Improving Fault Tolerance in 802.11 Wireless Long Distance Rural Networks

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Motivation & Background

• More percentage of rural areas than urban areas in countries like India.
• Most of the rural areas are without any facilities of phone, internet....
• High cost of long distance wired networks than wireless networks to connect the rural areas.
• Increasing usage of wireless networks for connecting rural areas.
• **Network Disconnection due to problems at one or more nodes (e.g. power failure).**
Motivation & Background

Digital Gangetic Plains

- 802.11 for last-hop access within a village
- Point-to-Point 802.11 link
- Land-line access point (close to high-population density area)
- End to end distance ~80 Km
- Not to scale
Problem Statement
Problem Statement

- Intermediate node 4
- Backup node 7
Problem Statement

Intermediate node 4

Backup node 7
Advantage

Intermediate node 4
Backup node 7
Ashwini Network
Design Issues

• Three possible ways of changing the link
  – Replication of directional antennae and switching between them.
  – Using a Stepper Motor to rotate the directional antenna.
  – Using a sector antennae (cantenna).
Related Work

• Community networks
  – MIT Roofnet
    • Omni directional antenna
    • Routing problem only
  – Wireless Leiden
    • Multiple radios and antennae
    • Routing problem

• Ad-hoc networks with directional antennae.
  • Multiple directional antennae at nodes
  • Routing problem
  • Not implemented.
Replication

RF Switch

Far end node

Intermediate node

Backup node

Central node
Rotation

A

Stepper Motor
Far end node

C

Intermediate node

E

Central node

D

Backup node
Cantenna

- Far end node
- Intermediate node
- Backup node
- Central node
Thesis Contributions

• Implemented Replication and Cantenna solutions.
• Partially implemented Rotation solution.
• Evaluated and documented performance and cost issues of the solutions.
Design and Implementation

• **Replication:**
  – PSW-1211 switch circuit.
  – RSW-2-25-P switch circuit.
  – Hardware for generating control signals.
  – Software sending control logic to hardware.

• **Rotation:**
  – Circuit to interface the stepper motor.
  – Software to rotate the motor in full step and half steps.
  – Antenna mounting to the motor.

• **Cantenna:**
  – Software to switch the link.
Design and Implementation

Replication:
PSW-1211 switch circuit
Design and Implementation

Replication:
RSW-2-25-P switch circuit
Design and Implementation

Replication:
Hardware for control signals
Design and Implementation

Replication: Software

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<tr>
<th>Logic</th>
<th>Serial Port</th>
<th>Baud rate</th>
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<tr>
<td>'1'</td>
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<td>Higher than 0</td>
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Design and Implementation

Rotation:
Interface circuit for motor
Design and Implementation

Rotation:
Control logic sequence

<table>
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<tr>
<th>Full Step (1.8°)</th>
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<tbody>
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<td>Red</td>
<td>Orange</td>
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<table>
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<th>Half Step (0.9°)</th>
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</table>
Design and Implementation

Rotation:
Antenna Mounting

Diagram showing the rotation mechanism with a Stepper Motor, Spur Gear, Worm Gear, and Bearings.
Design and Implementation

Cantenna:

Software:

- Software to change the link is done by using commands (monitoring link using ‘ping’ & changing the wireless link)
Evaluation

• Two links FBTOP – CSE and FBTOP – MLA.
• FBTOP:
  – Two directional Antenna:
    • MLA: beam width 13° and Gain 22.5 dBi
    • CSE: beam width 8° and Gain 24 dBi
• MLA:
  – One directional Antenna with beamwidth 13° and Gain 22.5 dBi.
• CSE:
  – One sector Antenna with beamwidth 65° and Gain 12 dBi.
  – Attenuator (28 dB)
• One Laptop and prism chipset based Senao wireless card at each place.
• Hostap driver 0.4.7 and hostap utils 0.3.7.
Evaluation

Preliminary:

FBTOPY - CSE (other link is not up)
Signal Strength:
  FBTOP: -67 dBm
  CSE: -67 dBm
Throughput:
  FBTOP -> CSE: 5.71 Mbps
  CSE -> FBTOP: 5.6 Mbps

FBTOPY - MLA (other link is not up)
Signal Strength:
  FBTOP: -68 dBm
  MLA: -66 dBm
Throughput:
  FBTOP -> MLA: 6.35 Mbps
  MLA -> FBTOP: 5.8 Mbps
Evaluation

Replication (PSW-1211):
Calibration - Transmission:
Evaluation

Replication (PSW-1211):
Calibration - Isolation:
Evaluation

Replication (PSW-1211):

FBTOP – CSE (through Antenna A and selection of I – A, MLA is idle)

Signal Strength:
- FBTOP: -72 dBm
- CSE: -72 dBm

Throughput:
- FBTOP → CSE: 6.2 Mbps
- CSE → FBTOP: 6.4 Mbps

FBTOP – MLA (through Antenna B and selection of I – A, CSE is idle)

Signal Strength:
- FBTOP: -85 dBm
- MLA: -84 dBm

Throughput:
- FBTOP → MLA: 3-4.5 Mbps
- MLA → FBTOP: 1.8 Mbps

Both CSE and MLA sending data:

Throughput:
- CSE → FBTOP: 5.8 Mbps
Evaluation

Replication (PSW-1211):

FBTOP → CSE (through Antenna A and selection of I-B, MLA is idle)

- Signal Strength:
  - FBTOP: -89 dBm
  - CSE: -89 dBm

- Throughput:
  - FBTOP → CSE: 0 Mbps
  - CSE → FBTOP: 0 Mbps

FBTOP → MLA (through Antenna B and selection of I-B, CSE is idle)

- Signal Strength:
  - FBTOP: -70 dBm
  - MLA: -70 dBm

- Throughput:
  - FBTOP → MLA: 6.3 Mbps
  - MLA → FBTOP: 6 Mbps

Both CSE and MLA sending data:

- Throughput:
  - MLA → FBTOP: 5.9 Mbps
Evaluation

Replication (RSW-2-25-P):
Calibration - Transmission:
Evaluation

Replication (RSW-2-25-P):
Calibration - Isolation:
Evaluation

Replication (RSW-2-25-P):

FBTOP – CSE (through Antenna A and selection of I – A, MLA is idle)

Signal Strength:
FBTOP: -72 dBm
CSE: -72 dBm

Throughput:
FBTOP → CSE: 6.1 Mbps
CSE → FBTOP: 5.8 Mbps

FBTOP – MLA (through Antenna B and selection of I – A, CSE is idle)

Signal Strength:
FBTOP: -85 dBm
MLA: -85 dBm

Throughput:
FBTOP → MLA: 2.3 Mbps
MLA → FBTOP: 0.4 Mbps
Evaluation

Replication (RSW-2-25-P):

FBTOP – CSE (through Antenna A and selection of A – B, MLA is idle)

Signal Strength:
- FBTOP: -88 dBm
- CSE: -88 dBm

Throughput:
- FBTOP → CSE: 0 Mbps
- CSE → FBTOP: 0 Mbps

FBTOP – MLA (through Antenna B and selection of A – B, CSE is idle)

Signal Strength:
- FBTOP: -70 dBm
- MLA: -70 dBm

Throughput:
- FBTOP → MLA: 6.2 Mbps
- MLA → FBTOP: 6 Mbps
Evaluation

• Rotation:
  – Interface circuit and software for rotation are implemented.
  – Antenna mounting not implemented.
  – Will be same as Preliminary case.
Evaluation

- **Cantenna:**
  - Implemented using a Splitter.
# Comparison

<table>
<thead>
<tr>
<th></th>
<th>Preliminary</th>
<th>Replication</th>
<th>Rotation</th>
<th>Cantenna</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PSW-1211</td>
<td>RSW-2-25-P</td>
<td></td>
</tr>
<tr>
<td>No. of Antenna</td>
<td>N/A</td>
<td>2</td>
<td></td>
<td>1</td>
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<tr>
<td>Switching Time</td>
<td>N/A</td>
<td>Order of micro seconds</td>
<td>Order or minutes</td>
<td>Order of micro seconds</td>
</tr>
<tr>
<td>Interference from other link</td>
<td>Negligible</td>
<td>17 dB less than other link signal strength</td>
<td>Negligible</td>
<td>Equal to signal strength</td>
</tr>
<tr>
<td>FBTOP – CSE</td>
<td>5.7 Mbps</td>
<td>6.2 Mbps</td>
<td>6.1 Mbps</td>
<td>5.7 Mbps</td>
</tr>
<tr>
<td>FBTOP – MLA</td>
<td>6.2 Mbps</td>
<td>6.3 Mbps</td>
<td>6.2 Mbps</td>
<td>6.2 Mbps</td>
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<tr>
<td>At FBTOP when CSE and MLA are transmitting data</td>
<td>N/A</td>
<td>5.8 Mbps</td>
<td>Will be same as PSW-1211</td>
<td>6 Mbps</td>
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<td>Cost</td>
<td>N/A</td>
<td>2*$50+$33</td>
<td>2*$50+$4</td>
<td>$50+$59</td>
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</table>
Conclusion

• Presently no cost-effective solutions.
• Presented and implemented three solutions Replication, Rotation (partially implemented) and Cantenna.
• Replication and Rotation are good for all cases.
• Cantenna is good only when one of the intermediate node or backup node is serving the far-end nodes.
Future Work

• Assumed that intermediate and backup nodes are given.
• Find the intermediate and backup nodes optimally.
• Rotation has to be implemented completely.