Interactive WiFi Connectivity from Moving Vehicles

Aruna Balasubramanian, Ratul Mahajan
Arun Venkataramani, Brian N Levine, John Zahorjan

University of Massachusetts Amherst
Microsoft Research
University of Washington

Motivation

- Increasing demand for network access from vehicles
  - E.g., VoIP, Web, email
  - Cellular access expensive

- Ubiquity of WiFi
  - Cheaper, higher peak throughput compared to cellular
Our work

Given enough coverage, can WiFi technology be used to access mainstream applications from vehicles?

• Existing work shows
  • the feasibility of WiFi access at vehicular speeds
  • focus on non-interactive applications. e.g., road monitoring

Talk outline

• Can popular applications be supported using vehicular WiFi today?
  • Performance is poor due to frequent disruptions

• How can we improve application performance?
  • ViFi, a new handoff protocol that significantly reduces disruptions

• Does ViFi really improve application performance?
  • VoIP, short TCP transfers
VanLAN: Our Vehicular Testbed

Uses MS campus vans
Base stations (BSes) are deployed on roadside buildings
Currently 2 vans, 11 BSes

Measurement study

- Study application performance in vehicular WiFi setting
  - Focus on basic connectivity
- Study performance of different handoff policies
- Trace-driven analysis
  - Nodes send periodic packets and log receptions
Handoff policies studied

- Practical hard handoff
  - Associate with one BS
  - Current 802.11

- Ideal hard handoff
  - Use future knowledge
  - *Impractical*

- Ideal soft handoff
  - Use all BSes in range
  - Performance upper bound
**Comparison of handoff policies**

**Summary**
- Performance of *interactive applications* poor when using existing handoff policies
- Soft handoff policy can decrease disruptions and improve performance of interactive applications

**Talk outline**
- Can popular applications be accessed using vehicular WiFi?
- How can we improve application performance?
  - ViFi, a practical diversity-based handoff protocol
- Does ViFi really improve application performance?
  - VoIP, short TCP transfers
Designing a practical soft handoff policy

- Goal: Leverage multiple BSes in range
  - Not straightforward

Constraints in Vehicular WiFi
1. Inter-BS backplane often bandwidth-constrained
2. Interactive applications require timely delivery
3. Fine-grained scheduling of packets difficult

Why are existing solutions inadequate?

- Opportunistic protocols for WiFi mesh (ExOR, MORE)
  - Uses batching: Not suitable for interactive applications

- Path diversity protocols for enterprise WLANs (Divert)
  - Assumes BSes are connected through a high speed back plane

- Soft handoff protocols for cellular (CDMA-based)
  - Packet scheduling at fine time scales
  - Signals can be combined
ViFi protocol set up

- Vehicle chooses anchor BS
  - Anchor responsible for vehicle’s packets
- Vehicle chooses a set of BSes in range to be auxiliaries
  - e.g., B, C and D can be chosen as auxiliaries
  - ViFi leverages packets overheard by the auxiliary

ViFi protocol

1. Source transmits a packet
2. If destination receives, it transmits an ack
3. If auxiliary overhears packet but not ack, it probabilistically relays to destination
4. If destination received relay, it transmits an ack
5. If no ack within retransmission interval, source retransmits
Why relaying is effective?

- Losses are bursty
- Independence
  - Losses from different senders independent
  - Losses at different receivers independent

Guidelines for probability computation

1. Make a collective relaying decision and limit the total number of relays
2. Give preference to auxiliary with good connectivity with destination

How to make a collective decision without per-packet coordination overhead?
Determine the relaying probability

Goal: Compute relaying probability $R_B$ of auxiliary B

Step 1: The probability that auxiliary B is considering relaying

\[ C_B = P(B \text{ heard the packet}) \cdot P(B \text{ did not hear ack}) \]

Step 2: The expected number of relays by B is

\[ E(B) = \cdot P(\text{destination hears B}) \]

Step 4: B estimates $P(\text{auxiliary considering relaying})$ and $P(\text{destination heard auxiliary})$ for each auxiliary

ViFi Implementation

- Implemented ViFi in windows operating system
  - Use broadcast transmission at the MAC layer
  - No rate adaptation

- Deployed ViFi on VanLAN BSes and vehicles
Talk outline

• Can popular applications be accessed using vehicular WiFi?
  • Due to frequent disruptions, performance is poor

• How can we improve application performance?
  • ViFi, a practical diversity-based soft handoff protocol

• Does ViFi really improve application performance?

Evaluation

• Evaluation based on VanLAN deployment
  • ViFi reduces disruptions
  • ViFi improves application performance
  • ViFi’s probabilistic relaying is efficient

• Also in the paper: Trace-driven evaluation on DieselNet testbed at UMass, Amherst
  • Results qualitatively consistent
ViFi reduces disruptions in our deployment

ViFi improves VoIP performance

- Use G.729 codec

Disruption = When mean opinion score (mos) is lower than a threshold
ViFi improves performance of short TCP transfers

- **Workload**: repeatedly download/upload 10KB files

ViFi uses medium efficiently

- **Efficiency**:
  
  \[
  \text{Efficiency} = \frac{\text{Number of unique packets delivered}}{\text{Number of packets sent}}
  \]

![Graph showing performance improvement](image)

![Graph showing efficiency](image)
Conclusions

- Our work improves performance of interactive applications for vehicular WiFi networks
- Interactive applications perform poorly in vehicular settings due to frequent disruptions
- ViFi, a diversity-based handoff protocol significantly reduces disruptions
- Experiments on VanLAN shows that ViFi significantly improves performance of VoIP and short TCP transfers

Practical soft handoff

- AllBS itself is not a practical protocol
- How does diversity even work in the downstream?

http://research.microsoft.com/netres/Projects/vanLAN/
Distributed computation

B needs to compute for each auxiliary
(1) contending probabilities (2) P(V will hear from the auxiliary)

Can be computed using loss rates between the auxiliary and its neighbors

- Compute loss rates using beacon receptions
- Embeds its loss rates in beacons
- Learns loss rates of auxiliaries from their beacons
- Estimates relaying probability of B, C and D

Distributed probability computation

B need to know for C and D
1. Probability that C and D are making a relaying decision
2. Probability that vehicle will hear from C and D

Both can be estimated using loss probabilities between C and D and their neighbors

- Nodes exchange 2-hop loss rates using beacons
- B computes relaying probabilities for B, C and D