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

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An International Conference on Advanced Networks and Telecommunications Systems
19^{th} December 2019

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.

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Novelty

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

AllJoyn Features

- Discover

Figure: Alljoyn Features

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  - Allows dynamic configuration of the network.
  - Platform independant.
  - 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.

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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).

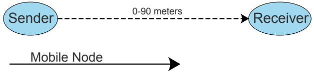


Figure: Topology for experiment

Results for HIS

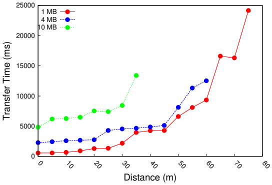
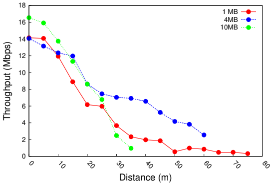


Figure: Transfer Time vs Inter-node distance (1, 4, 10 MB file transfer)



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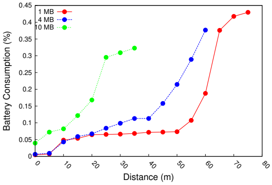
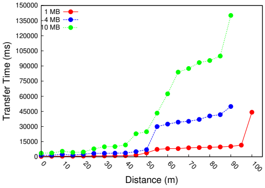


Figure: Battery Consumption vs Inter-node distance (1, 4, 10 MB file transfer)

- 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.

Results for LIS



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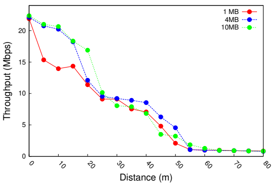

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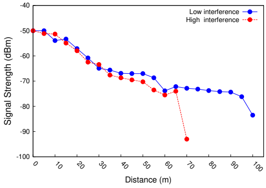

Figure: Signal Strength vs Inter-node distance (1, 4, 10 MB file transfer)

- 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.

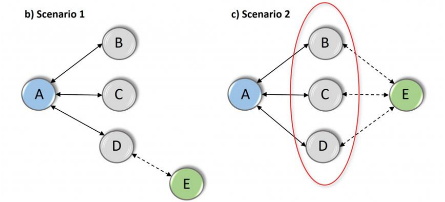

Figure: Multi-Hop Topology

Regression Analysis of Network data

- 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.)

Parameter (Y)	R-sq	Regression Equation
Signal Strength	86.94	Y = - 47.93 - 0.5973 X + 0.002923 X^2
Throughput	88.92	Y = 17.56 - 0.4790 X + 0.003370 X^2
Battery Drain	87.97	Y = 0.05925 - 0.004742 X + 0.000129 X^2
Delay	79.34	Y = 1185 - 124.7 X + 4.302 X^2

table1

Optimal Routing for Disaster Networks

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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** $(ODiN_T)$
  - 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^w_{max} denotes the maximum power of a transmitting node
- Transmission power of a relay node i in a spectrum chunk z is calculated as $p^z_i \times P^w_{max}$, where the power value (in watts) lies in the range of $0 \leq p^z_i \leq 1$

$$SINR_{ij} \leq \frac{Inf \times (1 - Q^z_{ij}) + G_{ij} p^z_i P^w_{max}}{N_o + \sum_{w \in W_k} G_{wj} P^i_{max} + \sum_{i' \in I \setminus i} G_{i'_j} p^z_{i'} P^w_{max}} \quad (1)$$

$$\forall i \in I, \forall j \in J, \forall z \in Z$$

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 - 0.5973 X + 0.002923 X^2

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    Y = - 47.93 - 0.5973 X + 0.002923 X^2
  - Advantages of regression inspired optimization
    - Optimal relay node selection.
    - Reduced convergence times.

Throughput Results

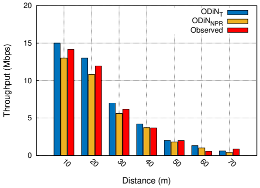

Figure: Throughput vs Inter-node distance (1 MB file transfer)

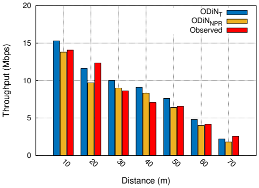

Figure: Throughput vs Inter-node distance (4 MB file transfer)

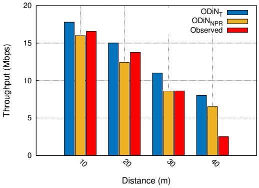

Figure: Throughput vs Inter-node distance 10 MB file transfer)

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

Convergence Time Results

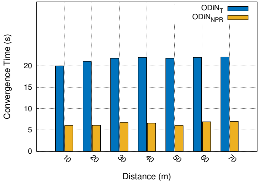

Figure: Convergence Time vs Inter-node distance (1 MB file transfer)

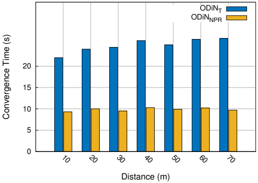

Figure: Convergence Time vs Inter-node distance (4 MB file transfer)

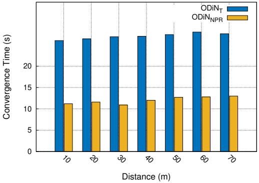

Figure: Convergence Time vs Inter-node distance 10 MB file transfer)

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

Acknowledgement

This work is supported by the project under Visvesvaraya PhD Scheme of Digital India Corporation, GoI.

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Thank You

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