Challenges in Emergency Medical Services in India

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CMU-Heinz and GVK-EMRI Collaboration

• GVK-EMRI (Emergency Medical Research Institute)
  – First EMS (911-type) Provider in India
  – Started in 2005 in one state
  – Now present in 10 states

• CMU Team
  – Prof. Ramayya Krishnan
  – Lavanya Marla
  – Yisong Yue
  – Aayush Kumar
  – Understanding operations in Hyderabad
Ground realities at EMRI

- Prior to EMRI, no central ambulance provider
  - Ad-hoc emergency provider networks
  - Hospital ambulances, taxis
- Public-private partnership
  - Funding: 95% state gov, 5% private partner
  - No fees charged for service (paid by state)
- Highly resource constrained
  - 75M people, 75 ambulance bases (AP)
- Cell-phone-based communications
Challenges at EMRI

- Public acceptability
  - Clear traffic for ambulance
- Competition with ad-hoc networks
  - Decreases utilization of ambulances
- No real-time position availability
- New cities
  - New traffic patterns
  - High-rise buildings without elevators
  - New modes of transport
Key Questions of Interest and First steps

• How can performance be improved using existing resources (e.g., ambulances)?

• How to characterize the state of the system?

• How to model how the system is affected by current allocation and dispatching policy?

• Can a decision support tool be developed to answer these questions?
Key Concepts

- Network consists of ambulances located at bases
- Each base services calls that arise in a set of grids around it
- The default (EMRI) model is to have one ambulance in each base to serve calls in the associated grids
- A call that is serviced consists of the ambulance arriving from the base to a scene and then taking the patient to a hospital from the scene and then returning to base
Design Principles

• Consistency with current dispatching model
  – Assign nearest free ambulance available
  – Priority order for ambulances

• Do not add extra bases than those determined by EMRI
  – Logistical challenges

• Do not add extra ambulances

• Derive congestion information from data logs
Modeling Concept: Chain Formation

Dependency Graph

25 min
(20 min)
30 min
(15 min)
45 min
(25 min)

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Modeling Concept: Chain Formation

Modified Dependency Graph for new allocation

- 25 min (12 minutes saved)
- 18 min
- 15 min (30 minutes saved)
- 25 min (no vehicle assigned previously)
Breaking dependencies - improves service
Simulation framework

Based on call logs we can model:

- Call congestion patterns
- Chains and other long-range system effects
- Utilization of various base locations

Simulation approach to evaluate ambulance-to-base allocations

- Simulate Dispatch Officer assigning ambulances to calls
- Simulate response times and outcomes
- Data-driven approach (based on actual call logs)
Mathematical formulation

- $G =$ dependency graph
- $C(G) =$ total cost of graph $G$
- $T(G, S) =$ modified dependency graph with change $S$ to allocation
- Change in objective $(F)$:
  $$F(G, S) = C(G) - C(T(G, S))$$
- $F(G, S)$:
  - Monotonically increasing
  - Order-invariant
  - Approximately sub-modular
Simulation-optimization approach

Goal: Allocate $N$ ambulances among $M$ bases

- Test adding an ambulance at location $m \in M$
- Number ambulances added < $N$?
- Simulate calls
- Simulate calls
- Simulate calls
- Find location $m^*$ with most improvement
- Add ambulance at $m^*$

Add one ambulance per iteration
Visualization tool (1)
Visualization tool(2)
<table>
<thead>
<tr>
<th>Metric</th>
<th>Current EMRI</th>
<th>Optimized</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td># Calls w/ Base-to-Scene &lt; 15 min</td>
<td>5459</td>
<td>6415</td>
<td>18%</td>
</tr>
<tr>
<td># Calls w/ Total-Service-Time &lt; 60 min</td>
<td>2940</td>
<td>3279</td>
<td>12%</td>
</tr>
<tr>
<td># Vehicle Busy</td>
<td>61</td>
<td>20</td>
<td>67%</td>
</tr>
<tr>
<td># Calls serviced by primary segment</td>
<td>6569</td>
<td>7297</td>
<td>11%</td>
</tr>
</tbody>
</table>

*Measured using simulation based on one month of data*
Existing routes
  - Currently use data-driven models for traffic congestion capture
  - Allows to extrapolate data for routes taken in past

New routes?
  - Crowdsourced/obtain traffic information from other ambulances
  - Communication between ambulances to share traffic data (Prof. Ramayya Krishnan)
Needed technology: Human behavior models

- ‘Conflict’ between existing ad-hoc networks and EMRI network
- Customer calls multiple service providers
  - Choose the one which arrives first
- Modeled higher abandonment in select urban areas
- How to improve ambulance utilization?
- What system can lead to improved social welfare?
Ongoing research directions

**Improved ambulance-base allocations:**
- Better traffic congestion model to estimate service time
- Further benefits
  - lower average service time
  - Serve more calls within survival threshold

**Real-time ambulance deployment:**
- Predict high demand regions
  - ‘System stress’
- Re-position ambulances in real-time
  - Real-time position data
Solution Approach Summary

Ambulance Location

Dynamic Reposition

OPTIMIZATION

TRAFFIC MODELING

HUMAN BEHAVIOR MODELING

SIMULATION VISUALIZATION

REAL-TIME INFORMATION

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