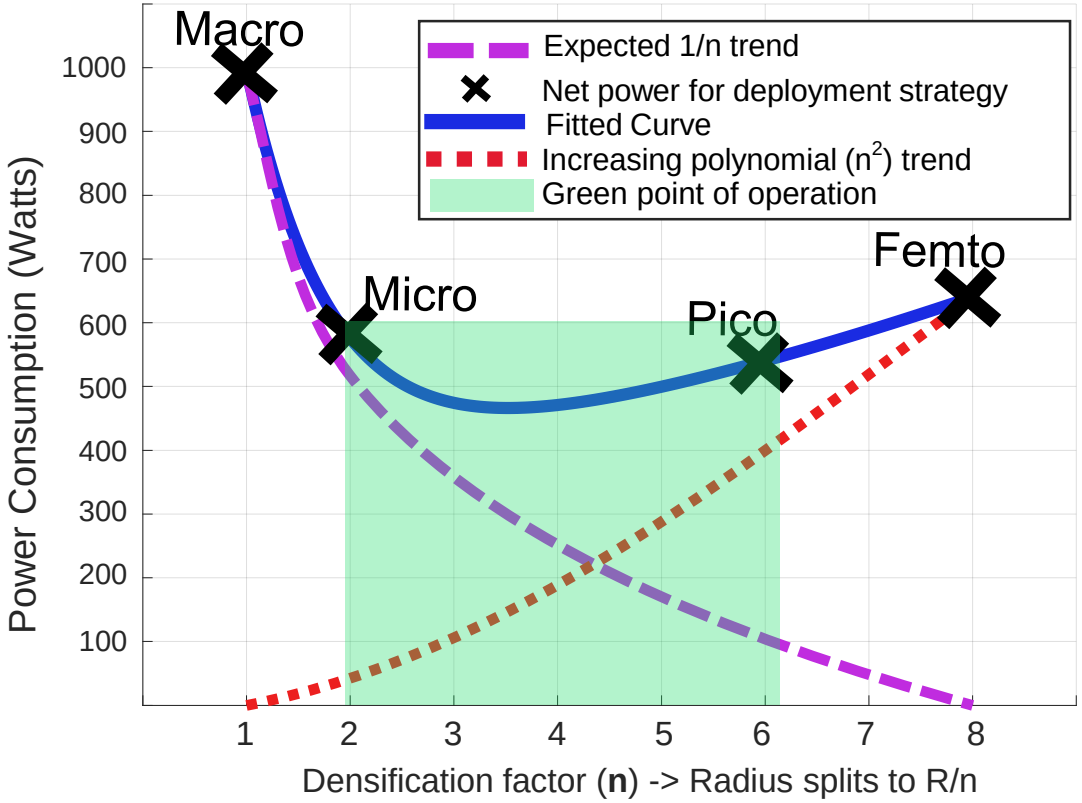
All 4 Green BS combined consume ½ the power of red BS!

Generalization to n-levels of densification

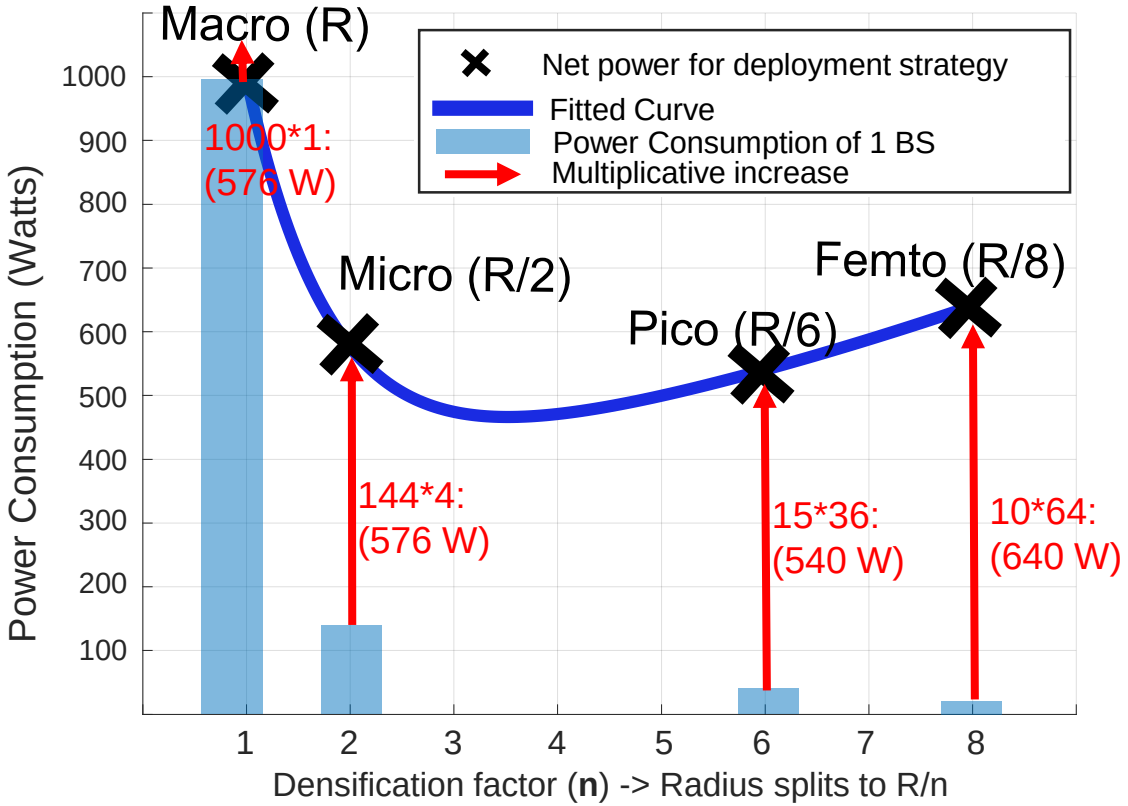


- Splitting radius to R/n -> Requires n^2 BS
- n^2 Green BS transmit $P_R*(K(R/n)^3) = P_R*(KR^3)/n^3$
- Total n^2 Green BS, net power: $n^2 *P_R*(KR^3)/n^3$
- n^2 Green BS consume net **1/n** power of single Red BS
- Splitting to R/1000 => 1000 times power savings?

How much to densify? The green pt. of densification



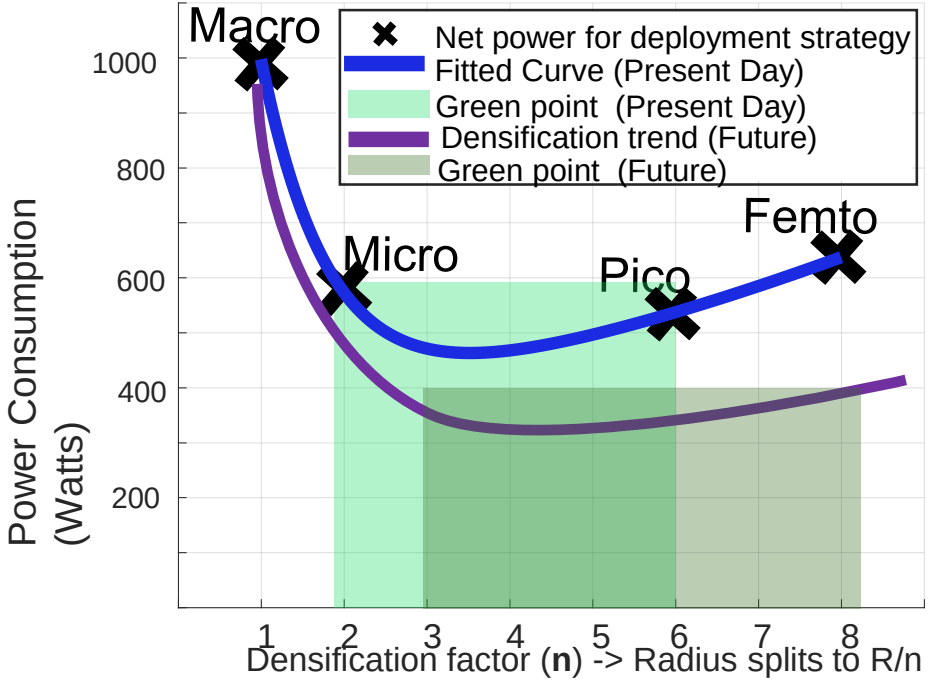
Curse of numbers -> Multiplicative increase in power



Upcoming innovations can shift the green point further

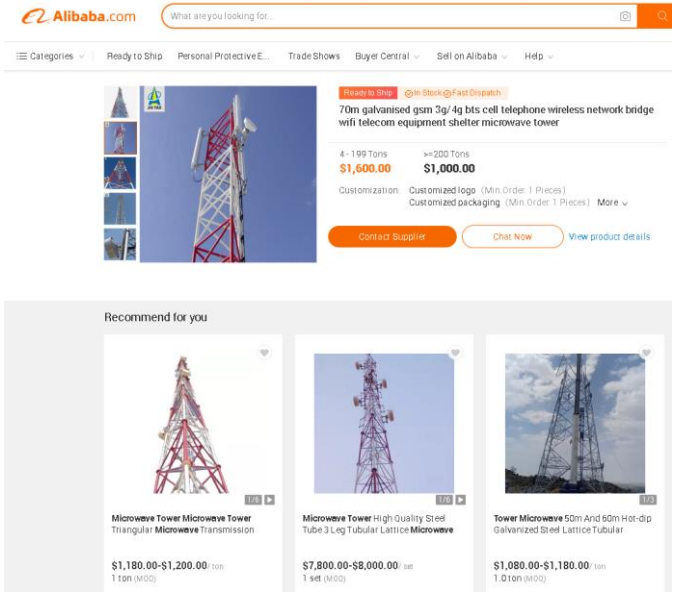
(1) **Reduce fixed cost**: Design efficient PAs + Optimize RF/BB power

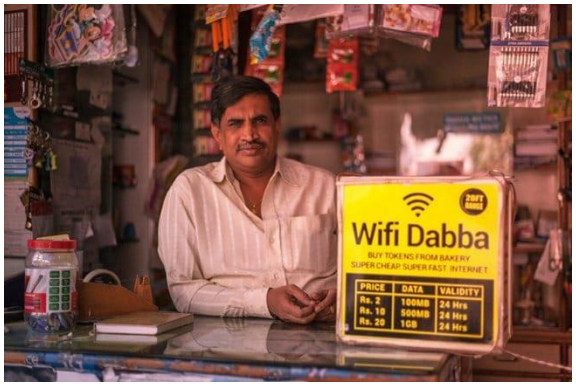
(2) **On-demand flexible reduction of 'n':** Softwarized cloud management



Who will setup these 100's of base-stations?

Deployment challenges: incentivising communities to set up BS

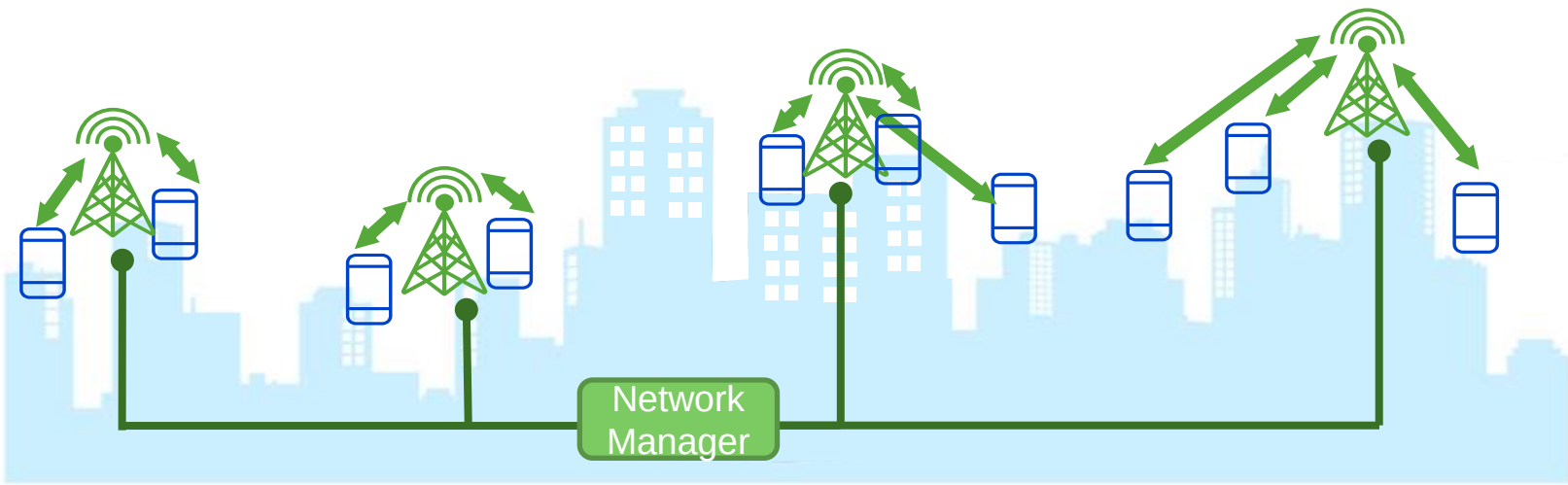




Who will orchestrate this big network of base-stations?

Not just the base-stations, but a network of base-stations

- **Sustainable backhaul:** use existing laid telecom cables instead of specialized fibre networks
- **Interoperability:** designing low-power micro base-stations compatible with O-RAN stackup
- **Hardware Reuse:** Use 3G/upgraded WiFi APs as smaller BS+ old CPUs/Smartphones for compute



Conclusion: Densified base-station deployment can lead to a greener and scalable future of wireless networks

- Reduced net “air-time” of wireless transmission => **power savings**
- Curse of distance vs Curse of numbers tradeoff => **densification green point**
- Deployment and Management challenge of uniformly dense networks => **incentivisation**