ODiN : Enhancing Resilience of Disaster Networks through Regression Inspired Optimized Routing

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Introduction

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- Disaster-hit zones are often completely or partially damaged.

- Need infrastructure less frameworks like AllJoyn for communication in these scenarios.
Contributions and Novelty

Research Contributions

1. We design and test a basic AllJoyn Disaster Network application (DiNet App) capable of file exchange between devices in proximity.

2. We Carry out Regression Analysis of empirical results to identify relationships between network parameters.

3. Propose optimal routing for disaster networks that offers a solution specific to the challenges in routing in DiNets.

Novelty

We propose a novel method of replacing optimization model constraints with empirically derived regression relationships.
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AllJoyn Features

- Discover
  - DISCOVER nearby devices
  - IDENTIFY services running on those devices

- Control and Manage
  - CONTROL AND MANAGE devices near and far
  - MANAGE remote and local

- Interoperate
  - INTEROPERATE across OS, device and manufacturer

- Adapt
  - ADAPT to devices coming and going

- Span
  - SPAN diverse transports

- Secure
  - SECURE against bad actors

Figure: Alljoyn Features
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**Diagram:**
- Discover: nearby devices
- Identify: services running on those devices
- Control and Manage: devices near and far
- Manage: remote and local
- Interoperate: across OS, device, and manufacturer
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  - Automatic device discovery and service advertisement mechanism.
  - Allows dynamic configuration of the network.
  - Platform independent.
  - Can use C, C++, Java for developing applications.
  - Provides greater security (Simple Authentication and Security Layer (SASL)) by allowing access at the granularity of application-to-application communication.
DiNet App

- AllJoyn provides basic chat application.
- Modified the chat application to implement the DiNet application.
- Used C++ for development on Ubuntu.
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- Modified the chat application to implement the DiNet application.
- Used C++ for development on Ubuntu.
- Implemented several important modules:
  - AcceptSessionJoiner
  - FoundAdvertisedName
  - MyBusListener
  - BusAttachment
  - TransferFile
Field Experiment for Single-Hop Topology

- Sender is sending 1, 4 and 10 MB file.
- Receiver is moving away from sender.
- The network metrics observed at every 5m interval are the Transfer Time (TT) of each file, Signal Strength, and Throughput.
- Considered 2 scenarios: HIS (High Interference Scenario) and LIS (Low Interference Scenario).

Figure: Topology for experiment
Results for HIS

- 4 MB file transfer fails beyond 60 meters and 10MB file transfer fails beyond 35 meters.
- As file size increases transfer time increases.
- Battery consumption is high for large files.

Figure: Transfer Time vs Inter-node distance (1, 4, 10 MB file transfer)

Figure: Throughput vs Inter-node distance (1, 4, 10 MB file transfer)

Figure: Battery Consumption vs Inter-node distance (1, 4, 10 MB file transfer)
Results for LIS

- 4 and 10MB file transfer fails beyond 90 meters and 1MB file transfer fails beyond 100 meters.
- Transfer time is less and throughput is more for LIS than HIS.
Multi-Hop Scenario

- However, a mobile device may move to a location which is beyond the direct transmission range of AD.

- A direct single-hop communication between the AD and PD (Participating Device) is necessary.

- Extended Proximity.

Figure: Multi-Hop Topology
Conducted Regression Analysis of several network parameters.

Motivation is to use these empirical relationships in optimizing network performance.

Regression equations from the DiNet field experiment are presented below.

X is inter-nodal distance, and Y is response variable (Signal Strength, Delay, Throughput, etc.)

<table>
<thead>
<tr>
<th>Parameter (Y)</th>
<th>R-sq</th>
<th>Regression Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Strength</td>
<td>86.94</td>
<td>$Y = -47.93 - 0.5973 X + 0.002923 X^2$</td>
</tr>
<tr>
<td>Throughput</td>
<td>88.92</td>
<td>$Y = 17.56 - 0.4790 X + 0.003370 X^2$</td>
</tr>
<tr>
<td>Battery Drain</td>
<td>87.97</td>
<td>$Y = 0.05925 - 0.004742 X + 0.000129 X^2$</td>
</tr>
<tr>
<td>Delay</td>
<td>79.34</td>
<td>$Y = 1185 - 124.7 X + 4.302 X^2$</td>
</tr>
</tbody>
</table>
Optimal Routing for Disaster Networks

- **Theoretical ODiN Model** \((\text{ODiN}_T)\)

  - To maximize the overall throughput in the disaster network, we choose optimal ad-hoc links.
Optimal Routing for Disaster Networks

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  - Allocate the unlicensed spectrum chunk effectively to these links and tune the uplink power for these links.
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  - To maximize the overall throughput in the disaster network, we choose optimal ad-hoc links.
  
  - Allocate the unlicensed spectrum chunk effectively to these links and tune the uplink power for these links.

- **Terminologies used in equation of Theoretical ODiN Model** \( (ODiNT) \)
  
  - Let \( I = \{ i_1, i_2, \ldots, i_n \} \) be the set of relay (intermediate) nodes and \( J = \{ j_1, j_2, \ldots, j_n \} \) be the set of mobile (moving) nodes. \( z \) is spectrum which belongs to \( Z \).
  
  - The binary variable \( Q^z_{ij} \) is 1 when relay node \( i \) and mobile node \( j \) communicate through the spectrum \( z \).
  
  - \( G_{ij} \) is the channel gain from \( i \) to \( j \).
Equation for Theoretical ODiN Model: \( ODiN_T \)

- \( P_{\text{max}}^w \) denotes the maximum power of a transmitting node.
- Transmission power of a relay node \( i \) in a spectrum chunk \( z \) is calculated as \( p_i^z \times P_{\text{max}}^w \), where the power value (in watts) lies in the range of \( 0 \leq p_i^z \leq 1 \).

\[
\text{SINR}_{ij} \leq \frac{\ln f \times (1 - Q_{ij}^z) + G_{ij} p_i^z P_{\text{max}}^w}{N_0 + \sum_{w \in W_k} G_{wj} P_{\text{max}}^i + \sum_{i' \in I \setminus i} G_{i'j} p_{i'}^z P_{\text{max}}^w}
\]

\[\forall i \in I, \forall j \in J, \forall z \in Z\]
Optimal Routing for Disaster Networks

Regression Inspired ODiN ($ODiN_{NPR}$)

- We replace the theoretical constraints in an optimization model with Network Performance Relationships derived through Regression Analysis of empirically observed data.

- NPR between inter-nodal distance and SINR replaces Equation 1 shown earlier
  \[ Y = -47.93 - 0.5973X + 0.002923X^2 \]
Optimal Routing for Disaster Networks

- **Regression Inspired ODiN** \((ODiN_{NPR})\)

  - We replace the theoretical constraints in an optimization model with Network Performance Relationships derived through Regression Analysis of empirically observed data.
  
  - NPR between inter-nodal distance and SINR replaces Equation 1 shown earlier
  
  \[
  Y = -47.93 - 0.5973 \times X + 0.002923 \times X^2
  \]

- Advantages of regression inspired optimization
  - Optimal relay node selection.
  - Reduced convergence times.
**Throughput Results**

*Figure: Throughput vs Inter-node distance (1 MB file transfer)*

*Figure: Throughput vs Inter-node distance (4 MB file transfer)*

*Figure: Throughput vs Inter-node distance 10 MB file transfer*

- $ODiN_{NPR}$ outperforms $ODiN_T$ in terms of Throughput.
- As file size increases throughput increases.
- As distance increases throughput decreases.
Convergence Time Results

- **Figure**: Convergence Time vs Inter-node distance (1 MB file transfer)
- **Figure**: Convergence Time vs Inter-node distance (4 MB file transfer)
- **Figure**: Convergence Time vs Inter-node distance (10 MB file transfer)

- $ODiN_{NPR}$ outperforms $ODiN_T$ in terms of Convergence Time.
- Average % convergence time reduction by $ODiN_{NPR}$ for 1MB, 4MB, and 10MB files is 69.94%, 60.36%, 55.55%, respectively.
Conclusions and Future work

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- Implemented an AllJoyn based DiNet application.
- Made use of Regression Analysis to optimize network performance.
- Formulated the model called ODiN that offers an optimal solution specific to the challenges in routing in Di Nets.
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- Formulated the model called ODiN that offers an optimal solution specific to the challenges in routing in DiNets.

**Future Work**
- Implement $ODiN_{NPR}$ in real-time Alljoyn Framework.
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References I


Thank You
queries?