

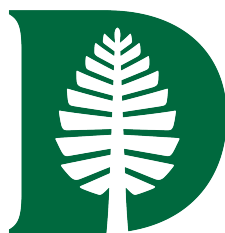


Proximity detection with single-antenna IoT devices

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October 2019



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Billions of IoT devices are projected to be deployed in the next few years



- Huge growth projected for connected devices
- Many devices are likely to have limited user interfaces
- Devices that have never met will need to communicate
- No root of trust between newly encountered devices

Proximity can serve as a basis of trust when devices are first encountered



**Distant
adversary**



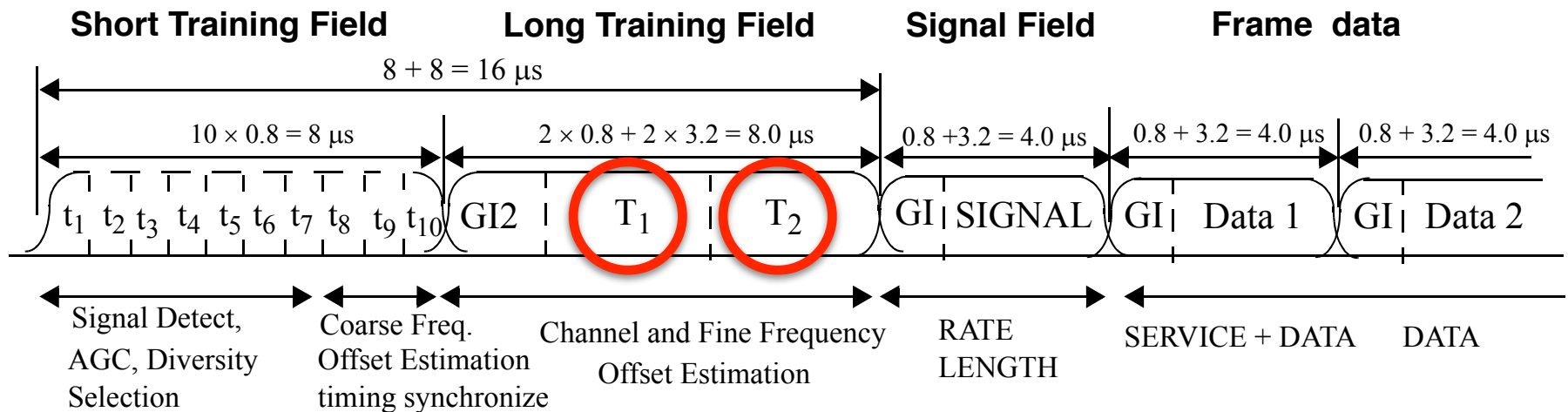
**Nearby
legitimate
devices**



- Assume adversary is not able to gain close physical proximity to devices (e.g., does not break into a home to gain proximity)
- Proximity can then serve as a basis for trust
- Techniques exist for multi-antenna devices to detect proximity^{1,2}
- No proximity techniques exist for single-antenna devices

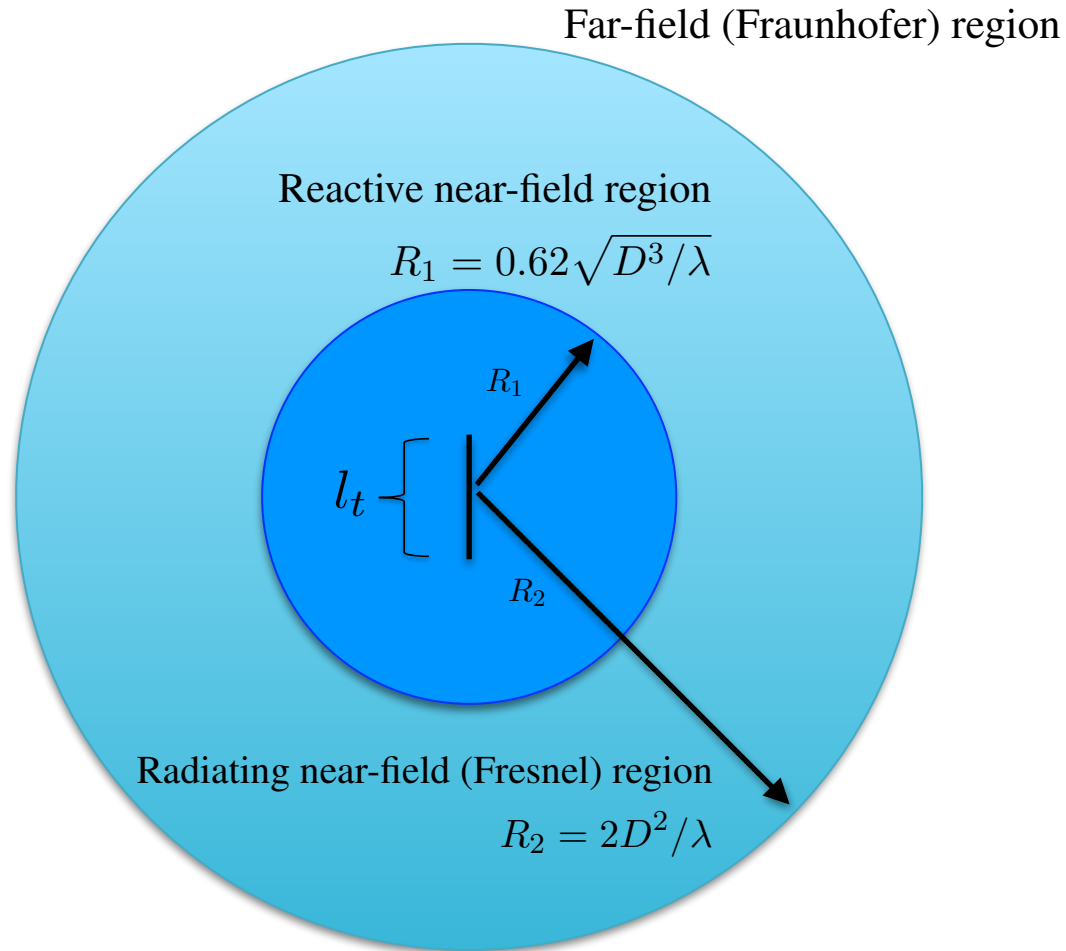
We can use repeating portions of the Wi-Fi preamble Long Training Field (LTF) for proximity

Wi-Fi preamble¹



- T_1 and T_2 are identical 64-sample portions of the preamble Long Training Field (LTF) used for fine frequency correction and channel estimation
- T_1 and T_2 are expected to match at the receiver (plus noise)
- All Wi-Fi receivers, even single-antenna devices, evaluate T_1 and T_2

Near-field effects can cause mismatches in the repeating portions of the LTF

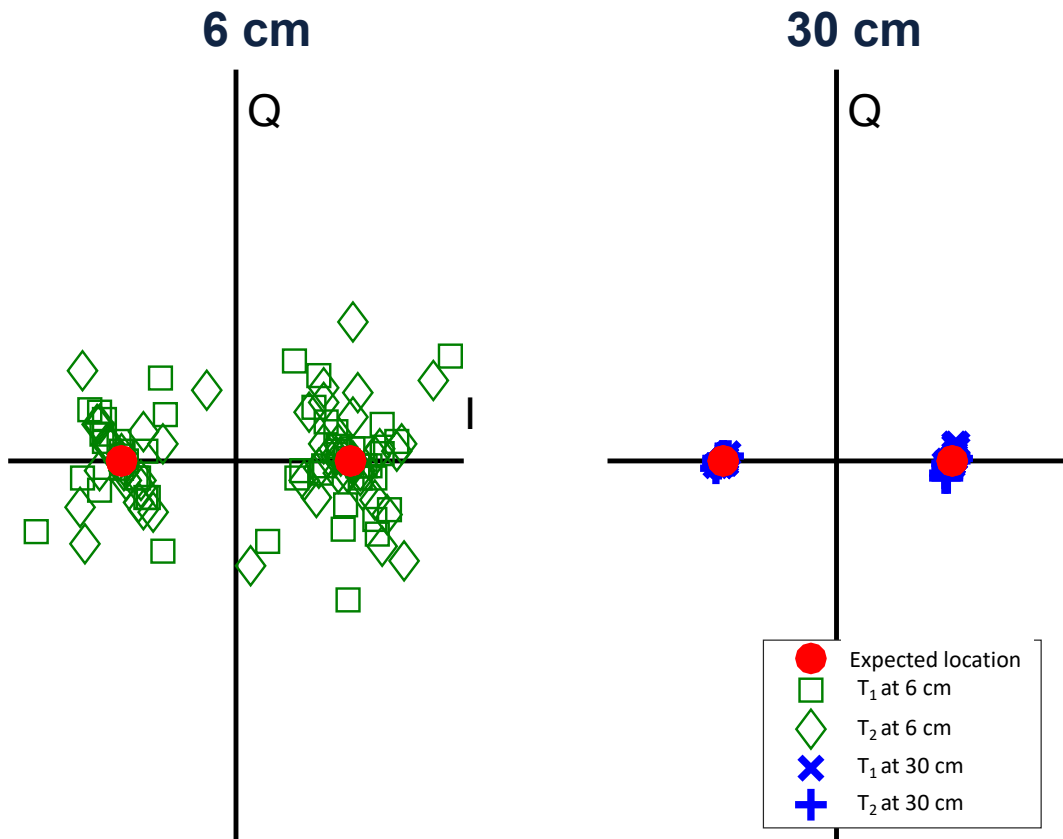


- In reactive and radiating near-field regions around a transmitter, electric and magnetic fields not yet aligned
- Fields form a vector that rapidly rotates in time in a plane parallel to the direction of propagation¹
- Rotation causes mismatches between T_1 and T_2
- With Wi-Fi, near-field effects extend to roughly 14 cm from transmitter



T_1 and T_2 mismatch at close range, but not at long range

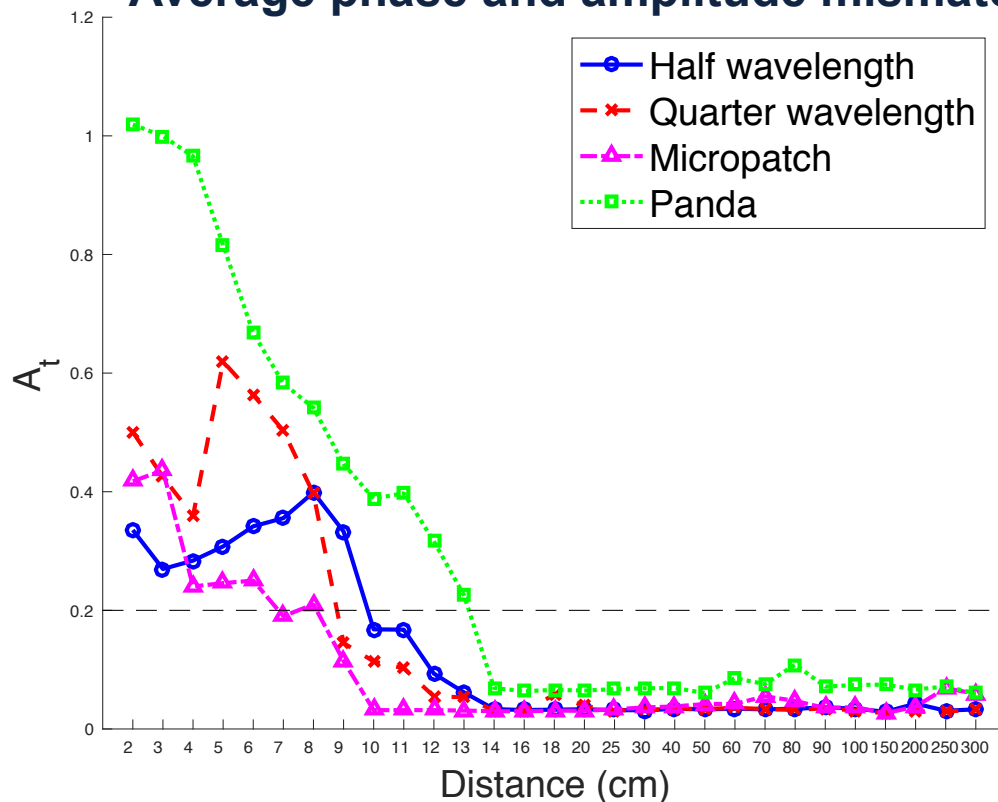
T_1 and T_2 on all subcarriers



- Rotating electric and magnetic fields at close range cause mismatch between T_1 and T_2
- Rotation dies out quickly as range increases¹
- Stable electric and magnetic field orientation at long range (≥ 14 cm) results in matching T_1 and T_2
- Matching not affected by moving objects due to $6.4 \mu s$ time between T_1 and T_2

Proximity is detected if the mismatch is above a fixed threshold

Average phase and amplitude mismatch



Average A_t of 1,000 transmitted from each antenna type

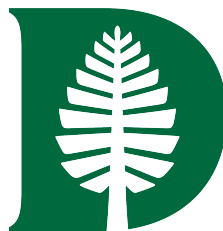
- A_t is the sum of the Euclidean distance between T_1 and T_2 over all 64 subcarriers
- A_t is high at close range, low at long range
- Declare proximity if A_t is above a fixed threshold
- Proximity determined with high probability at close range
- Proximity beyond 14 cm never falsely detected
- Four different antenna types perform similarly



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This research was supported by NSF award CNS-1329686.

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