Simplifying Fault Diagnosis in Locally Managed Rural WiFi Networks

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Joint work with Rabin Patra and Eric Brewer

Introduction

- Many rural wireless networks up in last few yrs
  - Aravind (India), CRCN et (New Zealand), etc.
- But operational maintenance is challenging!
- Long term support not guaranteed
- Training helps but high IT turnover
- Research agenda should expand to simplified diagnosis solutions
Motivation

- Chances of hardware failure are higher because of poor power quality
- Node locations are hard to access
  - Many times trips turn out to be unnecessary
- Rural users are inexperienced initially
  - Rely on experts: longer downtimes and higher cost
- **Goal**: Reduce downtimes, costs, and build local capacity in managing the network

Related Work in WiFi Diagnosis

- None for diagnosis in the context of rural WiLD (WiFi-enabled Long Distance) networks
- **802.11 Enterprise LAN Diagnosis**
  - WiFi Profiler [1]
  - Jigsaw [2]
  - Different operating environments and different faults
- **Recoverable Computing (e.g. RADS)**
  - System designed to re-initialize and recover on reboot
  - But we are also trying to diagnose more than just software service errors, e.g. if antenna is misaligned or pigtail is not working, reboots don’t really help

What do we need for diagnosis?

- Identify data
  - Instantaneous and historical
  - Power, Node, Link, System

- Back Channel
  - Gather data and take action when primary link is down

- Independent Monitoring (and Repair)
  - Diagnose subsystems when main link is down
  - No dependency on system functioning

The Aravind Eye Hospital Network
Over 25,000 consultations since Jan 2006
### Real Faults from Aravind (1)

#### Hardware Faults (since Jan 2005)

<table>
<thead>
<tr>
<th>Instances</th>
<th>Description</th>
<th>Total Downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>Router board not powered on (grid outage)</td>
<td>63 days</td>
</tr>
<tr>
<td>7</td>
<td>Router powered but hung</td>
<td>10 days</td>
</tr>
<tr>
<td>21</td>
<td>Router powered but not connected to remote LAN (burnt ethernet ports)</td>
<td>34 days</td>
</tr>
<tr>
<td>3</td>
<td>Router on, but wireless cards not transmitting (low voltage)</td>
<td>2 days</td>
</tr>
<tr>
<td>3</td>
<td>Router on, but pigtails not connected</td>
<td>45 days</td>
</tr>
<tr>
<td>3</td>
<td>Router on, but antenna misaligned</td>
<td>13 weeks</td>
</tr>
</tbody>
</table>

*Conservative Estimate
Undiagnosed: 41

### Real Faults from Aravind (2)

#### Software Faults (since Jan 2006)

<table>
<thead>
<tr>
<th>Instances</th>
<th>Description</th>
<th>Total Downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>No default gateway specified</td>
<td>4 days</td>
</tr>
<tr>
<td>3</td>
<td>Wrong ESSID, channel, mode</td>
<td>3 days</td>
</tr>
<tr>
<td>2</td>
<td>Wrong IP address</td>
<td>2 days</td>
</tr>
<tr>
<td>2</td>
<td>Misconfigured routing</td>
<td>3 days</td>
</tr>
</tbody>
</table>

*Conservative Estimate
Undiagnosed: 41
Scenario 1: Power/Hardware Problems

- How do we distinguish between these faults?
  - Power data, Board response data
  - May or may not need site visit

Scenario 2: Software Misconfiguration

- Reboot won't fix
  - Need additional actions
  - No need for site visit
Scenario 3: Antenna Problems

- How do we distinguish?
  - Signal strength measurements at both ends
  - Reboots do not help
  - Need site revisit

Scenario 4: Preemptive Diagnosis

- Monitor battery discharge cycles
- Plan replacement for next trip
- Also plan around failures
  - Predict remaining battery uptime for free
Implementation

- Data Collection
  - PhoneHome
  - Delay Tolerant Networking (DTN) [1]

- Independent Back Channel
  - SMS backchannel

- Independent Monitoring (and Repair)
  - HW watchdog
  - Software watchdog
  - Cellphone device


Node Architecture

- Hardware watchdog
- Software watchdog
- Log collection software
- Power Controller
- SMS Backchannel
## Current Status: Data Collection

Data being collected currently

<table>
<thead>
<tr>
<th>Scope</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node</td>
<td>CPU, disk, memory util, interrupts, voltage, temp, reboot logs, kernel messages, power controller data</td>
</tr>
<tr>
<td>Link</td>
<td>Traffic volume, signal strength, #retransmissions, #dropped packets, #overheard stations, #corrupted packets, packet loss, maximum bandwidth</td>
</tr>
<tr>
<td>System</td>
<td>Route changes, pairwise traffic volume, pairwise end-to-end delay and maximum throughput</td>
</tr>
</tbody>
</table>

### PhoneHome
- Connections only able to be initiated from inside the network
- Open SSH tunnels to US server
- Have back channel at main node

### DTN (Delay Tolerant Networking)
- Store and forward overlay network
- User persistent storage to ensure delivery after link recovers
- Each node runs DTN demon
Current Status: Data Collection

Other example data
- One relay node rebooted 515 times in ~150 days
- If power data, could see if power was the problem at relay

Current Status: Power Controller

Features
- Combines grid, solar, battery input
- Maximum power point tracking
- Status reporting through Ethernet and Serial
- Can query and reboot the router
Future Work

- Add Cellphone
  - SMS-based Back channel
    - 160-byte (40 integer parameters)
  - Independent Monitor
    - Communicate over serial with board and controller

- Deployment at Aravind by end of 2007

Thank You!
http://tier.cs.berkeley.edu/wiki
Backup Slides

Goals

- Ultimately, reduce the need for CS PhD students or other such “experts” to go there
  - Prevent elongated downtimes
  - High cost: last year alone, I went 5 times ( $10K in tickets only!)

- Pinpoint faults for quicker fixes: reduce downtime
- Reduce unnecessary or blind travel
- Provide ability to plan around faults
- Educational benefit over time (capacity building); demystify faults to inexperienced users
What is a Fault?

- “The link is down!”
  - Some nodes cannot be reached
  - Generally an email (many times sent after few days)

- Hard to find the root cause
  - Any component could have failed

Conclusions

- Separate
One Extreme Example

- Downtime: 2 months!

What does a WiLD link look like?

Diagram showing the components of a WiLD link:
- Battery
- Solar Panel
- Grid
- Power Controller
- CF
- Router
- Wireless link
- Directional Antenna
- Local Antenna
Requirements Distilled

- History is a valuable diagnosis tool
  - Monitor status
  - Compare with expected behavior
  - Possibly predict using simple techniques

- Out-of-band access to various link components
  - Hardware
  - Software
  - Back Channel

How Does it All Come Together?

- Walk down a decision tree
  - Can do binary or smarter searches
- Package up status info
- Send over the back channel
- Take local action if possible (reboot)
Implementation Details to Consider

- SMS to router protocol
  - What phones or other devices to choose?
  - How much programmability required?
  - Polling interface?
  - How much can be packed into SMS message for status?
    - Can we do routine log collection over SMS?
  - Transport protocol over SMS?