Location-Aware Networking and its Vehicular Applications

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Why Location-Aware Networking?

- “The Revenge of Geography”
  - While at first, the Internet seemingly shrunk distances, as we increasingly intertwine physical and virtual world, geography remains important
  - Low cost localization (GPS system-on-a-chip ~$5-10)

- Can also improve network protocols
  - High node densities
  - Highly mobile systems

- Research Challenges
  - Exploiting location to enable opportunistic forwarding in highly mobile networks
  - Integration into network architecture
  - Maintaining location privacy
  - Testbed infrastructure

- Automotive safety
- Mobile Sensing (e.g., Traffic Information)
Motivation: Automotive Safety Challenges

- Next generation safety applications need reliable, higher bandwidth communications

- Challenges
  - High node density
  - Severe fading channel due to obstructions and low antenna heights
  - Opportunistic use of access points
MAC: Geo-Cooperative Forwarding

- Highly-time varying channels (shadow fading)

- Traditional routing selects next hop prior to transmission
  - too slow for fast link changes
  - Need more opportunistic protocols not based on static link assumption

- Geobackoff for selecting next-hop from successfully received nodes: Receiver Diversity, and cooperative ARQ
Sample Implementation at MAC Layer

- Source Starts Txmit
- GeoBackoff Starts
- GeoBackoff Pauses at Nodes 1 & 2 (Node 3 txmits)
- GeoBackoff Resumes (Node 2 retransmits)
- Forwarding Completes

Source
- DATA
- f(p1)
- f(p2)
- f(p3)
- VACK
- DATA
- CRQ
- DATA
- VACK

Node 1
- SIFS

Node 2
- SIFS

Node 3
- SIFS
- VACK Timeout

Destination
- SIFS

DIFS

WINLAB
WIRELESS INFORMATION NETWORK LABORATORY
Example: Geocast / Georouting for Safety Applications

- Challenge: Reliability, Scaling (high node density)
- Strong integration with physical environment
- Location natural mechanisms for scoping / addressing
  - Location-distance based power and rate control
  - Selecting forwarders
    Location information can help in selection forwarding nodes

(Idealized) Broadcast range
Desired message delivery zone

Broadcast range

Irrelevant vehicles in radio range for few seconds

Geometric Stack Service Providers

Internet Integration: Georouting Overlay
Mobile Sensing: Privacy for Traffic Monitoring through Probe Vehicles

Geocoded Address Database (TIGER/LINE):

John Doe
1234 Main St
Anywhere, US
(515110X 4300483Y, 13Z)

Identification based on public records, subpoenas not necessary
Target Tracking and Tracking Uncertainty

\[ \hat{p}_i = e^{-\frac{d_i}{\mu}} \]

\[ H = -\sum p_i \log p_i \]
Snapshot of privacy-preserving GPS traces: black dots are removed samples (5min, 0.95)
Location-Aware Protocol Stack

- MAC – Geo-Cooperative
- Network - Georouting
- Transport – Reliable Geocast
- Application: Search, Sensor Aggregation, Proximity Detection, Geofencing
- Location Service
- Location Fusion
- Localization (e.g. Wifi Radar, GPS)
- Application-specific representations

- NSF-FIND Project

Future Internet Services
Location-Aware Networking and its Vehicular Applications

Traffic monitoring, sensing with probe vehicles, privacy

V2V and V2I Geocast and Georouting

V2V Radio Propagation Measurements at 5 GHz

ORBIT Testbed: High-density 802.11 protocols
Questions?