A Software Framework for Mobile Ad hoc Data Communications Using Voice-Centric Tactical Radios

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Motivation

- **State of Practice:** Modern C2 capabilities often don’t reach front line troops
  - situation awareness still voice centric
  - transition to information centric operation limited by legacy stove-pipe system designs

- **State of Art:** Mobile ad hoc networking is becoming a commodity technology in the civilian sector
  - ubiquitous high speed access to multimedia
  - minimum configuration
Research Objectives

- Investigate feasibility of providing data networking capability to small units with legacy radios
- Minimize requirement for additional “networking hardware”
Proof of Concept via SINCGARS Radio
System Components

- Data Link Protocol
- Multi-hop Routing Capability
  - Expected Relative Positioning Routing with Congestion Avoidance (ERP/CA)
- Tactical Chat Application
  - SINCGARS Data Demo
Data Link Protocol

- Media Access Control
  - ALOHA & CSMA Functionalities

- Flow Control and Error Control
  - Simple Stop-and-Wait

- “802.11-Lite”
  - Minimum subset of 802.11 features
    - MAC, Encapsulation, Error Control
  - No sync, beacons, probes, NAVs, authentication, etc.
Media Access Control

[Diagram showing a flowchart with steps for Media Access Control, including stages such as Awaiting Input, Awaiting Idle Channel, CSMA Mode, Random Back Off, Max Attempts, Frame Transmitted, and Awaiting ACK.]
ERP/CA Routing Protocol

- Operation-aware
  - Exploit Operational Knowledge about Node Movements

- Bandwidth-Efficient
  - Minimize Overhead of Control Traffic
Operational Knowledge

- TTPs (Tactics, Techniques, and Procedures) Used by Tactical Units
  - Military formations
  - Wingman concept

- Unit Leaders Maintain Physical Proximity
  - Maintain Radio Contact
  - Facilitates Command and Control
Operation-aware Routing

- Route Selection Based Upon Relative Positions of Nodes Within Formation
  - Relative positions between nodes (or node relationships) are policy-driven
  - Links between nodes with “close” relationship tend to be persistent

- Mechanism: Nodes wait for a period of time before responding to route request
  - Node with closest relationship to destination responds to route request first
Route Response Wait Formula

\[ RRW = CW + CAV + IRW \quad \text{milliseconds} \]

**CW values:**

<table>
<thead>
<tr>
<th>Relationship Category</th>
<th>Wait Time Assigned (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOD</td>
<td>1500</td>
</tr>
<tr>
<td>BETTER</td>
<td>1000</td>
</tr>
<tr>
<td>BEST</td>
<td>500</td>
</tr>
<tr>
<td>DIRECT LINK</td>
<td>0</td>
</tr>
</tbody>
</table>
Bandwidth-Efficient Routing

- On-demand Route Discovery

- Controlled Flooding
  - Node stops flooding if it has route to destination

- Node Relationships are Input to Protocol
  - No need to discover them (this is novel!)
Tank Company Wedge Formation

Company commander & executive officer

Wingmen relationships
Neighbor Discovery

HELLO

1

HELLO

2

3

4
Neighbor Discovery
(HELLO Response)
Frames Sent Between 1-Hop Neighbors
(Previously Known Routes)
Frames Sent Between 1-Hop Neighbors (Previously Known Routes)
Frames Sent Between Multi-Hop Neighbors
(Dynamic Discovery Of Routes)
Dynamic Discovery
Of Route
From White3 To Red3
Dynamic Discovery
Of Route
From White3 To Red3

I can reach Red3

No route. No response
Forwarding of message from White3 to Red3, via White2.
New Scenario

- Assume this new state:
  - No white node is in range of Red3
  - Red3 and Red1 are in new positions
Requests are broadcasted and flooded

TTL limits life of flood

Route response ends flooding
Response To Route Request

- All responses are unicast.
- Responses are based on categories.
- Actual destination responds first.
- Wingman responds next.
- Followed by Platoon Commander.
- Last to respond are all others with a route.

Not sent because Red4’s response is heard first.

I can reach Red3
Assume all within circle are within range of one another

Route requests from White3, for Blue2.
Congestion Avoidance

- Range of White3 is shown
- Blue3’s wingman and Platoon Commander are not in range
- Nodes will respond to the request based upon size of respective routing tables
SINCGARS Data Demo

- Tactical Chat Application
- File Transfer Capability
- Runs Directly Above Link Layer
Call signs reflect node relationships, e.g., Red1 and Red2 are wingmen to each other.
Conclusions

- Demonstrated feasibility to deploy data centric C2 capabilities with legacy voice centric radios using *only* software.

- Many opportunities exist to develop low cost *stop-gap* C2/network centric capabilities for front line troops.