White Paper for NSF Future Wireless Cities Workshop

Wi-Fi Goes to Town

Kyle Jamieson
Princeton University

We propose truly seamless Internet connectivity for the thousands of commuters utilizing a densely-populated urban area's metropolitan underground transport system or roads. We are considering systems that can handle hundreds of commuters on a single train or freeway, all simultaneously watching YouTube videos, surfing the web, chatting with friends over video, or downloading files while moving up to 30–60 mph.

Association time can dominate connection time in current Wi-Fi radios, so handoff protocols are critical. Furthermore, the question of how and when to handoff is intertwined with how we deploy AP antennas. We illustrate this with a preliminary experiment: Figure 1(a) shows capacity (measured in bits/second/Hz) available to a mobile client when it roams between two APs. We see a gradual then sharp drop in capacity followed by a jump in capacity after the (perfect) handover is complete. Figure 1(b) contrasts this when the AP is connected to a leaky feeder cable that spreads its energy out over the span of the cable (typically 75–150 feet). Here we see over the same space a less consistent capacity, but no large-scale fading nor handoff overhead. Our goal is to design a handoff that combines the best of both these worlds: providing high and seamless capacity and hence quality-of-service as the user moves from one AP to the next.

(a) An 802.11n handoff at walking speed. **(b)** A leaky-feeder cable at walking speed.

Figure 1: Comparing link capacity (bits/sec/Hz) of a Wi-Fi handoff with a leaky feeder cable over the same physical space, when the mobile is moving at walking speed.

While there are many existing handoff protocols for both Wi-Fi and mobile cellular data networks, we find ourselves in an extreme position in the design space when a car passes by a series of APs at 30–60 mph. Imagine TCP flows traversing between an Internet server and a user's mobile with inter-packet times in the 100s of milliseconds to seconds. In this situation, traditional roaming protocols will either incur unnecessary overhead in the form of control packets to signal transitions between APs, or fail, stalling the TCP connection and pausing video playback, or interrupting an ongoing teleconference.

Instead, we intend to investigate location-aware predictive handoff protocols that send downstream packets to the AP the user will be near once the packet reaches our system's backhaul. This decision will likely involve estimating the vehicle's speed either indirectly or directly, estimating the strength of each AP's wireless channel based on the estimated speed, and then making a forwarding decision based on these estimates. A certain amount of "hedging bets" is possible by allowing two or more APs to transmit downlink traffic together, but spatial reuse then suffers, so the challenge in this part of the work is to make the best forwarding decisions based on available channel state information, vehicle pre-planned trajectory and the inertial sensor data (accelerometer, speedometer, gyroscope) measurements. Pre-planned vehicle trajectory is coarse-grained (only accurate down to the road level) and subject to change, so we will leverage previous work on location tracking (Phaser, ArrayTrack, ToneTrack) to estimate fine-grained location trajectories down to the lane level of accuracy. We anticipate this level of accuracy will aid the handoff process.