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NPS Wireless Research Group
Tactical Network Topology Experimentation
Camp Roberts, Army National Guard Base
February 2012

TRIP REPORT

Initial Proof of Concept: Small UAS Tactical Airborne Relay

Test Participants:

- Team Lead: Major Jose Menjivar, NPS Information Technology Student
- Senior Systems Engineer: Charles Prince, NPS Staff
- Systems Engineer: Aurelio Monarrez, NPS Staff and Student
- Raven 11B Crew: Sergeant Timothy Fisher, A-Troop 1-18 CAV, USANG, Specialist Michael V. Wilson C-Troop 1-18 CAV, USANG
- Facilitator: Professor John Gibson, NPS Computer Science Dept.

Objectives:

- Conduct non-intrusive modifications to Raven 11B by adding a Wave Relay Single Board Module communication payload, power source, and Omni-directional antenna to Small UAS. This modification will enable Small UAS to act as an airborne tactical communications relay station.
- Conduct initial static point-to-point relay tests with Raven 11B Small UAS airborne relay station and Wave Relay Quad Router Radio Systems
- Confirm Small UAS airborne relay station can enable static beyond line sight of tactical communications
- Confirm Small UAS airborne relay station equipped with Wave Relay Single Board Module can transmit voice communications beyond line of sight within three nodes that are masked by terrain

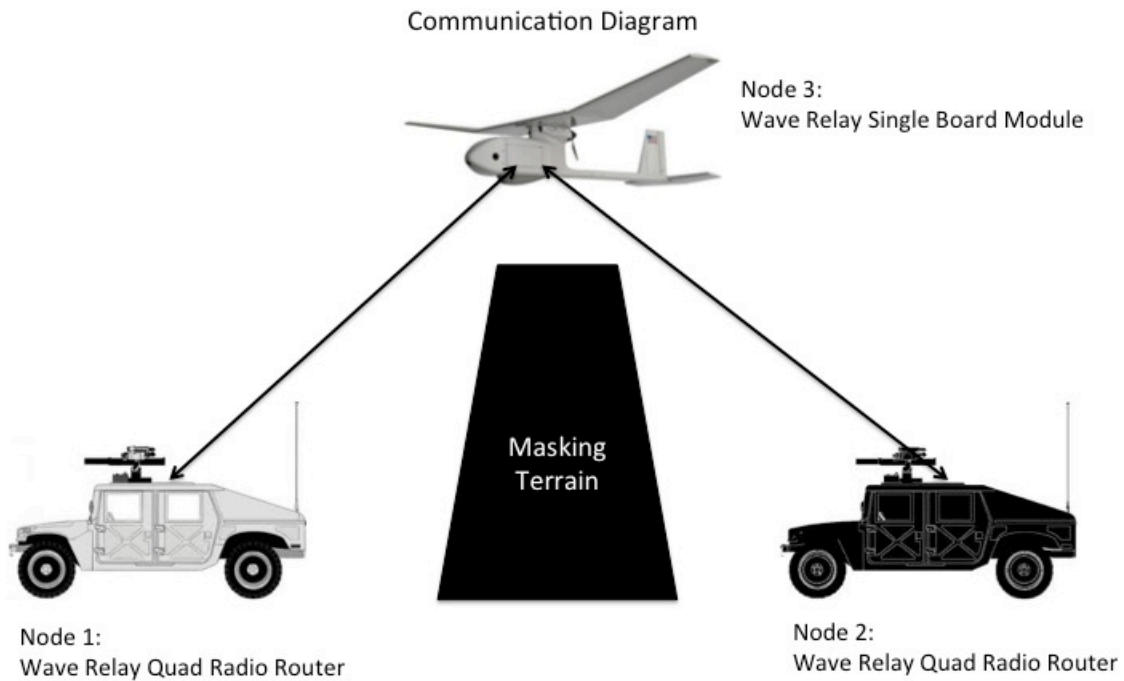
- Confirm Small UAS airborne relay station equipped with Wave Relay Single Board Module can transmit data packets beyond line of sight within three nodes that are masked by terrain

Test Environment:

- Node 1: HMMWV M1114 Tactical Vehicle equipped with proprietary Wave Relay Quad Radio Router System
 - Location: Stationary position approximately 2.5 kilometers away from node 2, line of sight was intentionally obstructed by masking terrain to prove beyond line of sight concept
- Node 2: HMMWV M1114 Tactical Vehicle equipped with proprietary Wave Relay Quad Radio Router System
 - Location: Stationary position approximately 2.5 kilometers away from node 1, line of sight was intentionally obstructed by masking terrain to prove beyond line of sight concept
 - See enclosure 1.
- Node 3: Aerovironment Raven 11B non-intrusive modifications that include the use of proprietary Wave Relay Single Board Module encased in cardboard box and weather proofed with a plastic bag and placed on fuselage with non-stick tape. The proprietary Wave Relay Single Board Module was powered by Thunder Power Lithium Polymer 65C 2250mAh 3-cell battery, which was also taped to fuselage. An omni-directional antenna was taped to bottom of fuselage. The weight of the payload was approximately .7 pounds. When placing payload on Small UAS aerodynamics and weight constraints were taken into consideration. To reduce impact on the integrity of the airframe the team carefully selected areas to place payload to ensure there was counter balance and even weight distribution. The team taped down extraneous parts to create better aerodynamics and mitigate loss of flight endurance.
 - Location: The Raven 11B crew was located approximately 2 kilometers from node 1 and 1.5 kilometers from node 2. Once the

Small UAS was airborne it climbed to 400 AGL (1200 MSL), and conducted circular flight patterns around nodes 1 and 2.

- See enclosure 2.



Test:

Team deployed node 2 and node 3 to training areas within Camp Roberts. Node 2 occupied static location behind a terrain feature large enough to mask line of sight communication capability with node 2. Node 2 was in placed behind terrain a voice communication check was attempted without the use of airborne relay. The masking terrain impeded voice transmission and also prevented from node 1 from tracking nodes 2 and 3 on the digital network. Once it was concluded that line sight communication was not feasible the team launched Node 3 (Raven 11B airborne relay.) The Raven operator launched the aircraft and noticed a slight wobble due added weight. The operator reported the aircraft corrected itself once sufficient airlift was gained. The Small UAS climbed to 400 AGL (1200MSL) was

established at set altitude the team conducted a voice communication test between node 1 and 2 relayed through node 3. The voice test was successful and transmissions were heard with high quality of service and low transmission latency. The follow on test was transmission of data packets simulating transfer of data files. The test began with small packets being transferred and incrementally increased in size (enclosure 3.) All data transfers transmitted by node 1 were received by node 2.

Findings: The field test proved the concept that airborne relay can enable beyond line of sight communications, both voice and data transmissions. At 400 AGL the airborne relay was able to provide a 2-kilometer radius communication area. The test also captured the quality of service and transfer rates improved when aircraft was directly overhead of ground nodes.

Any questions please contact team leader:

Major Jose Menjivar

Information Technology Management

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(Enclosure 1)

Wave Relay Quad Radio Router System Mounted M1114



(Enclosure 2)

Wave Relay Single Board Module Mounted on Raven 11B

Data transfer Report:

Server listening on TCP port 5001

TCP window size: 256 KByte (default)

[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50151

[ID] Interval Transfer Bandwidth

[4] 0.0-11.3 sec 896 KBytes 647 Kbits/sec

[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50152

[5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50153

[4] 0.0-15.8 sec 256 KBytes 133 Kbits/sec

[5] 0.0-46.5 sec 512 KBytes 90.3 Kbits/sec

[SUM] 0.0-46.5 sec 768 KBytes 135 Kbits/sec

[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50155
[5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50164
[5] 0.0-150.3 sec 256 KBytes 14.0 Kbits/sec
[5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50165
[4] 0.0-174.8 sec 896 KBytes 42.0 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50166
[5] 0.0-232.8 sec 1.12 MBytes 40.5 Kbits/sec
[4] 0.0-548.7 sec 256 KBytes 3.82 Kbits/sec
[SUM] 0.0-548.7 sec 2.50 MBytes 38.2 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50182
[4] 0.0-10.5 sec 2.12 MBytes 1.69 Mbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50183
[4] 0.0-11.3 sec 2.12 MBytes 1.58 Mbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50184
[4] 0.0-10.4 sec 3.25 MBytes 2.62 Mbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50185
[4] 0.0-11.4 sec 1.88 MBytes 1.38 Mbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50186
[4] 0.0-10.4 sec 3.75 MBytes 3.01 Mbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50187
[4] 0.0-10.8 sec 3.12 MBytes 2.43 Mbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50188
[4] 0.0-12.0 sec 1.62 MBytes 1.14 Mbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50189
[4] 0.0-13.0 sec 1.75 MBytes 1.13 Mbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50190
[4] 0.0-13.9 sec 1.62 MBytes 979 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50191
[4] 0.0-11.0 sec 512 KBytes 382 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50198
[4] 0.0-10.7 sec 1.25 MBytes 982 Kbits/sec

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[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50199
[ 4] 0.0-11.6 sec 1.38 MBytes 999 Kbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50200
[ 4] 0.0-10.4 sec 2.62 MBytes 2.11 Mbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50201
[ 4] 0.0-10.3 sec 3.75 MBytes 3.04 Mbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50202
[ 4] 0.0-11.0 sec 3.00 MBytes 2.29 Mbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50203
[ 4] 0.0-11.1 sec 2.25 MBytes 1.70 Mbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50204
[ 5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50205
[ 4] 0.0-15.3 sec 1.38 MBytes 756 Kbits/sec
[ 5] 0.0-25.5 sec 768 KBytes 247 Kbits/sec
[SUM] 0.0-25.5 sec 2.12 MBytes 700 Kbits/sec
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^C

```
sh-3.2#
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```
sh-3.2# cat /Users/jdmenjivar1971/iperf
```

```
iperf iperf.log1
```

```
sh-3.2# cat /Users/jdmenjivar1971/iperf.log1
```

```
-----
Server listening on TCP port 5001
```

```
TCP window size: 256 KByte (default)
-----
```

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[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50151
[ ID] Interval    Transfer    Bandwidth
[ 4] 0.0-11.3 sec 896 KBytes 647 Kbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50152
[ 5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50153
[ 4] 0.0-15.8 sec 256 KBytes 133 Kbits/sec
[ 5] 0.0-46.5 sec 512 KBytes 90.3 Kbits/sec
```


[SUM] 0.0-46.5 sec 768 KBytes 135 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50155
[5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50164
[5] 0.0-150.3 sec 256 KBytes 14.0 Kbits/sec
[5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50165
[4] 0.0-174.8 sec 896 KBytes 42.0 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50166
[5] 0.0-232.8 sec 1.12 MBytes 40.5 Kbits/sec
[4] 0.0-548.7 sec 256 KBytes 3.82 Kbits/sec
[SUM] 0.0-548.7 sec 2.50 MBytes 38.2 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50182
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[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50183
[4] 0.0-11.3 sec 2.12 MBytes 1.58 Mbites/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50184
[4] 0.0-10.4 sec 3.25 MBytes 2.62 Mbites/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50185
[4] 0.0-11.4 sec 1.88 MBytes 1.38 Mbites/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50186
[4] 0.0-10.4 sec 3.75 MBytes 3.01 Mbites/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50187
[4] 0.0-10.8 sec 3.12 MBytes 2.43 Mbites/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50188
[4] 0.0-12.0 sec 1.62 MBytes 1.14 Mbites/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50189
[4] 0.0-13.0 sec 1.75 MBytes 1.13 Mbites/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50190
[4] 0.0-13.9 sec 1.62 MBytes 979 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50191
[4] 0.0-11.0 sec 512 KBytes 382 Kbits/sec
[4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50198

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[ 4] 0.0-10.7 sec 1.25 MBytes 982 Kbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50199
[ 4] 0.0-11.6 sec 1.38 MBytes 999 Kbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50200
[ 4] 0.0-10.4 sec 2.62 MBytes 2.11 Mbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50201
[ 4] 0.0-10.3 sec 3.75 MBytes 3.04 Mbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50202
[ 4] 0.0-11.0 sec 3.00 MBytes 2.29 Mbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50203
[ 4] 0.0-11.1 sec 2.25 MBytes 1.70 Mbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50204
[ 5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50205
[ 4] 0.0-15.3 sec 1.38 MBytes 756 Kbits/sec
[ 5] 0.0-25.5 sec 768 KBytes 247 Kbits/sec
[SUM] 0.0-25.5 sec 2.12 MBytes 700 Kbits/sec
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sh-3.2#
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sh-3.2# cat /Users/jdmenjivar1971/iperf.log1
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Server listening on TCP port 5001
TCP window size: 256 KByte (default)
-----
```

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[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50151
[ ID] Interval      Transfer    Bandwidth
[ 4] 0.0-11.3 sec  896 KBytes 647 Kbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50152
[ 5] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50153
[ 4] 0.0-15.8 sec  256 KBytes 133 Kbits/sec
[ 5] 0.0-46.5 sec  512 KBytes 90.3 Kbits/sec
[SUM] 0.0-46.5 sec  768 KBytes 135 Kbits/sec
[ 4] local 192.168.113.13 port 5001 connected with 192.168.113.11 port 50155
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sh-3.2#

(Enclosure 3)