Scalable Geocast Based MANETs

“Quicksand area”

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Intro and Motivation

• **Goal:** bring timely information to every operator in the field, anytime/anywhere

• **Observation 1:** traditional approaches to field data networking in MANETs is problematic
  – Node mobility + terrain make routing topology dynamic and fragile, maint. overhead burdensome
  – Traditional unicast-based information distribution patterns do not scale well with (geographic) node density in MANETs
Intro and Motivation

• **Observation 2:** Worst scalability problems stem from need to send *same* information to all in an area
  
  • *Common operating picture problem*
    
    – Real time location and telemetry tracking of all to all
    
    – Mutual distribution of annotations and collaboration information

• **Field file transfer**
  
  – Transfer of imagery, maps, data to all operators in area
Solution Key Ideas

• **Key Idea 1:** Build field network on top of a *Scalable Ad Hoc Geocast Protocol (SAGP)* \(^1\)
  – Not built on IP, but can interoperate with it
  – More scalable than flooding (\(\lg n \text{ vs } n\))
  – *Side benefit:* geocast can discover a fresh unicast route for efficient 1-1 replies (reverse path forwarding)

• **Key Idea 2:** Exploit efficient 1-to-many geographic multicast for efficient applications
  – *Field Common Operating Picture (FCOP) Protocol* \(^2\)
  – *Geocast File Transfer (GFT) Protocol* \(^3\)

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2. MILCOM 2012
3. MILCOM 2013
SAGP Animation

Sender

Geocast Region

T distance

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SAGP Animation

1st Street

2nd Street

3rd Street

T distance

B Avenue

A Avenue

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SAGP Animation

1
3rd Street

2
2nd Street

T distance

1st Street

4

3

5

B Avenue

A Avenue
SAGP Heuristics

- Retransmit P iff (M or T or CD) and In FZ
- **M**: Heard < M transmissions of P?
- **T**: All transmissions at least T distant?
- **CD**: Am I closer to CGR than all heard?
- Forwarding Zone (**FZ**) = union of two circles

CGR = Center of Geocast Region
SAGP Is Scalable

• **Claim:** when all $n$ devices can hear each other, SAGP uses $O(lg n)$ transmissions/geocast average

• **Proof Sketch:**
  – Cost is dominated by CD heuristic
  – Each transmission approximately halves number of devices closer to CGR than transmitter

• This is the most critical special case
The FCOP Algorithm *

• For a device M to monitor region MR:
  – Initially set *Recent Response Cache* (RRC) to empty
  – Once per P seconds, geocast query message to MR
  – When device receives a query message Q:
    • Remove msgs from RRC older than P – ε
    • If no msg remains in RRC that was sent to a region containing location L of origin of Q, then
      – Geocast a response message w to targetRegion(L)
      – Record timestamped w in RRC
  – When device receives *any* response message, record info from it in client database for use by application

* See MILCOM 2012 paper for details
FCOP Algorithm Evaluation

• In dense *COP configuration*, FCOP uses $O(n \lg n)$ bytes per P seconds, because each of $n$ devices sends two geocasts per P sec (1 small query, 1 response)
• Major improvement over $\Omega(n^2)$ of other approaches
• Experimental evaluation: GC1/PSCommander prototype tested for $n = 2 .. 32$ devices in the field
• Measured bytes / sec transmitted over the (common) network
• Implemented using 802.11 (ad hoc WiFi) at 2.4 GHz

*COP configuration* = each device monitors all other devices
FCOP Experiment Results (Excerpt)

Bytes/sec vs # Devices

(Bytes/sec) / (n lg n) vs # Devices

Cost ≈ 154 n lg n
Geocast File Transfer (GFT) *

• File transfer to all in an area
• Novel protocol key ideas:
  – Geocast all file chunks in order
  – Receivers then request re-sends of missed chunks
  – Sender waits and pools requests
  – Sender geocasts requested chunks in order
• Results:
  – $O(k \lg n)$ bytes transmitted vs $\sim kn$ for traditional
  – Subconstant time per byte per recipient

* See MILCOM 2013 paper for details
GFT Results (Excerpt)

Fig. 7. Scenario 1: GFT Normalized Bytes vs # devices

Fig. 10. Scenario 1: GFT Normalized Time vs # devices

Fig. 12. Scenario 1: GFT Success vs #devices vs packet loss probability

Fig. 11. Scenario 2: GFT Normalized Time vs # devices

Time (Scenario 1)

Time (Scenario 2)

Bytes

Transfer Success
Summary

• **Key Idea 1:** Build field network on top of a *Scalable Ad Hoc Geocast Protocol (SAGP)*¹
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  - *Side benefit:* geocast can discover a fresh unicast route for efficient 1-1 replies (reverse path forwarding)

• **Key Idea 2:** Exploit efficient 1-to-many geographic multicast for efficient applications
  - *Field Common Operating Picture (FCOP) Protocol*²
  - *Geocast File Transfer (GFT) Protocol*³

² MILCOM 2012
³ MILCOM 2013