Wi-Fi Goes to Town:
Rapid Picocell Switching for Wireless Transit Networks

Speaker: Zhenyu Song

Zhenyu Song, Longfei Shangguan, Kyle Jamieson
{zhenyus, longfeis, kylej}@cs.princeton.edu

PAWS
Princeton Advanced Wireless Systems

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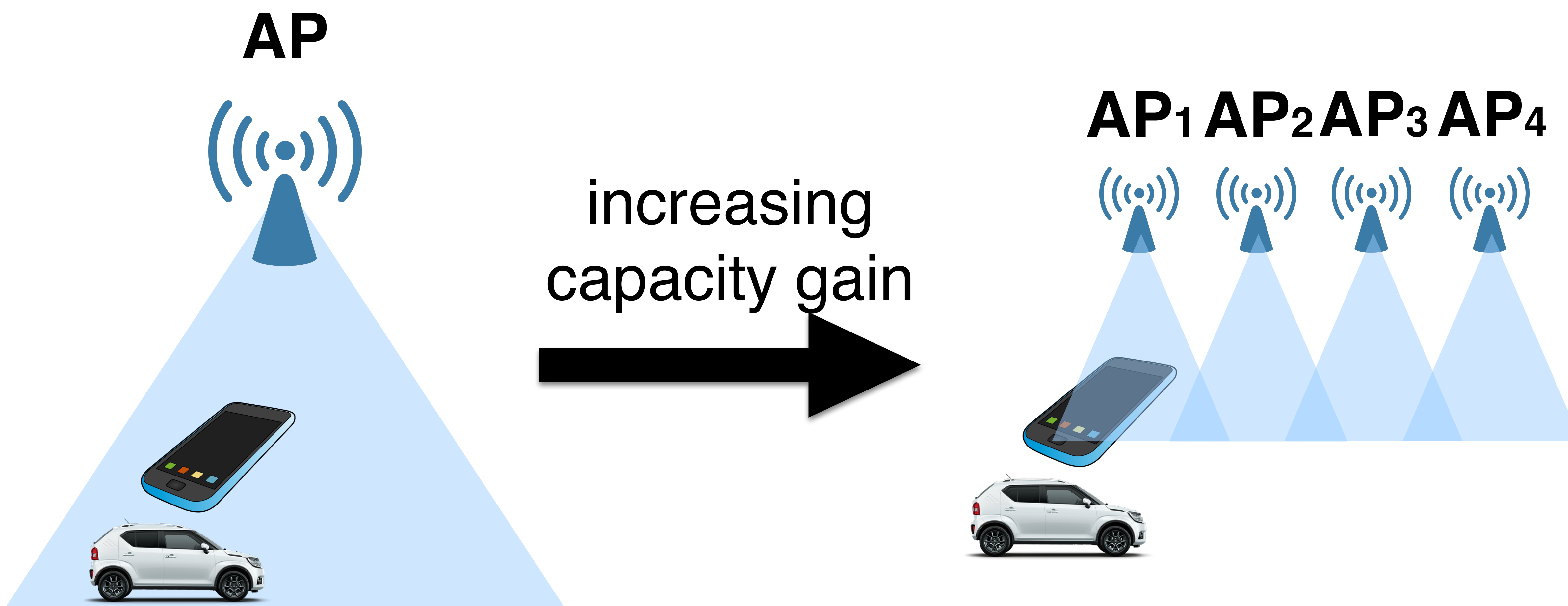
Motivation

- Billions of commuters on trains, light rails and in cars surf the internet

How can we increase the wireless network 1000X in bits/(second*dollar)?

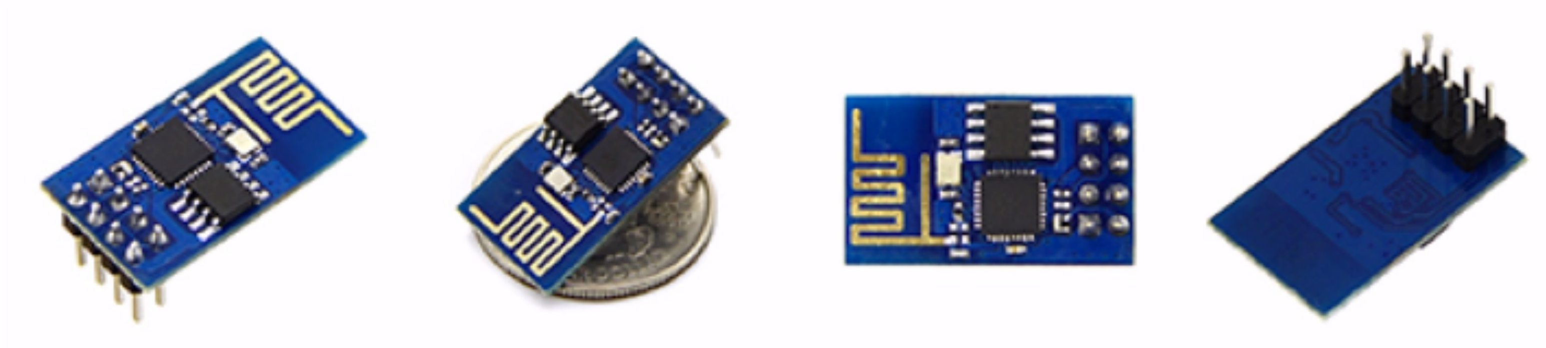
Motivation

- “*The majority of capacity gains over the past 45 years is due to the decreased size of each cell.”* ——Cooper



Two recent observations

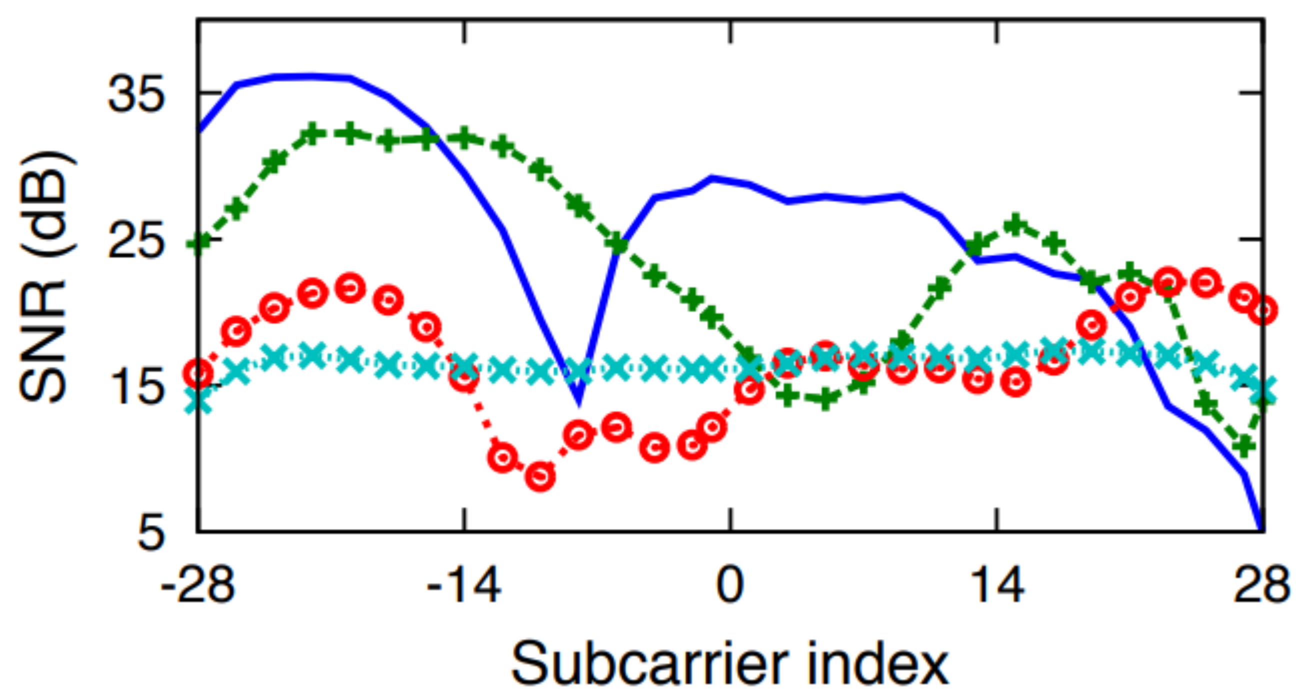
- Very low-cost AP (<= $5)



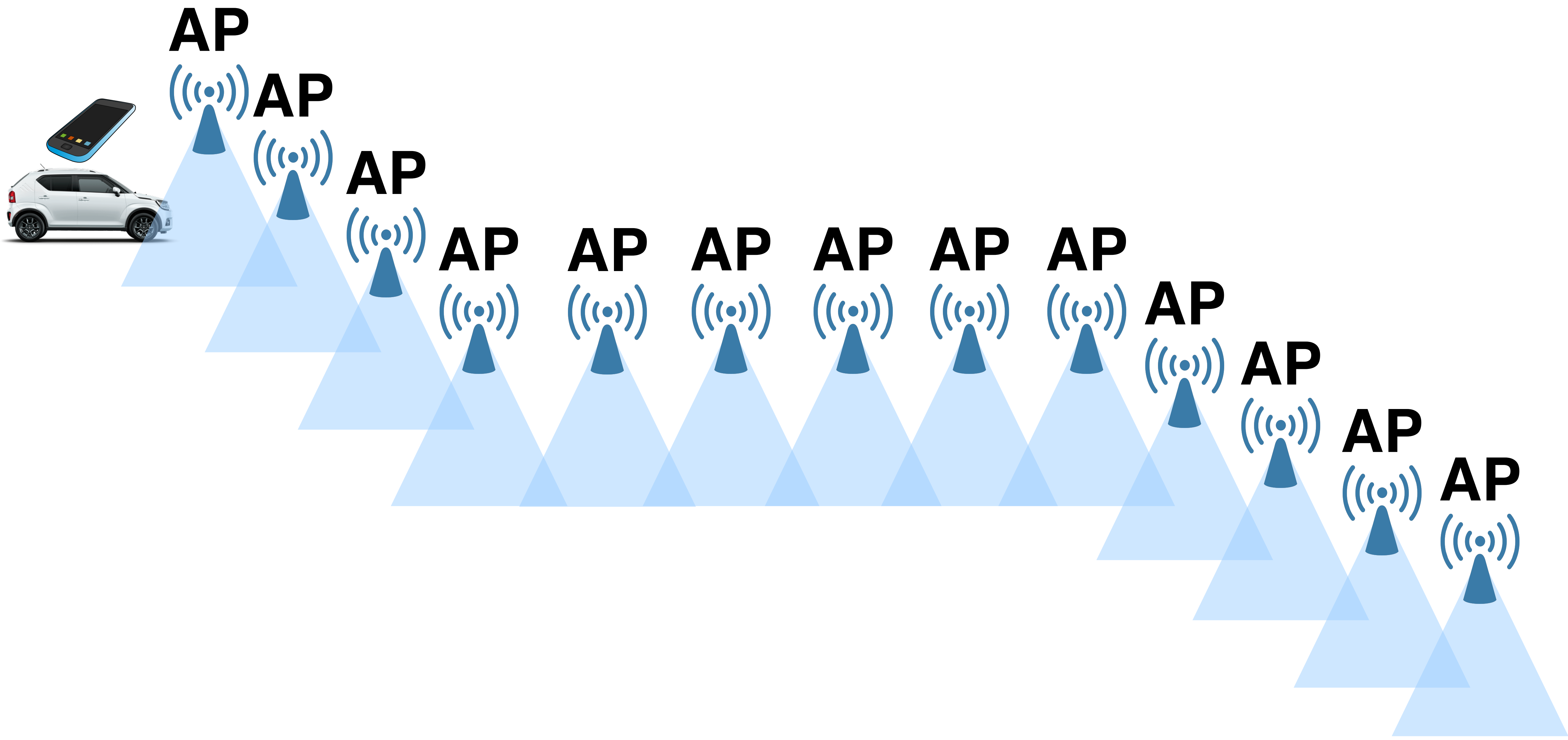
The ESP8266 Wi-Fi and system-on-chip module,available ca.2016 for $5.

- Commodity APs can extract fine-grained channel state information

[Halperin et al.]

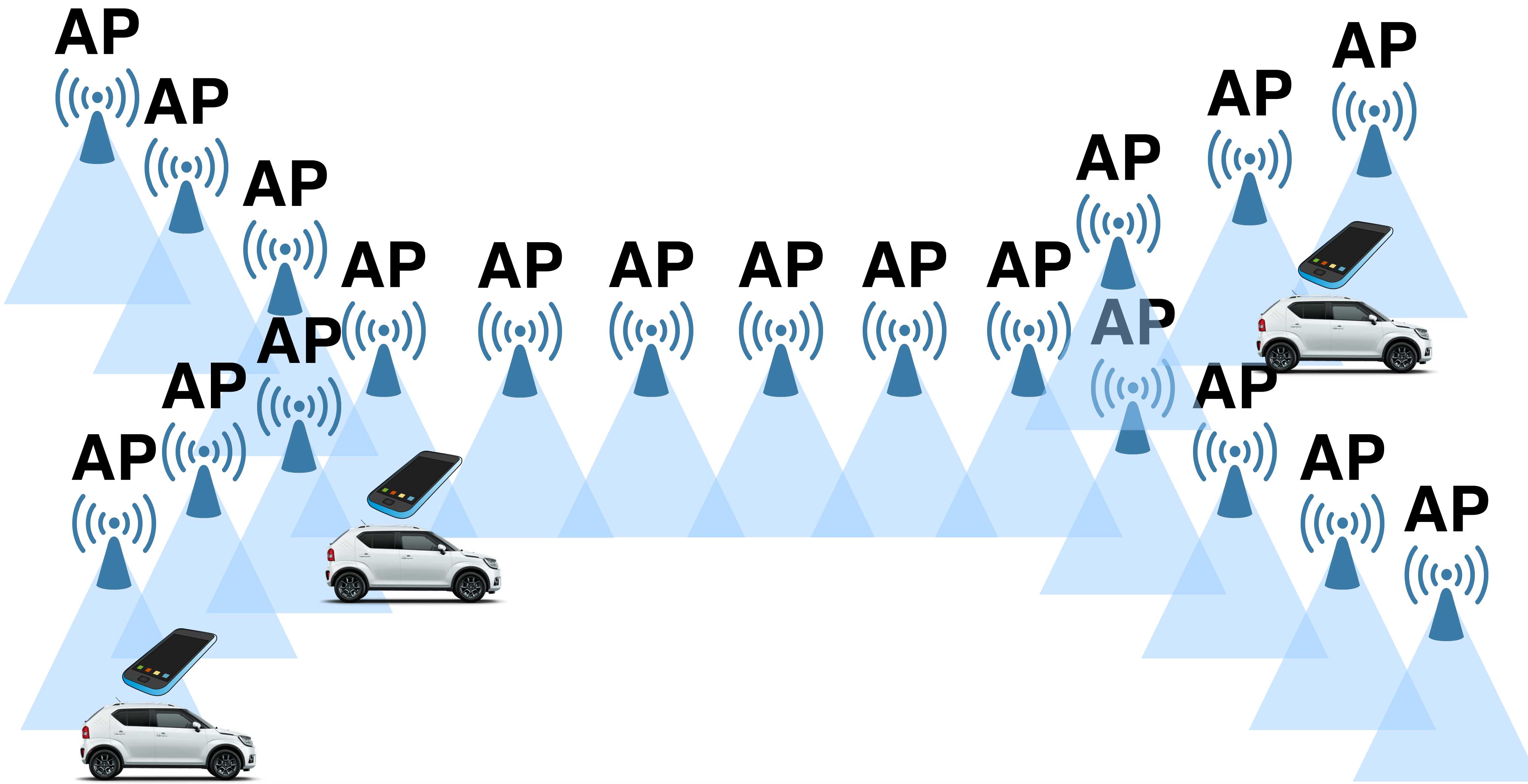


Wi-Fi Goes to Town: Picocell AP network for transit



Problem: picocells + vehicular speed

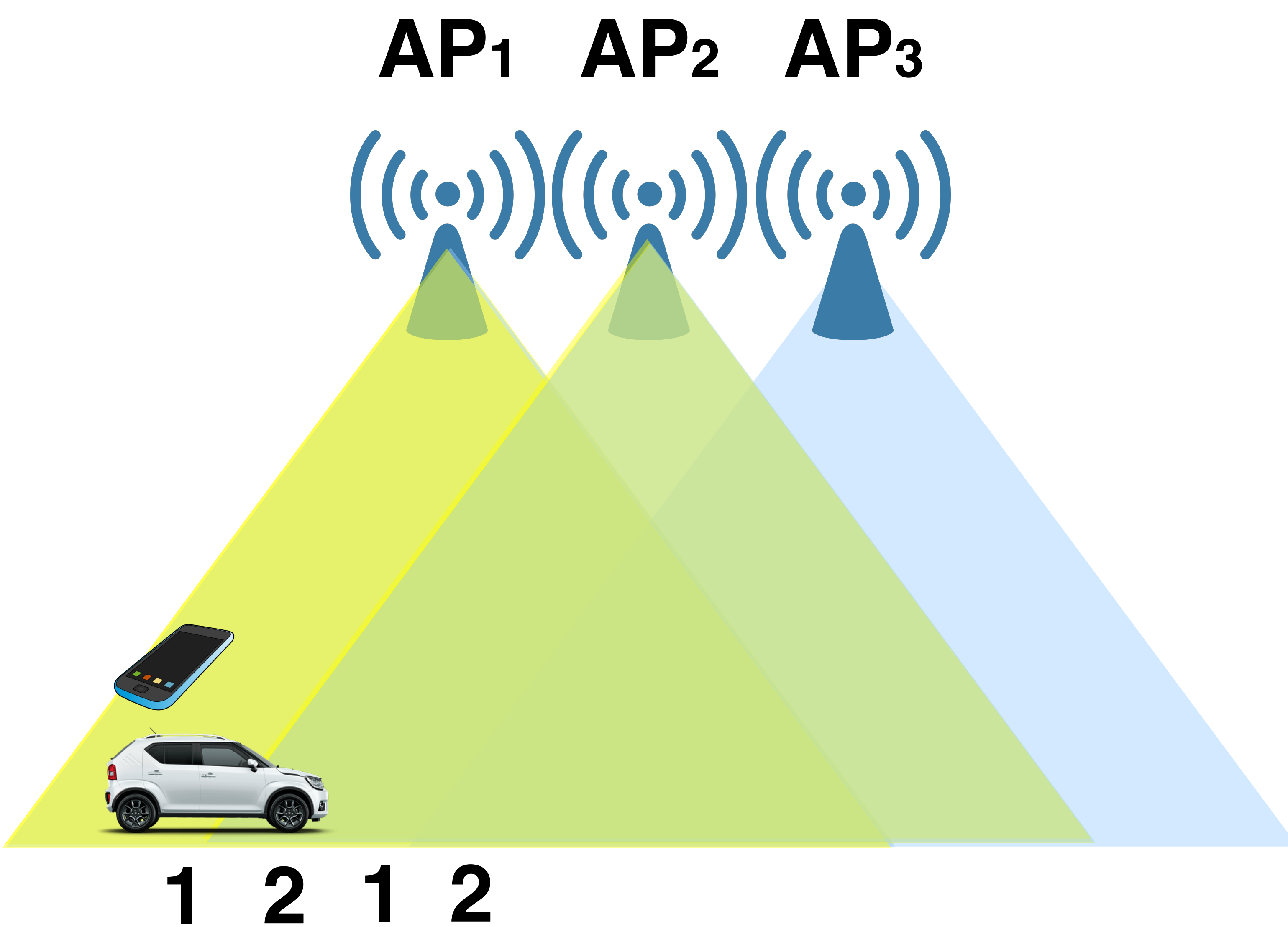
- How to support switching between APs?

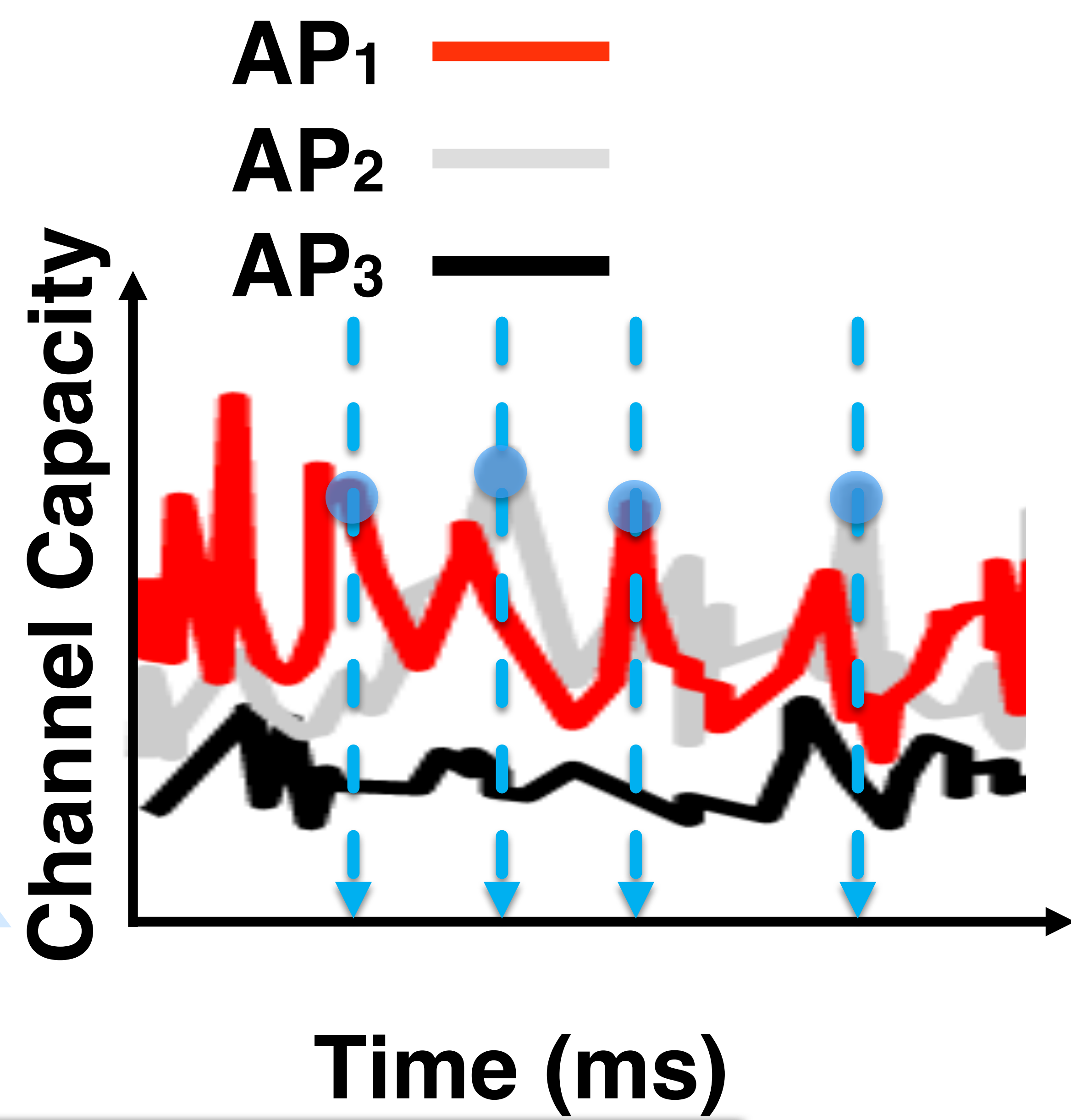


We need to switch fast!

Problem: rapid multi-path fading

- Rapid (***ms***-scale) channel fading due to the multi-path





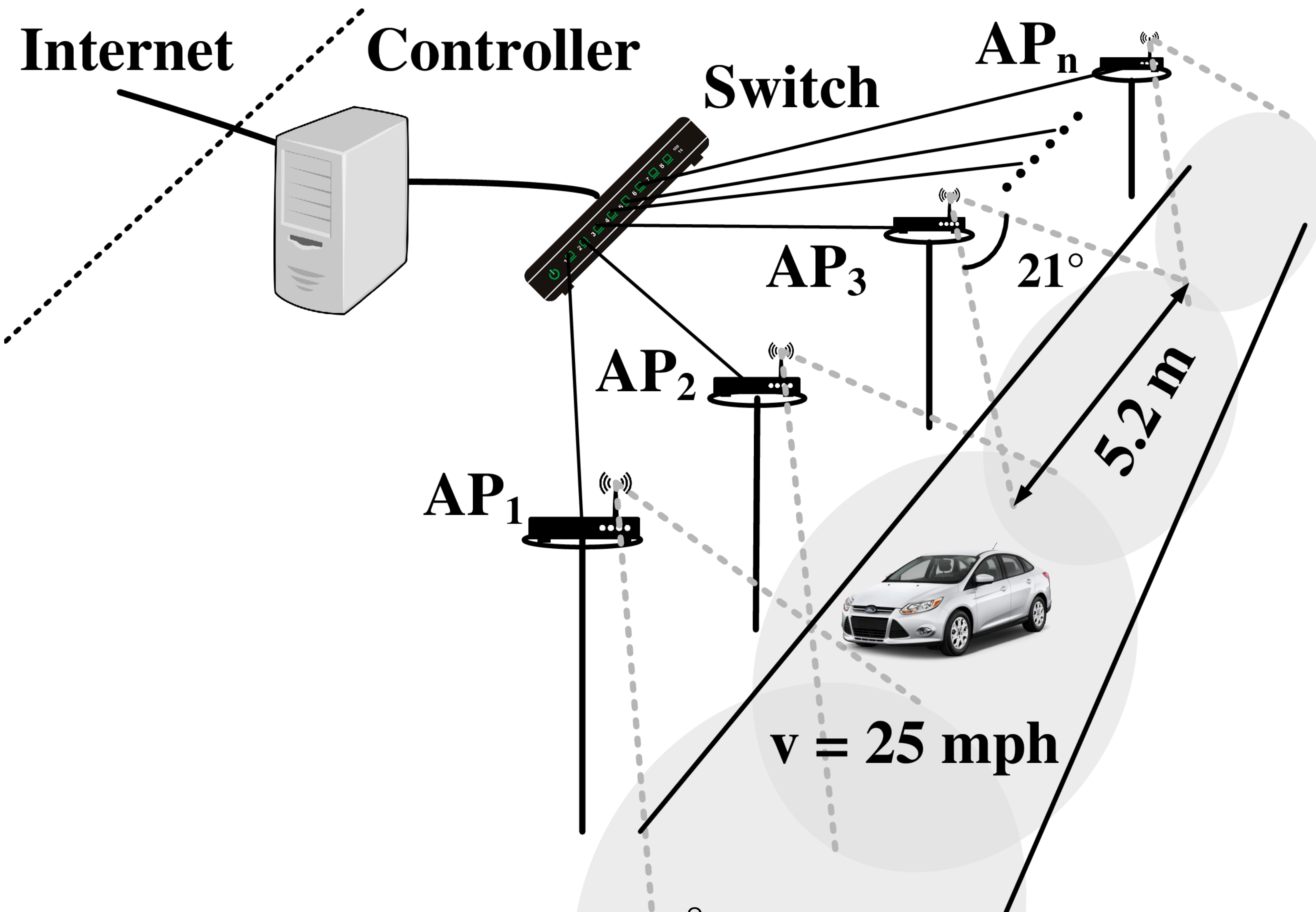
We need to switch at a millisecond level!

Design

- Who maintains states and makes switching decision
- When to switch (to which AP)
- How to switch

Design

- Wi-Fi Goes to Town: **system architecture**



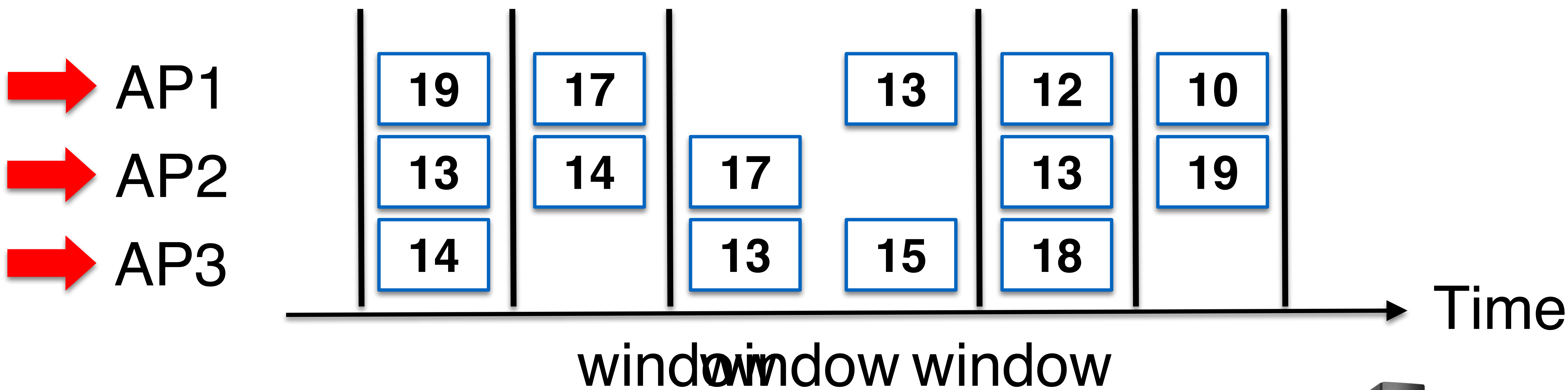
Design::who

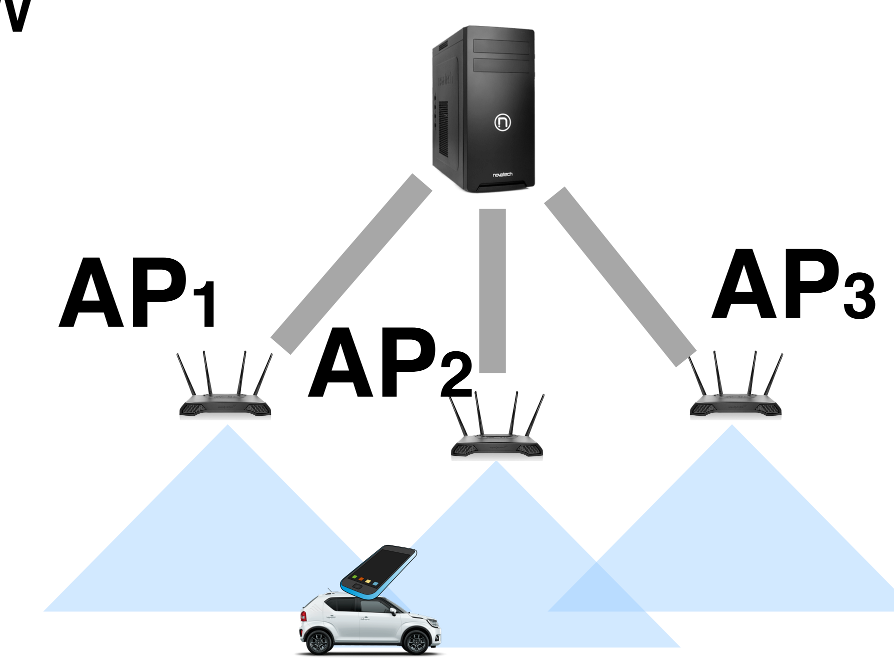
A controller maintains states and makes decisions

Design::when (and which)

- AP selection algorithm

Controller maintains an *Effective SNR* value window (10 ms), and selects AP with largest **median value**.





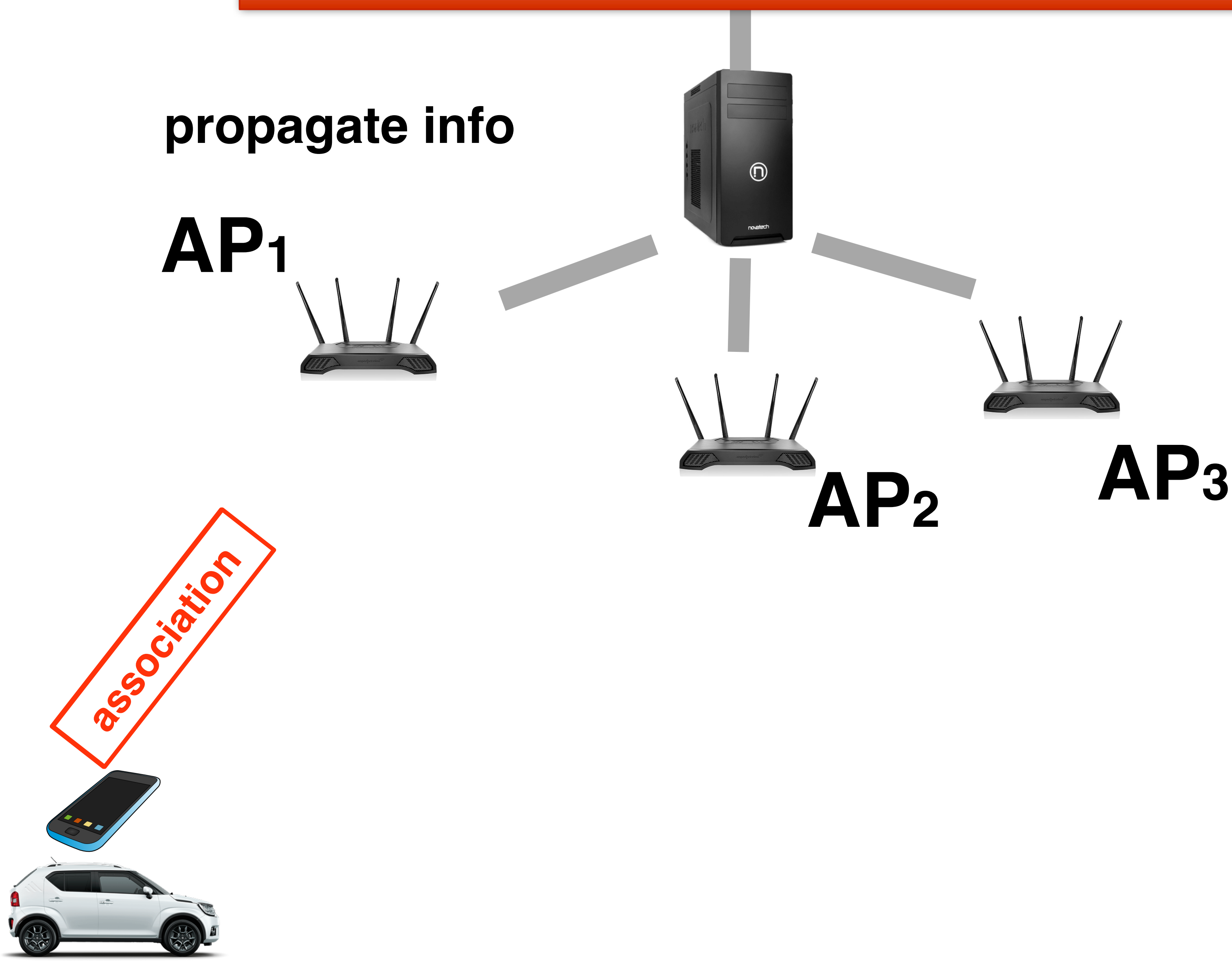
Design::how

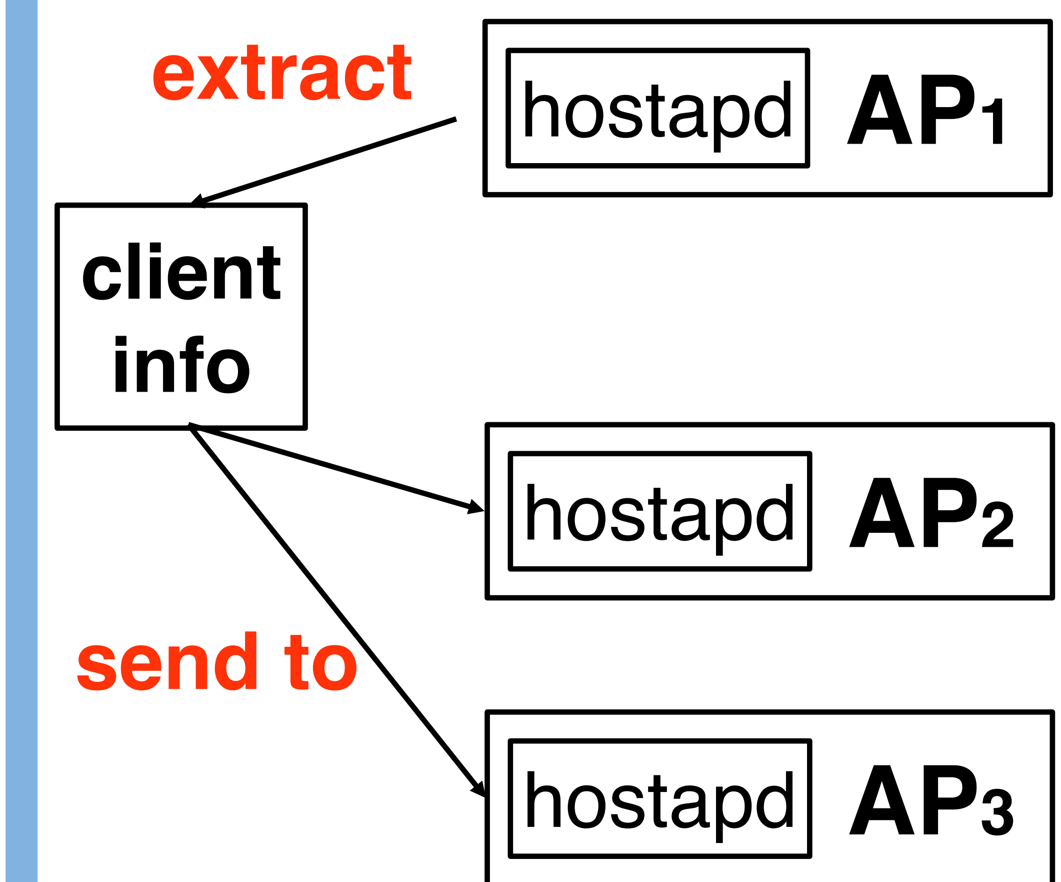
- Association
- Uplink (from client to AP)
- Downlink (from AP to client)

Design::how

- Wi-Fi Goes to Town: **AP-client association**

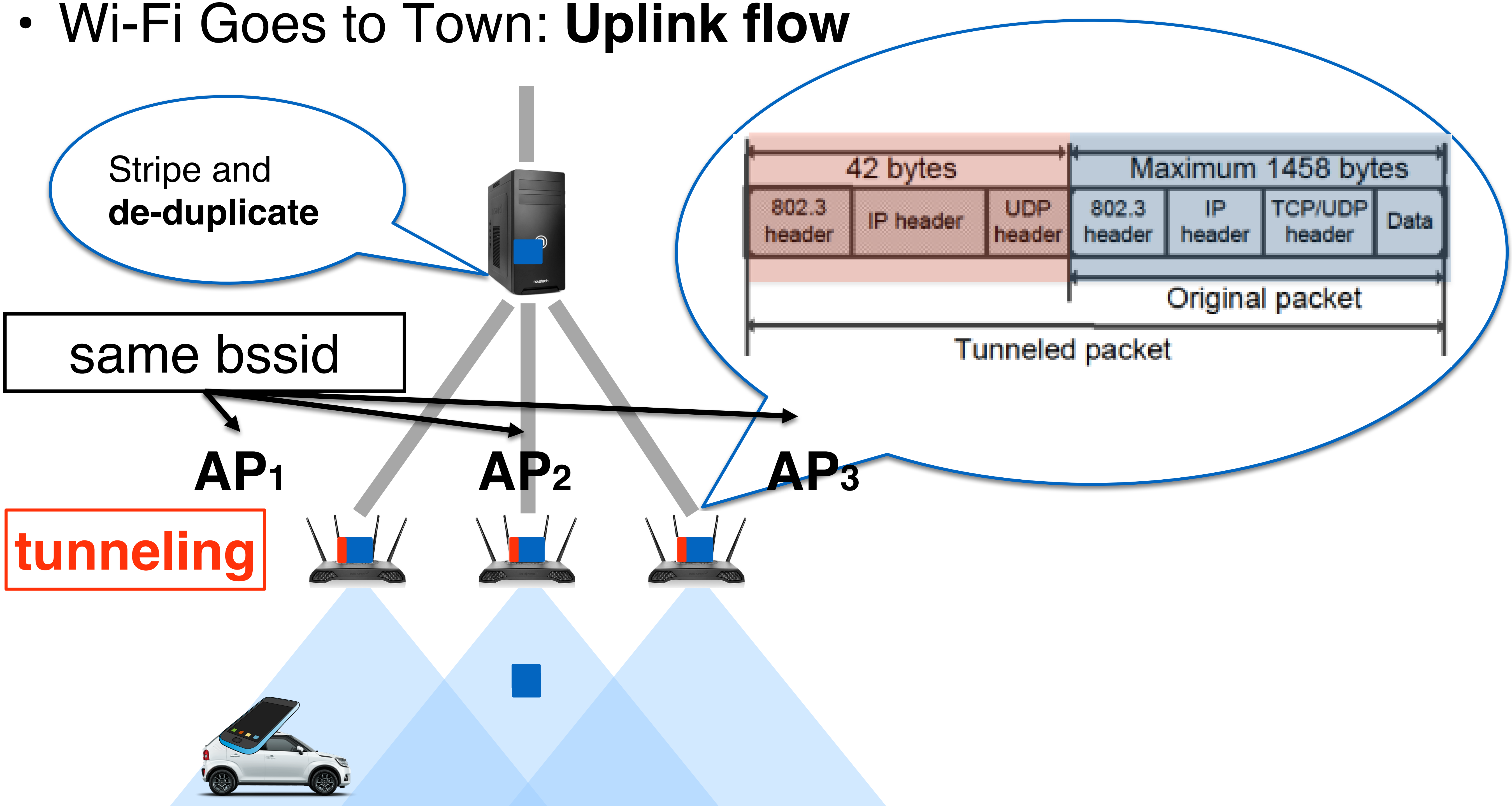
All APs associate with client





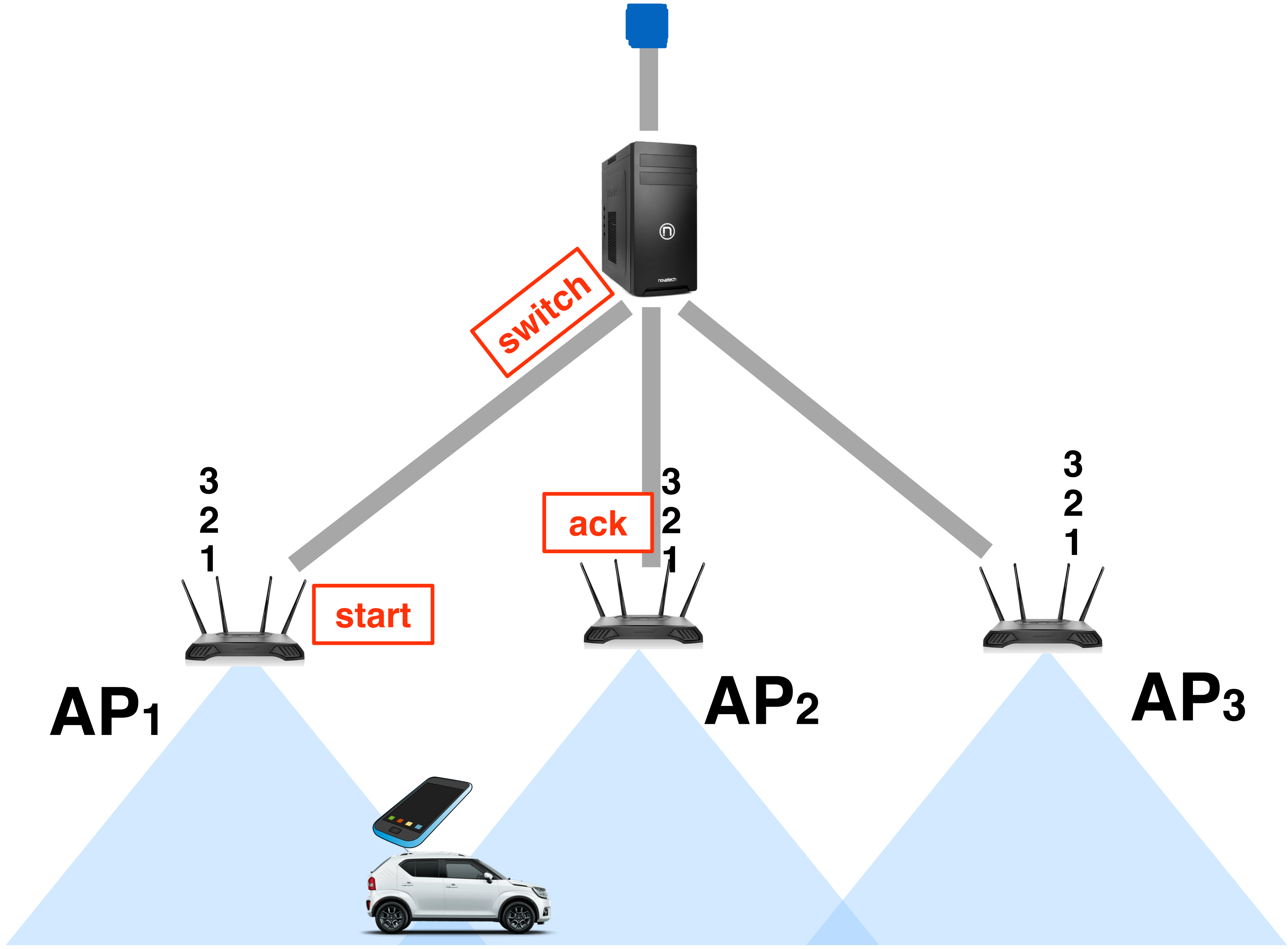
Design::how

- Wi-Fi Goes to Town: **Uplink flow**



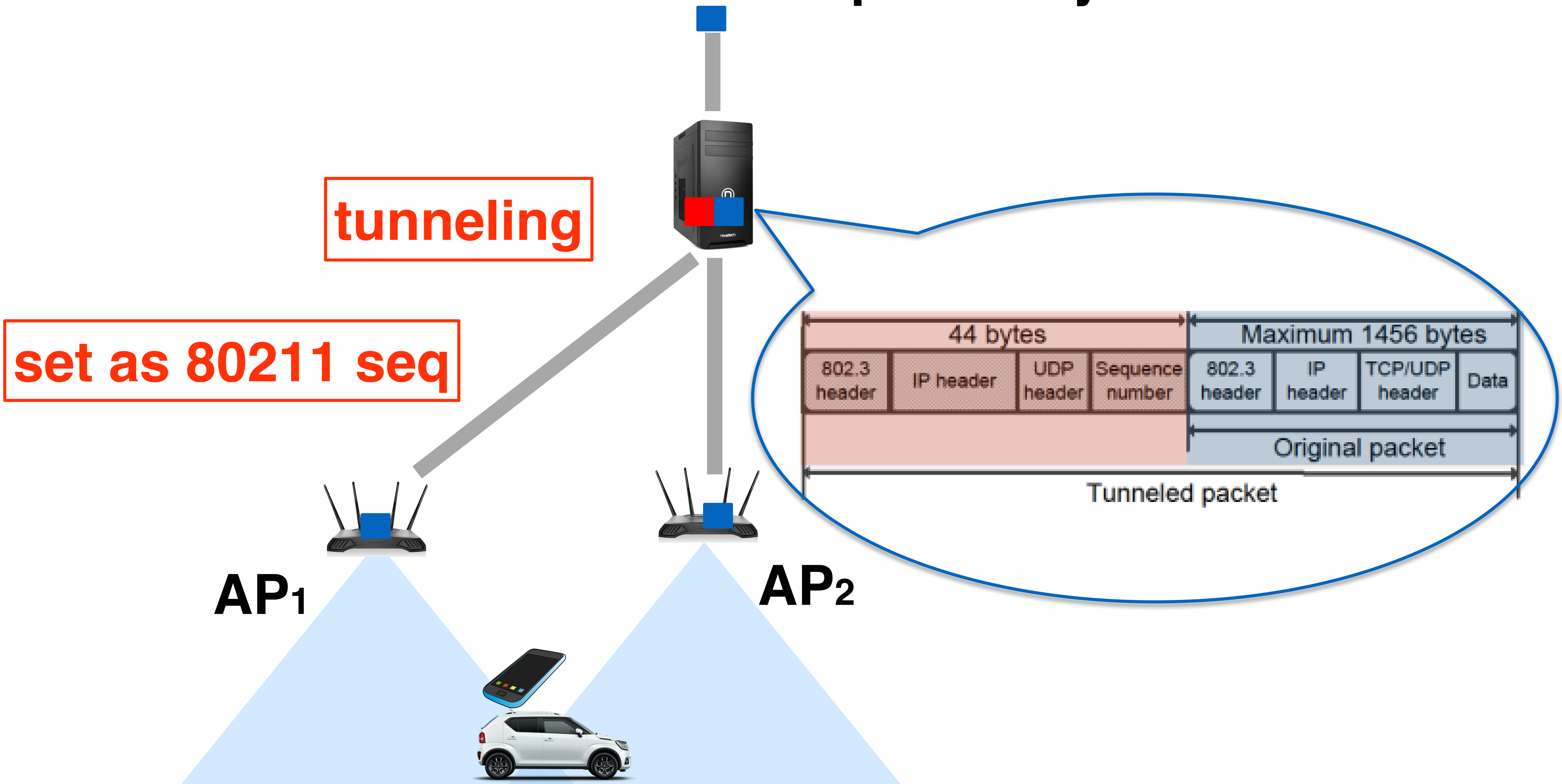
Design::how

- Wi-Fi Goes to Town: **Downlink flow**

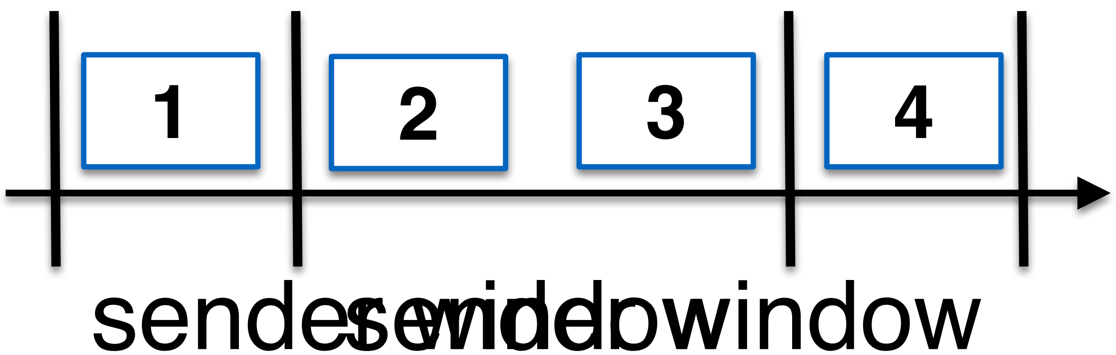


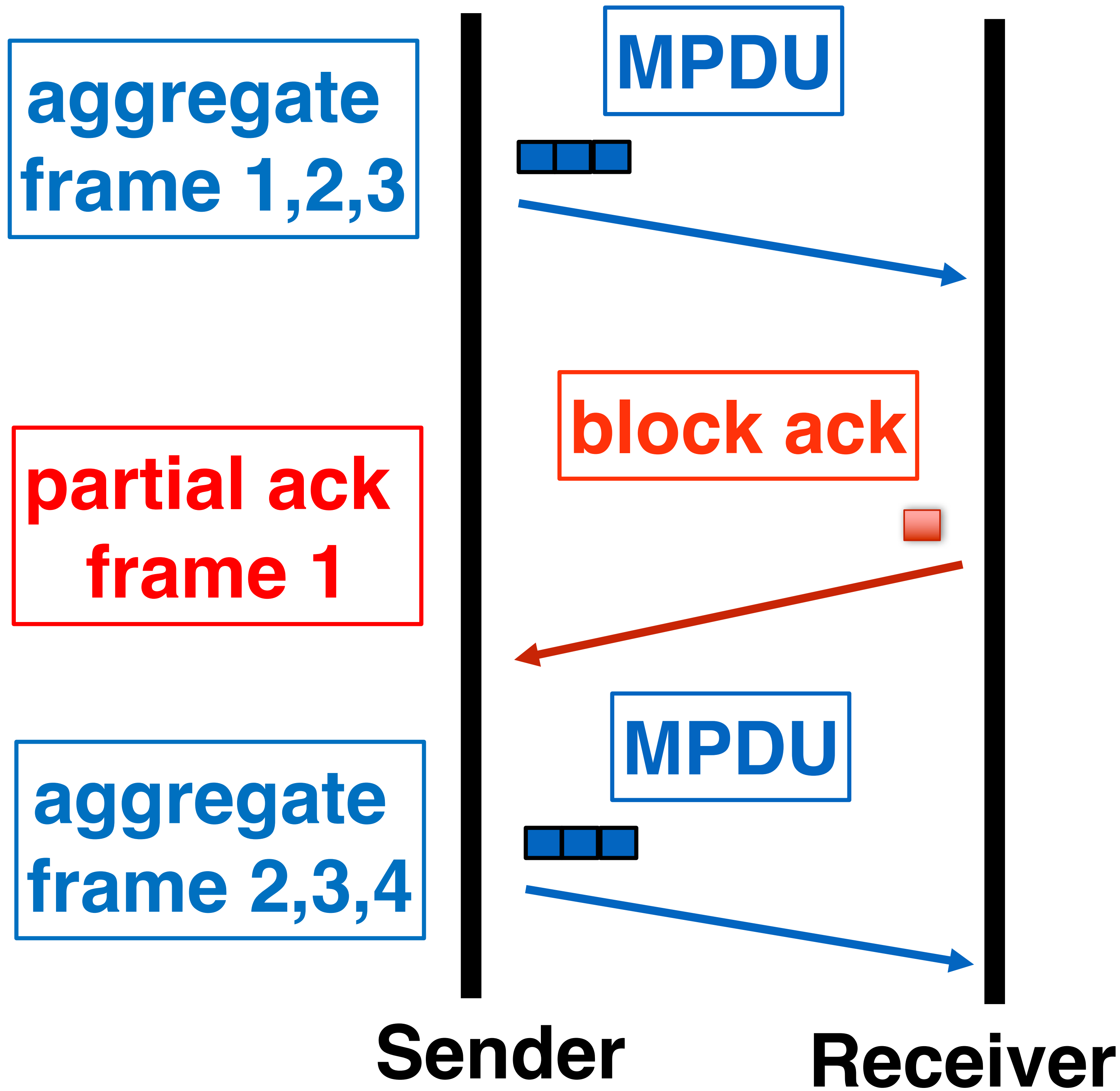
Design::how

- Wi-Fi Goes to Town: **Downlink packet synchronization**

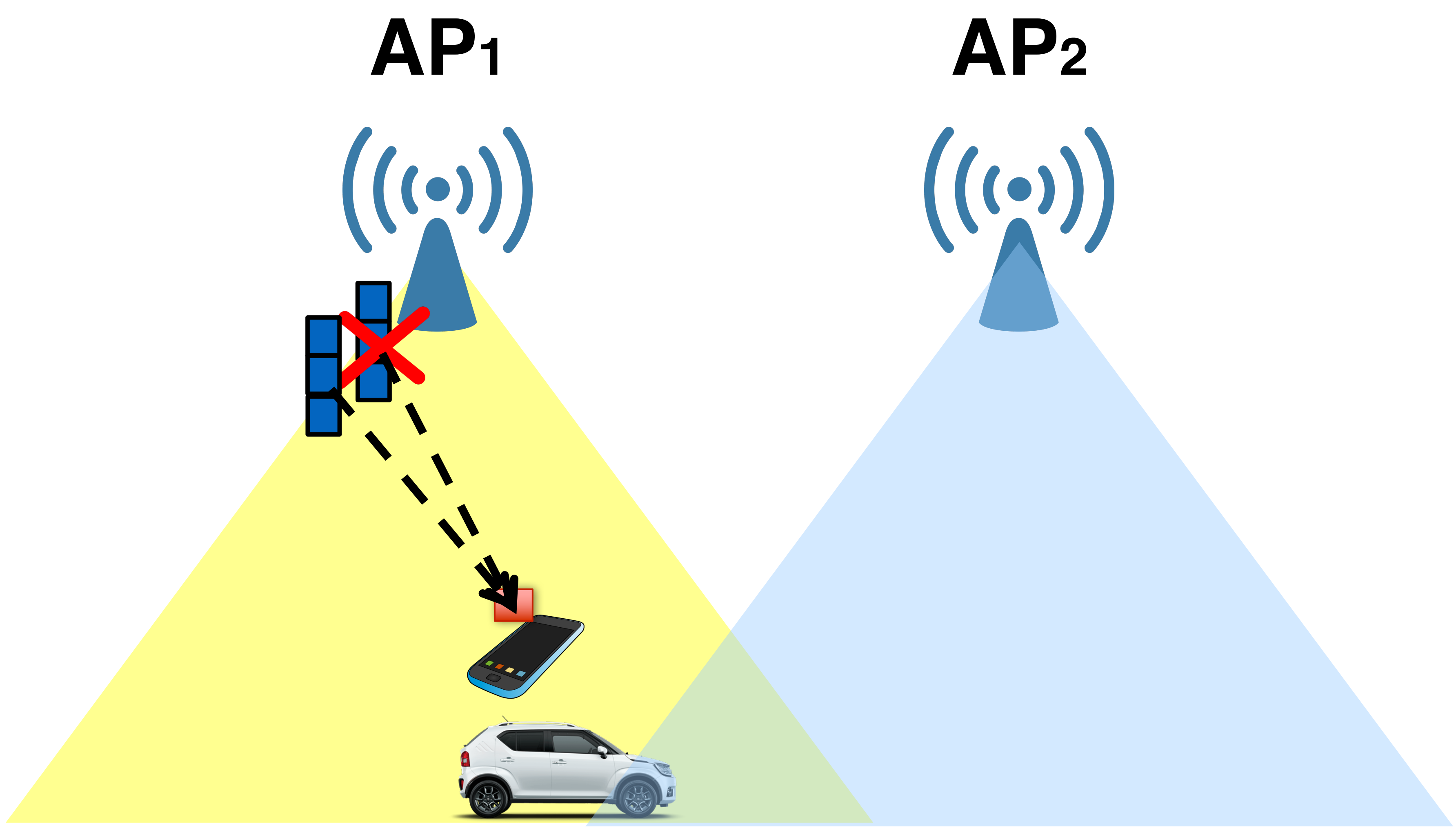


Introduction of aggregation in 802.11n



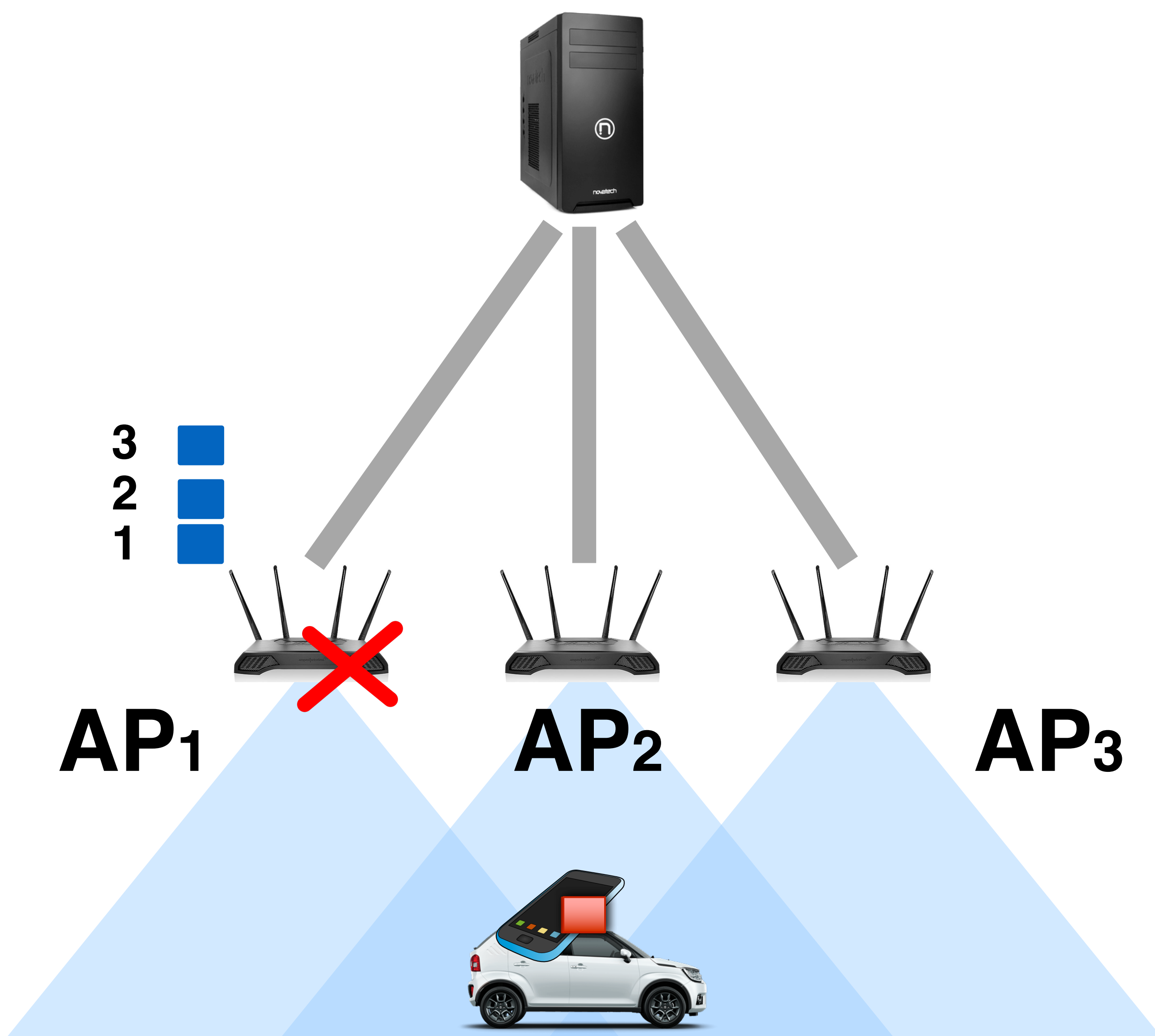


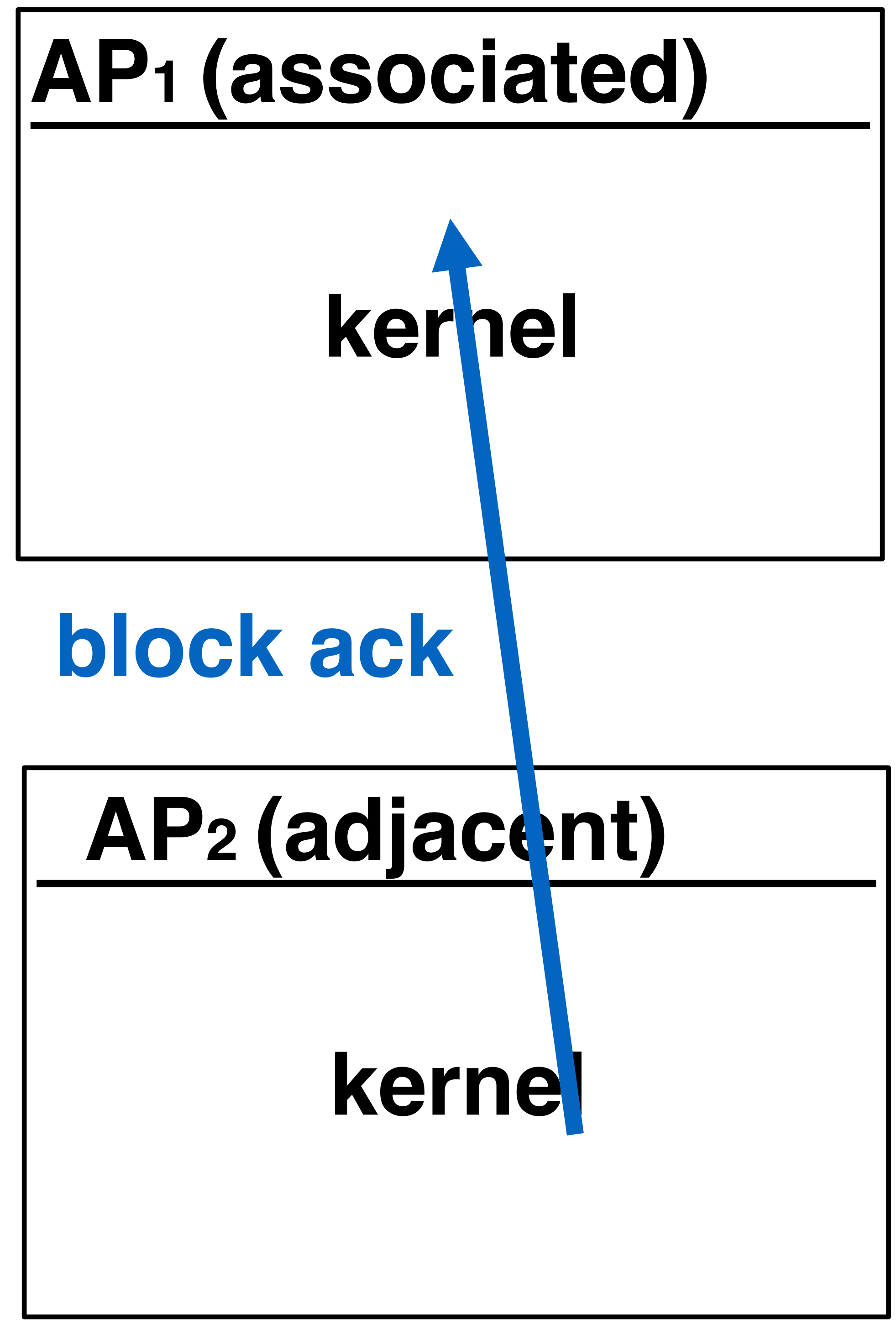
Problem: block ack lost causes mac layer inefficiency



AP1 needlessly retransmits whole aggregate

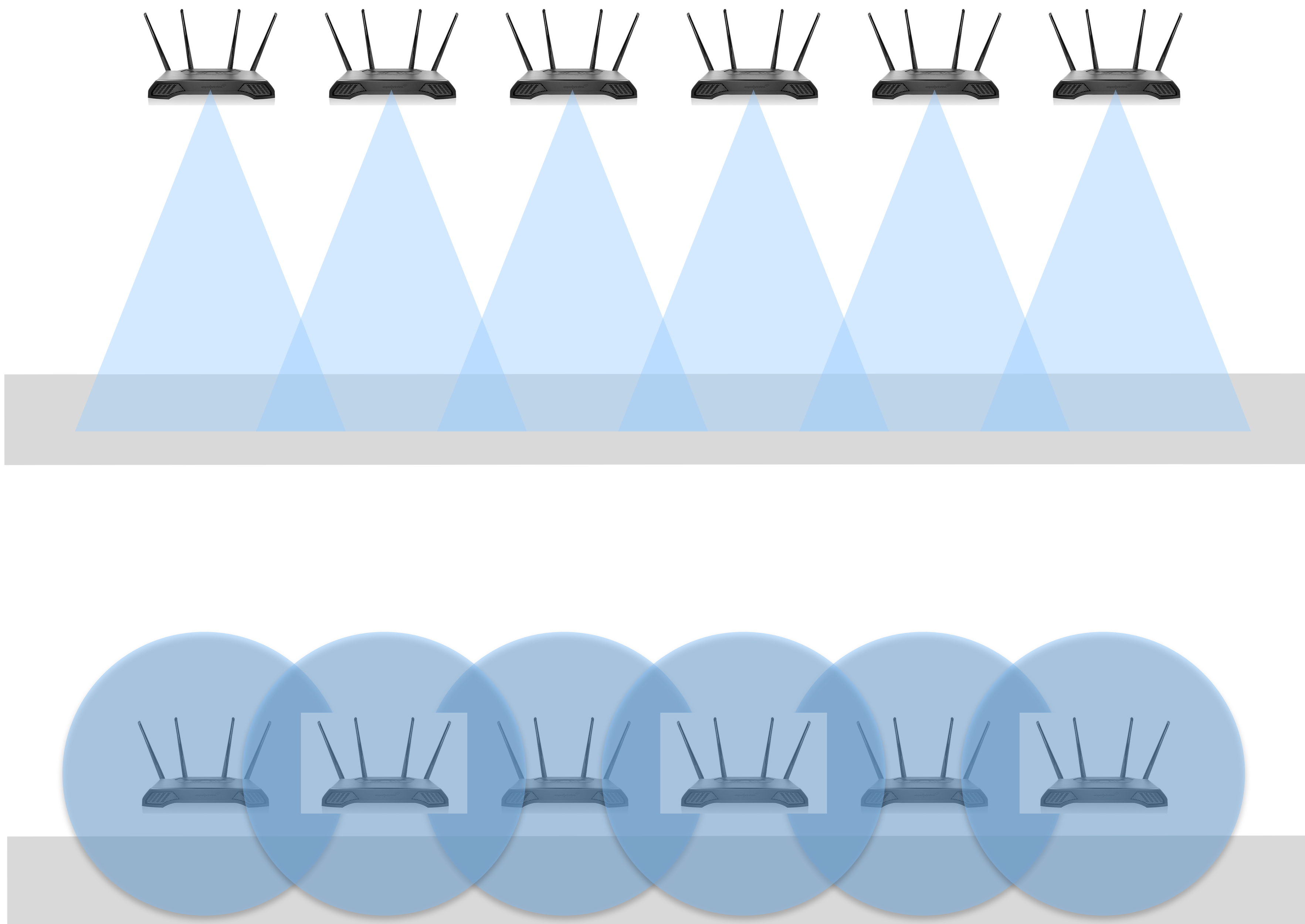
Solution: block ack forwarding





Implementation

- Wi-Fi Goes to Town: **Two Deployment Schemes**



Implementation: hardware

AP: TP-Link N750 AP, Larid directional antenna, Atheros CSI Tool ***[Xie et al.]***

Controller: Lenovo Thinkpad T430

Evaluation: questions

- How much does Wi-Fi goes to town improve uplink reception rate?
- Does Wi-Fi goes to town increase jitter?
- Does Wi-Fi goes to town achieve higher end-to-end throughput?

Short demo

AP

Downlink packet

Uplink packet

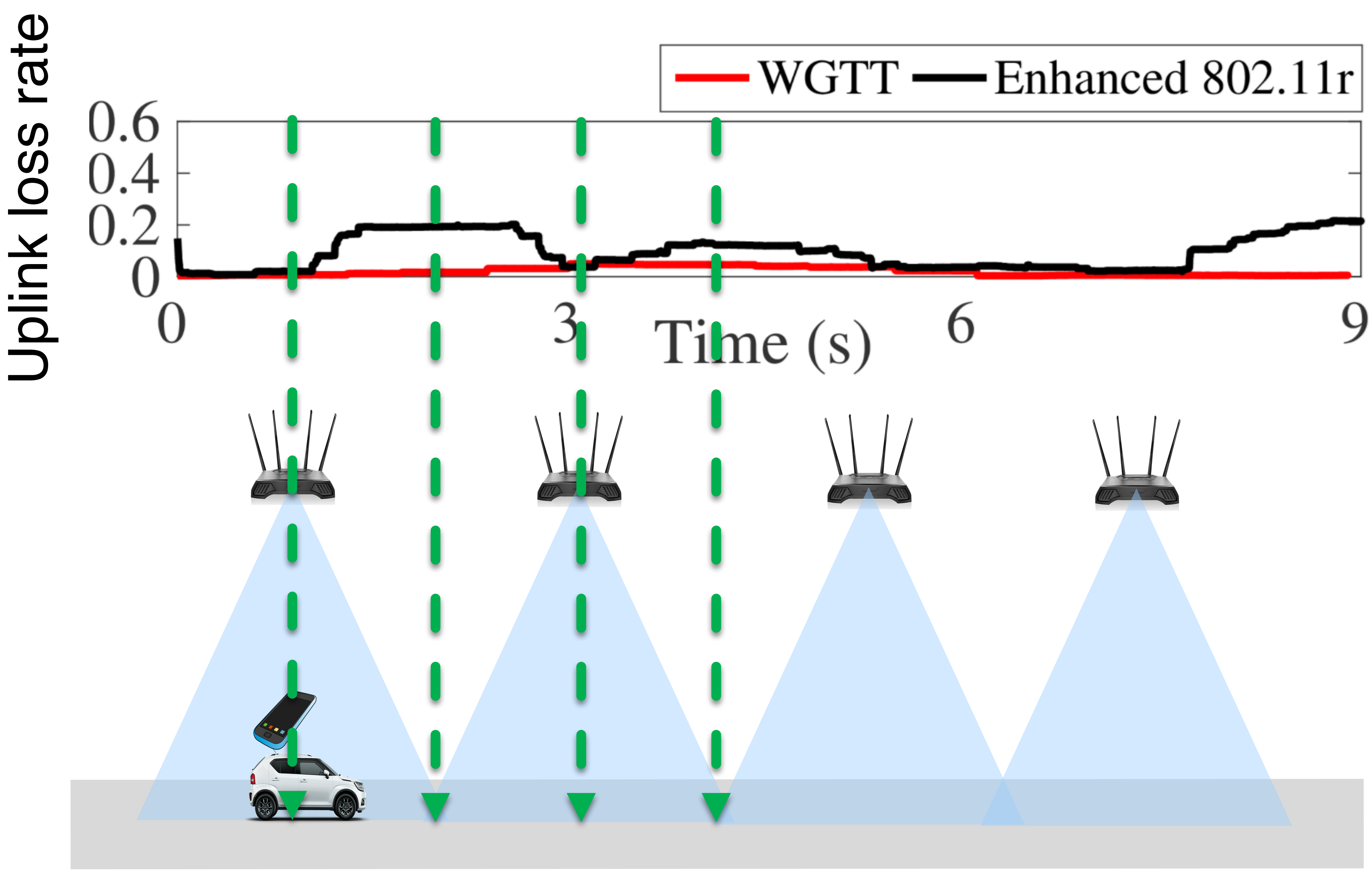
retrans packet

Strawman: 802.11r (enhanced)

- **(Original 802.11r)** Fast handover:
- Fast BSS transition.
- Client maintains time-averaged RSSI, and switch when below threshold

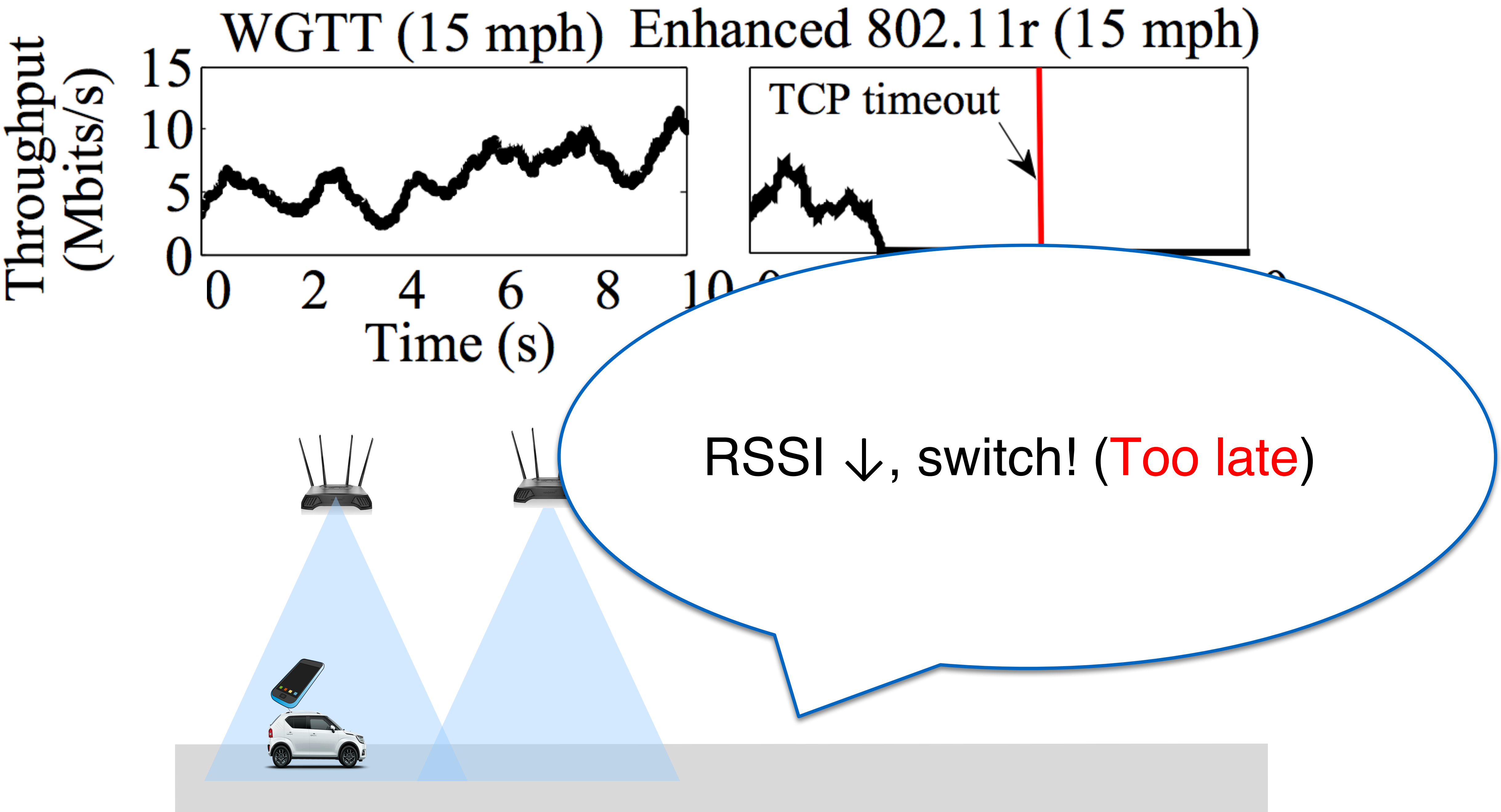
- **(Enhanced**) Fast nearby AP discovery:
- Each AP tells client nearby AP information
- Client overhears beacons

Wi-Fi goes to town achieve lower uplink loss rate by over-hearing



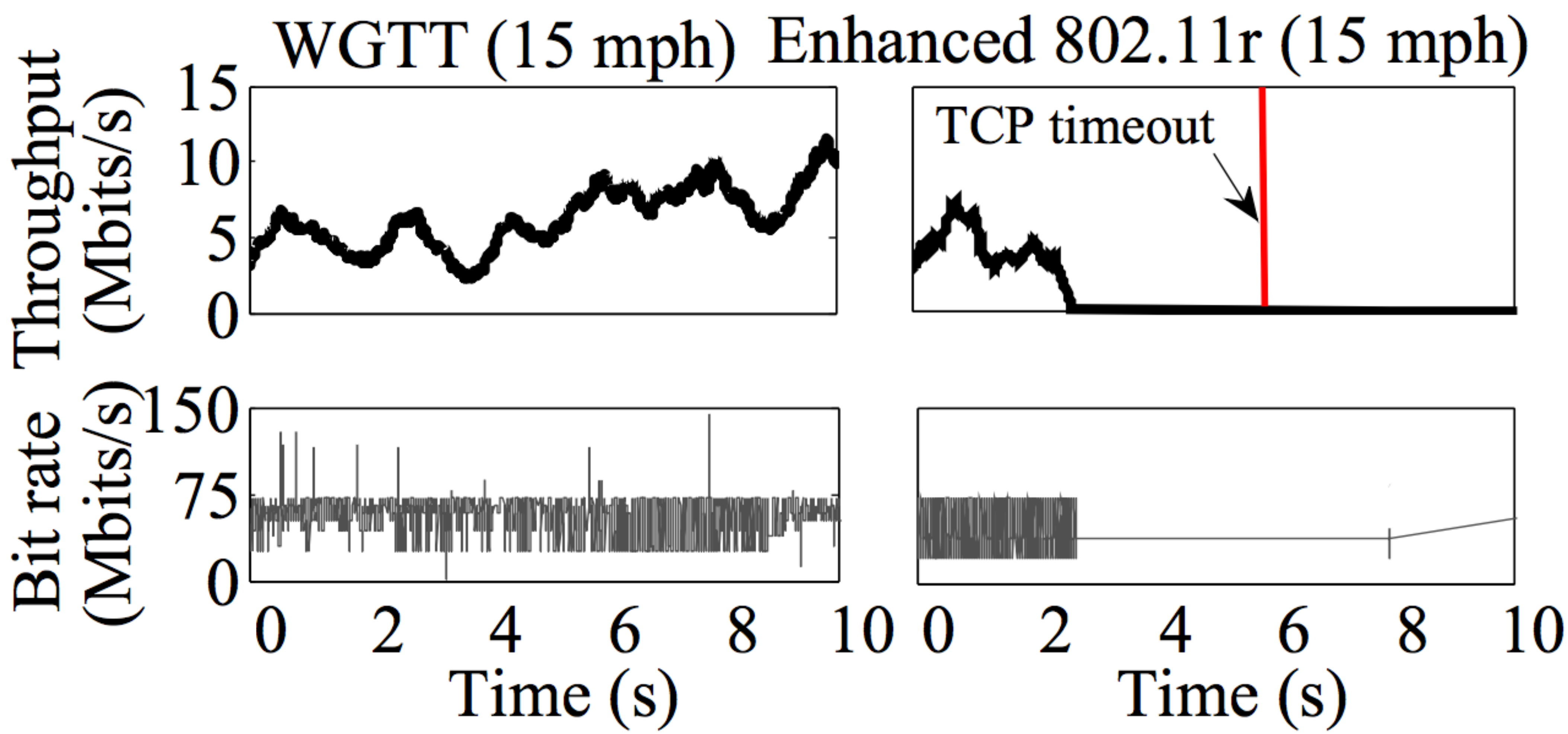
Wi-Fi goes to town achieves seamless switching at speed

- **TCP Download**



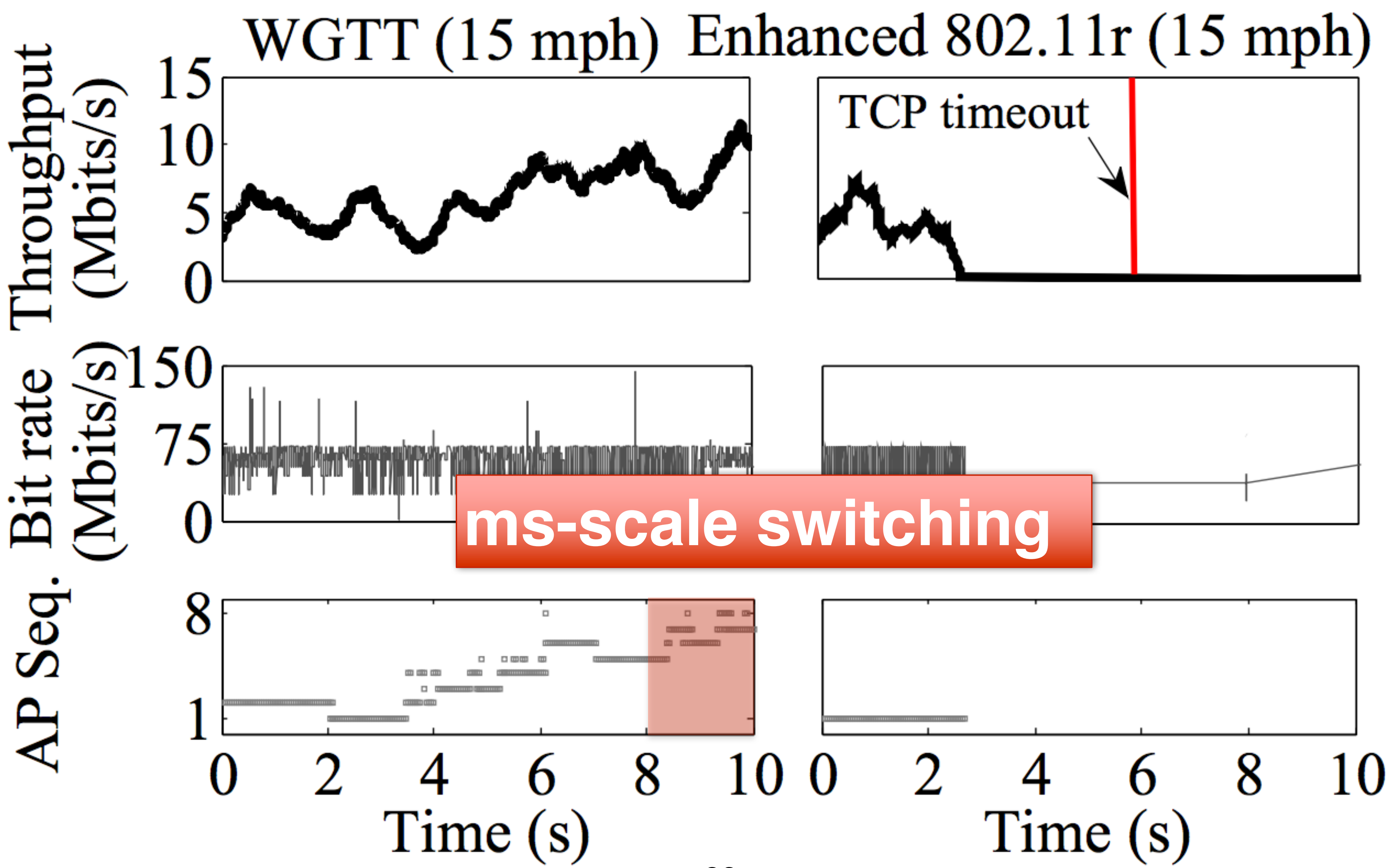
Wi-Fi goes to town achieves seamless switching at speed

- **TCP Download**



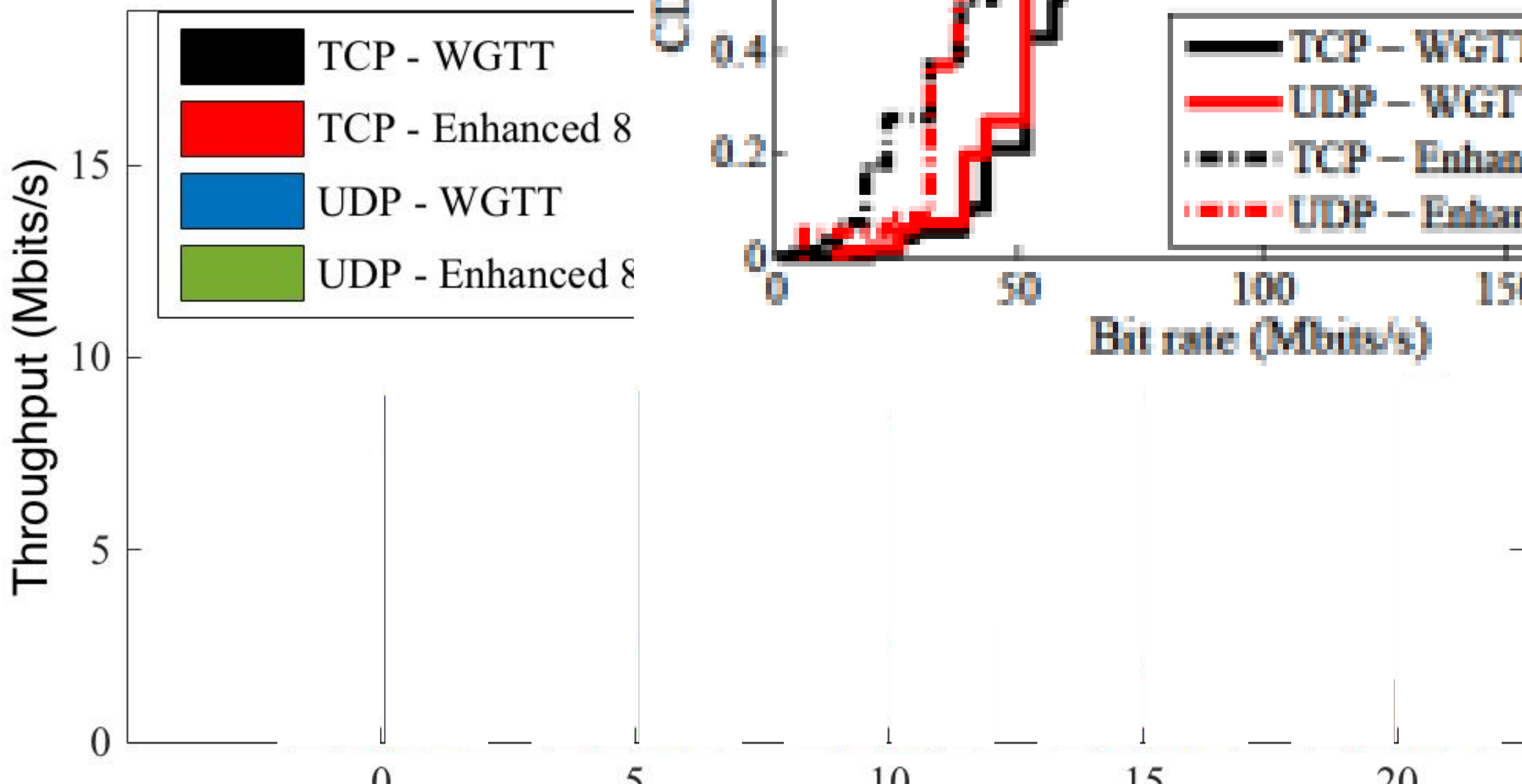
Wi-Fi goes to town achieves seamless switching at speed

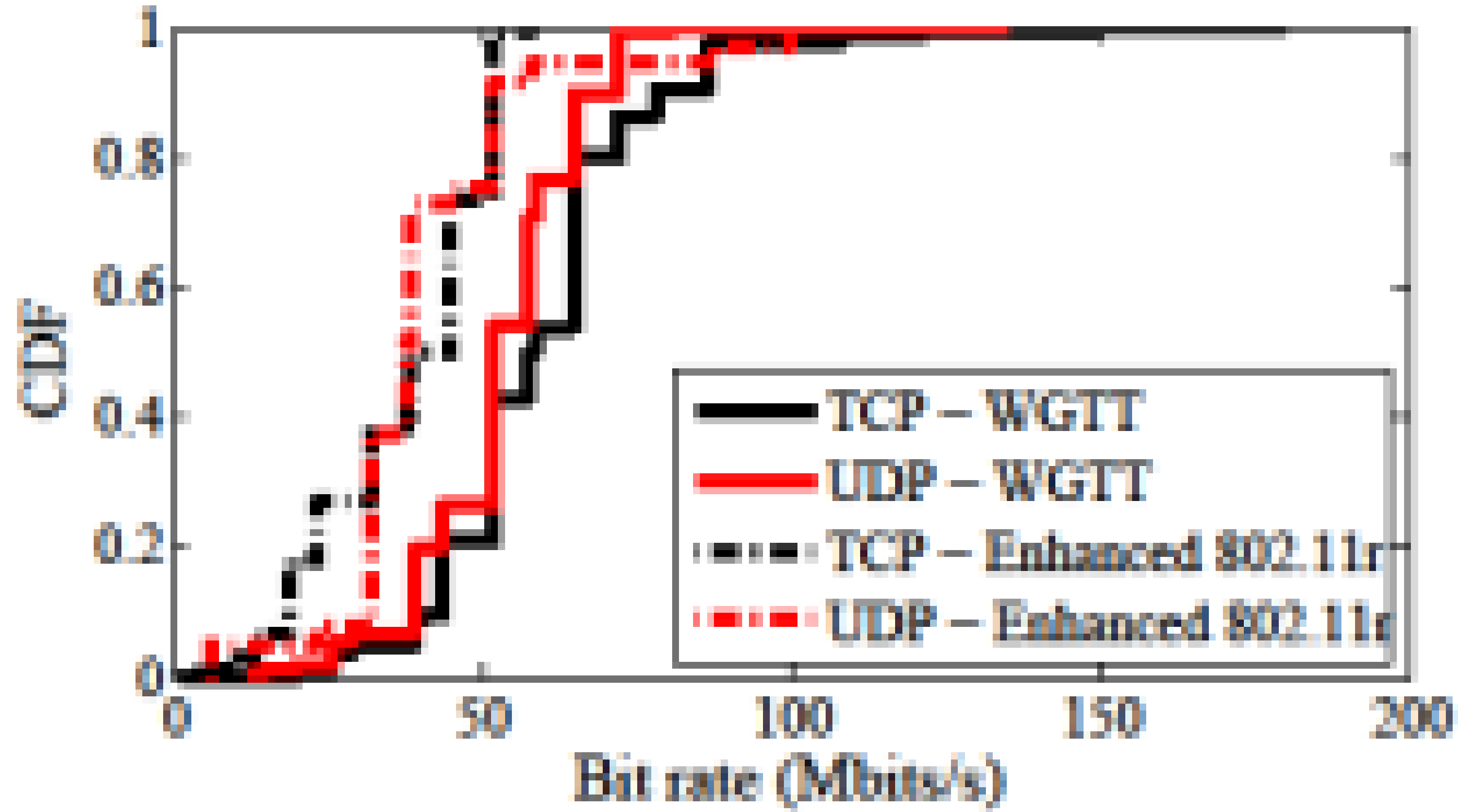
- **TCP Download**



Wi-Fi goes to town achieves higher end-to-end

- Single-client, downloa

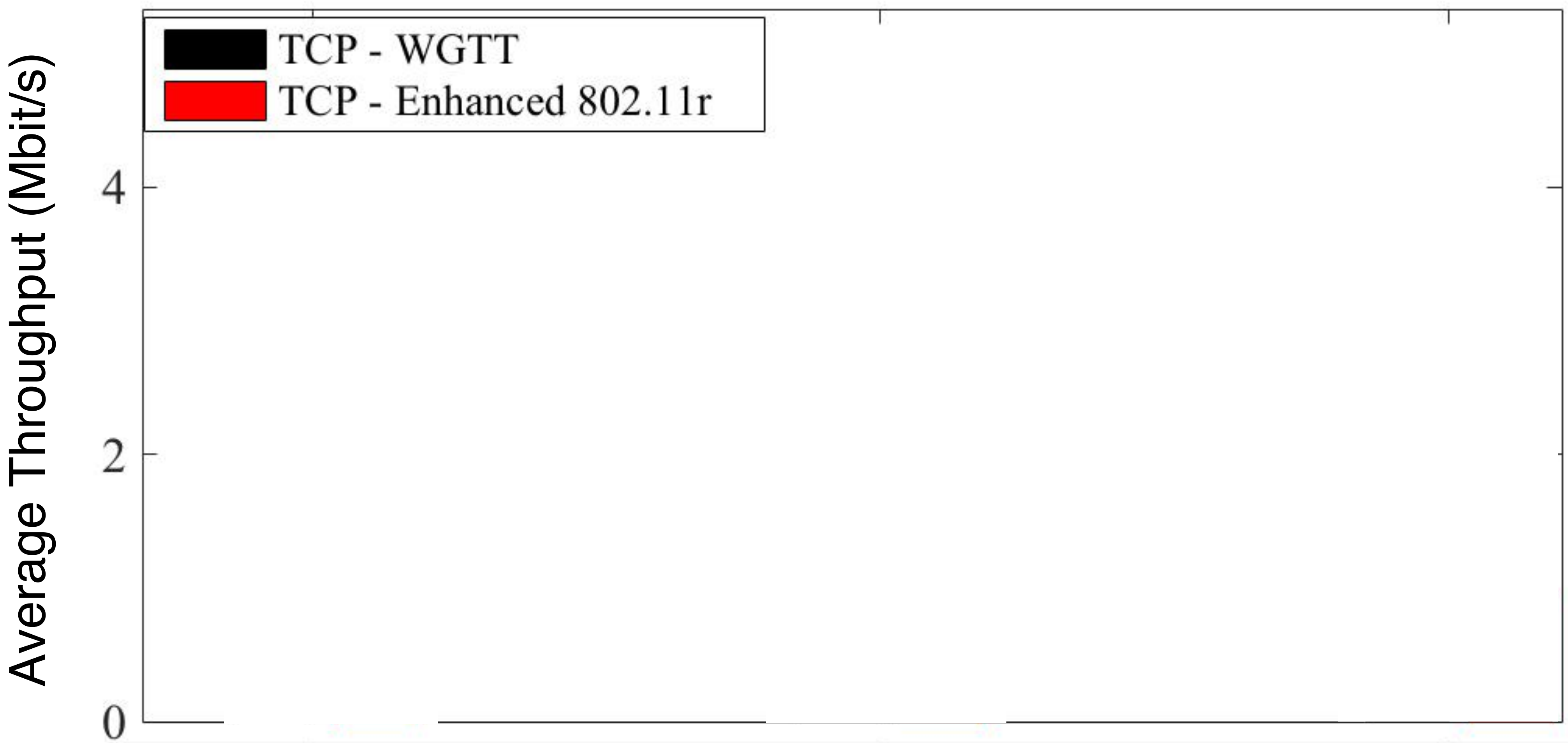




802.11r's performance degrades with speed while Wi-Fi goes to town not

Wi-Fi goes to town achieves higher end-to-end throughput

- **Multi-client**



Wi-Fi goes to town always achieves higher performance

Conclusion

- First roadside hotspot network at vehicular speeds with meter-sized picocells.
- Execute switch decisions at millisecond-level granularities.
- First step in a line of work that will scale out the wireless capacity of roadside hotspot networks using small cells.

Questions?

zhenyus@cs.princeton.edu

Thank you