A Mobile Geo-Communication Dataset for Physiology-Aware DASH in Rural Ambulance Transport

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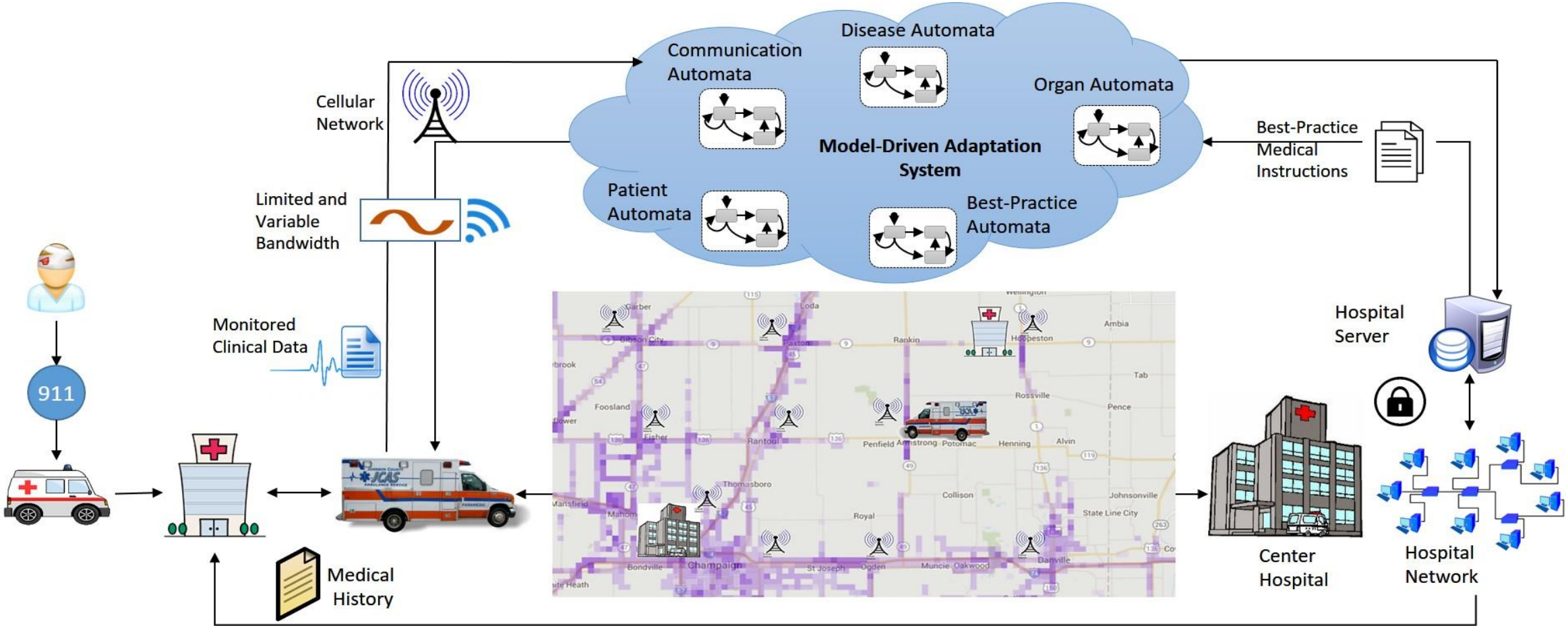
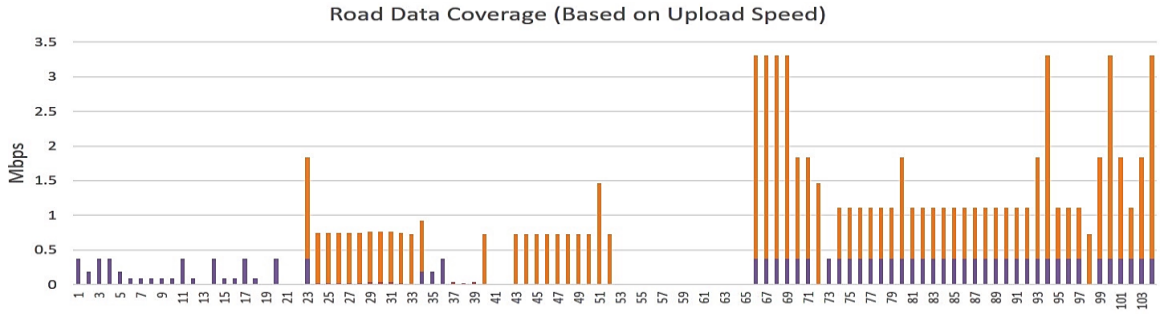
Available at:

http://web.engr.illinois.edu/~shossen2/carleProfiler.html

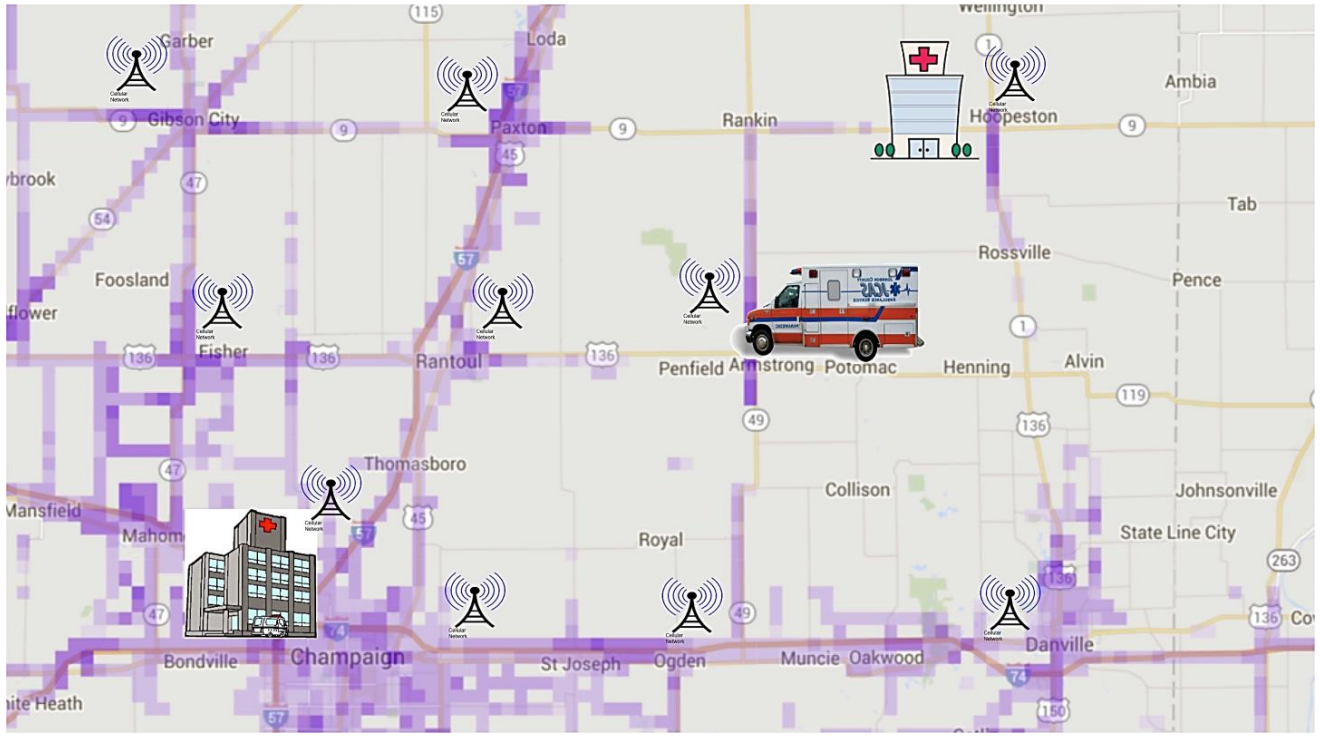
Problem Space: A Big Picture!





Motivation

- High QoS requirement of clinical data in remote monitoring of patients
- Bandwidth is **limited** and **variable** in en-route ambulances
  - Wireless networks along the roads in rural areas can range from 4G to 2G, some parts with no coverge
  - In rural areas and high speed ambulances, bandwidth can get even more limited



Objective, Challenges, and Approach

- **Objective**
  - Promoting the effectiveness of remote monitoring in rural ambulance transfer

- **Challenges** (include, but are not limited to)
  - Patient monitoring in ambulances under limited and variable bandwidth
  - Communication breakage in parts of major routes, especially along rural routes

- **Approach**
  - To propose an adaptive clinical data transmission framework
    - Study the semantic relation of clinical data adaptation with bandwidth and ambulance undertaken route in a physiology-aware manner
    - Real-world geo-communication profiling dataset to support experiments

Background: Adaptive Streaming

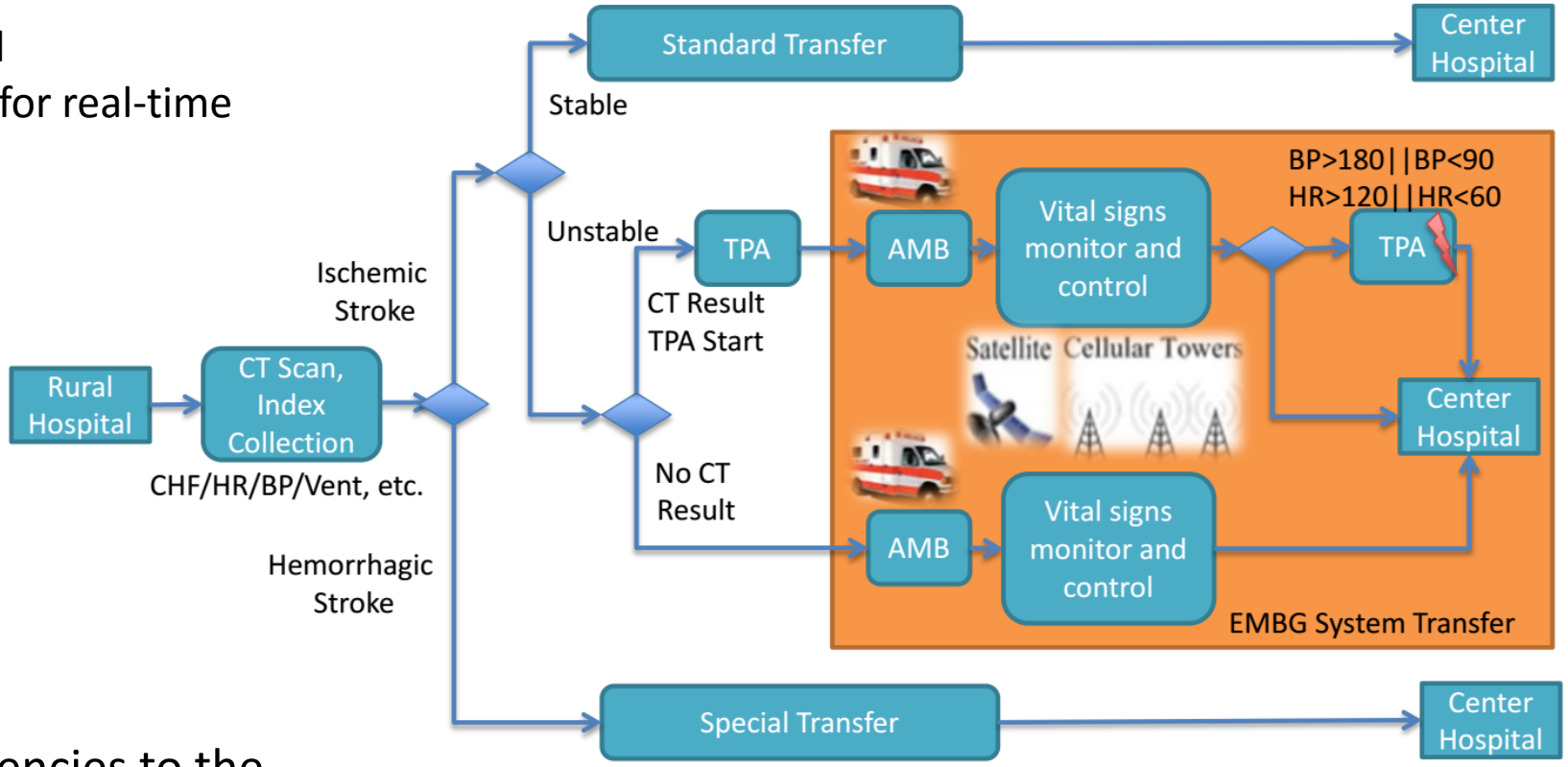
Adaptive Streaming

- A process where the quality of a data stream is altered in real-time during transmission
- The adaptation of quality can be the result of adjusting various network or device metrics, such as bandwidth

- Mostly applied to multimedia context
  - Dynamic Adaptive Streaming over HTTP (DASH), also known as MPEG-DASH
    - ISO standard for adaptive video streaming based on client's constrained resources such as bandwidth
  - Extend DASH towards clinical data streaming
    - Initial study towards a physiology-aware DASH with use of our dataset

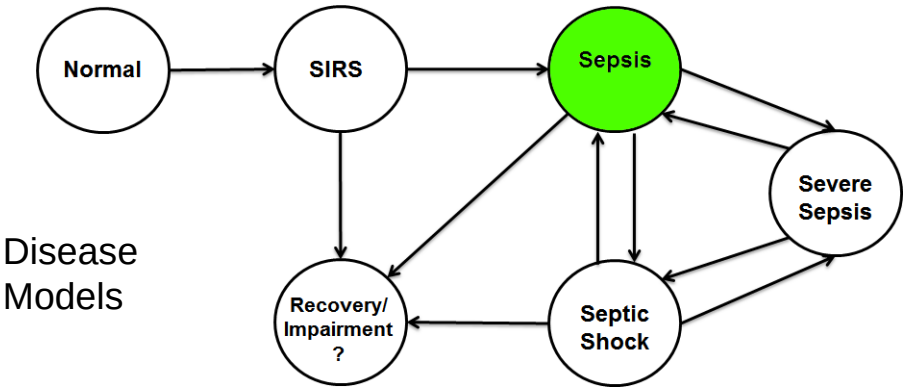
Background: Clinical Data

- Clinical data:
  - Clinical data are measured onboard and sent to the hospital physicians for real-time monitoring and remote guidance
  - Disease-dependent
    - ECG
    - Blood pressure
    - Blood glucose
    - Respiratory
    - Blood gases (e.g. SpO_2, etc.)
    - Blood coagulation
    - Clinical images
    - Audio-visual data
- Adapt clinical data's sampling frequencies to the available bandwidth
  - Adaptation based on a patient's physiological condition

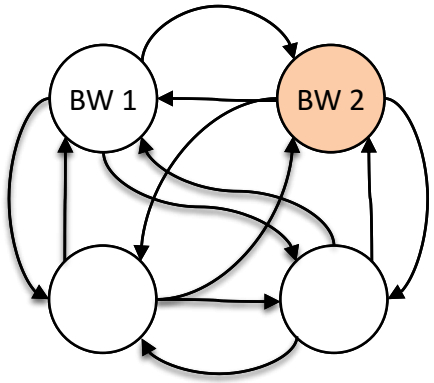


Background: Visual Scheme

- Adapt clinical data's sampling frequencies to the available bandwidth based on a patient's physiological status



Disease Models



Bandwidth Models

Higher sampling

Lower sampling

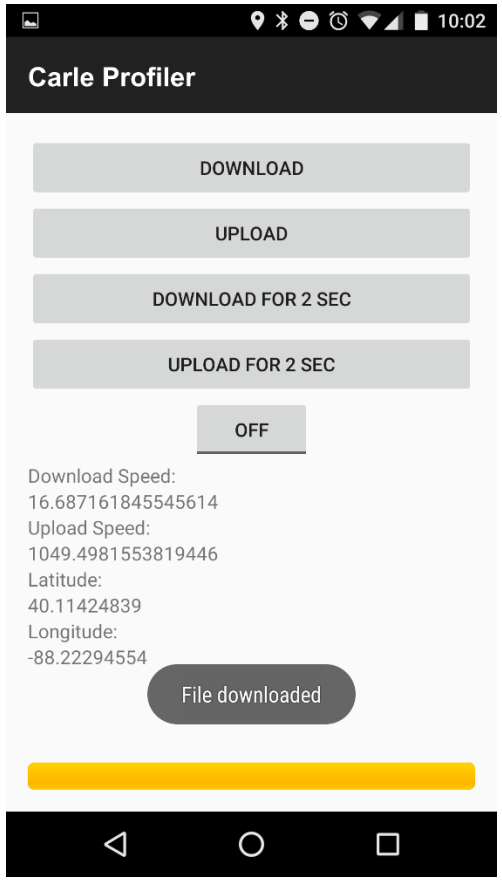
Data 1	Data 2	Data 3	Data 4	Data 5
Level 1	Level 1	Level 1	Level 1	Level 1
Level 2	Level 2	Level 2	Level 2	Level 2
Level 3	Level 3	Level 3	Level 3	Level 3
Level 4	Level 4	Level 4	Level 4	Level 4
Level 5	Level 5	Level 5	Level 5	Level 5

. . .

Criticality factor: p_1, p_2, p_3, p_4, p_5

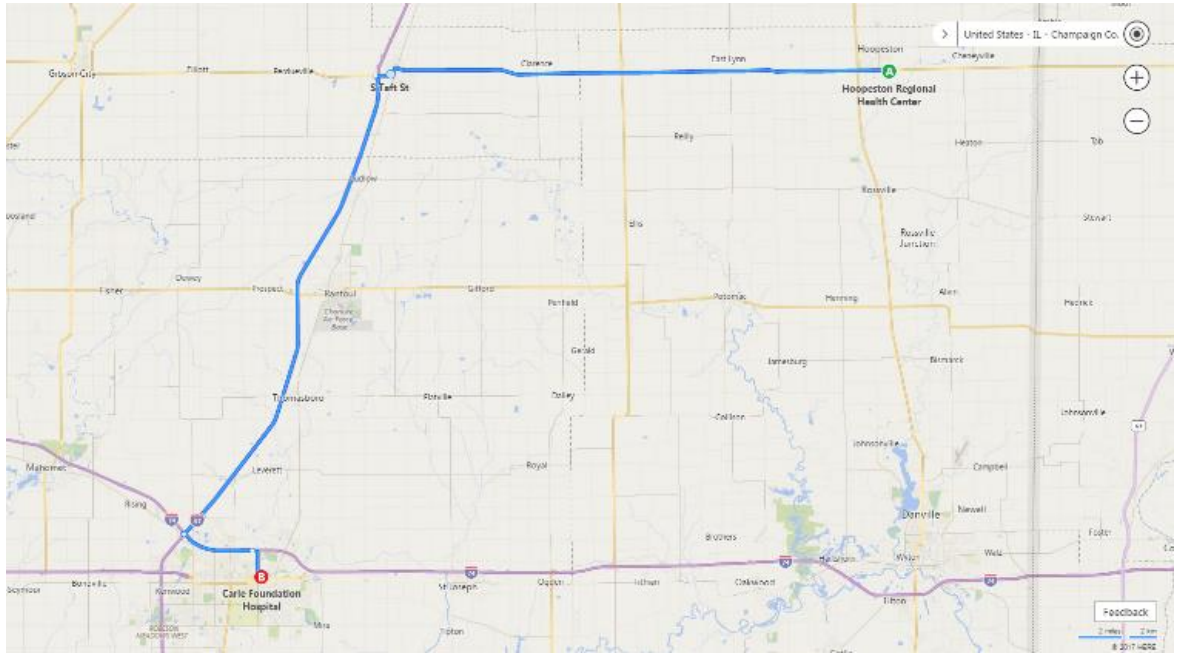
Profiler Design

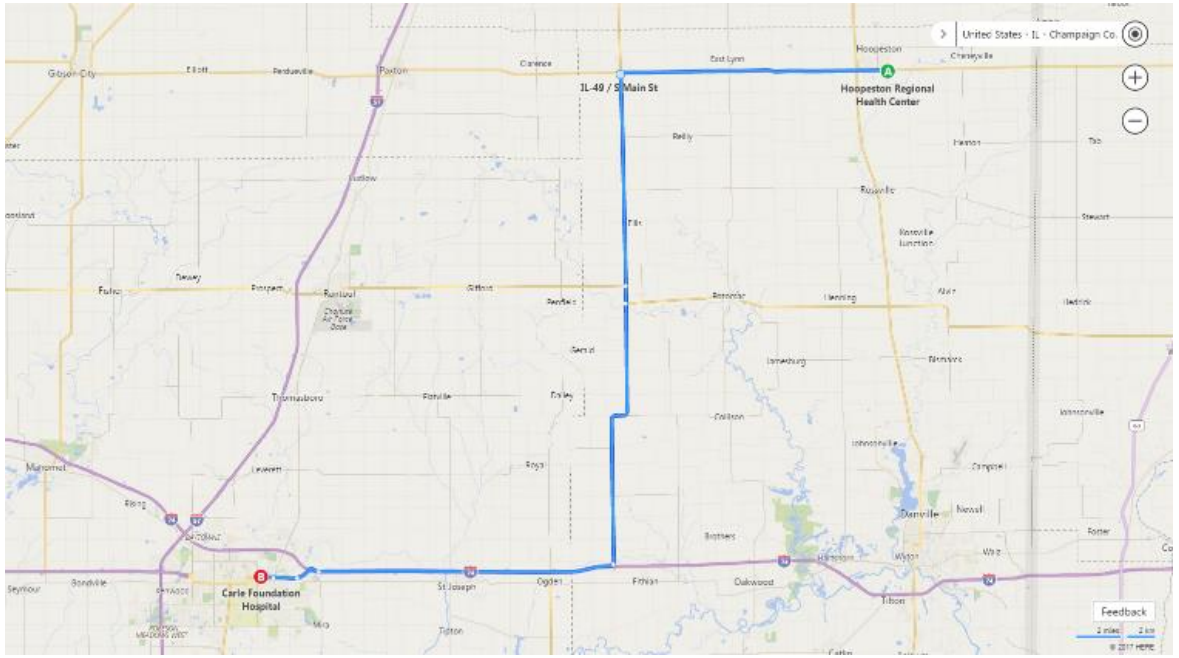
- Developed a geo-communication profiler in collaboration with Carle Foundation Hospital in Urbana, Illinois to collect traces
  - Android SDK 25 for development
  - Nexus 5 smartphone as the profiling platform
  - 4G LTE ICCID SIM Cards under 4 major cellular carriers
    - Sprint, Verizon, AT&T, and T-Mobile
  - Collected almost 54,000 samples
- Logs geo-communication information every 4 seconds



Profiling Region

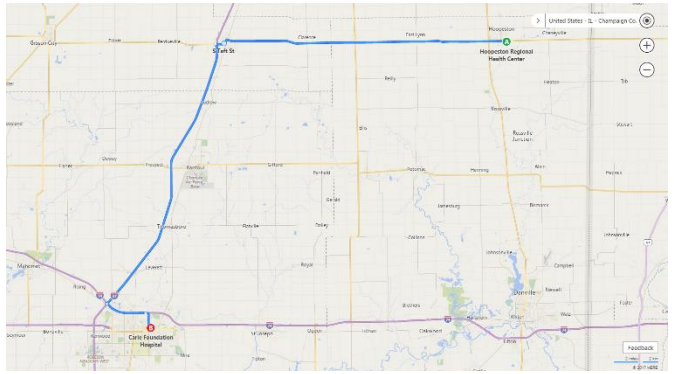
- Collected geo-communication information along two rural routes in Illinois
  - Hoopeston's regional hospital (rural hospital) to Carle Foundation Hospital (center hospital)

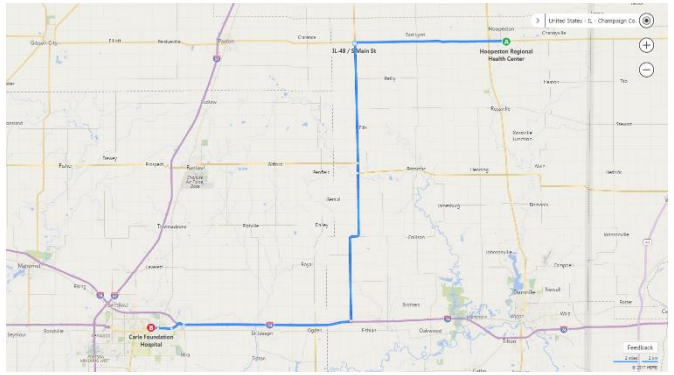




Collected Traces

- Our geo-communication dataset includes:
  - Time stamp
  - Download rate
  - Upload rate
  - GPS coordinates: Latitude and Longitude
  - GPS accuracy
  - Altitude
  - Velocity
  - Bearing





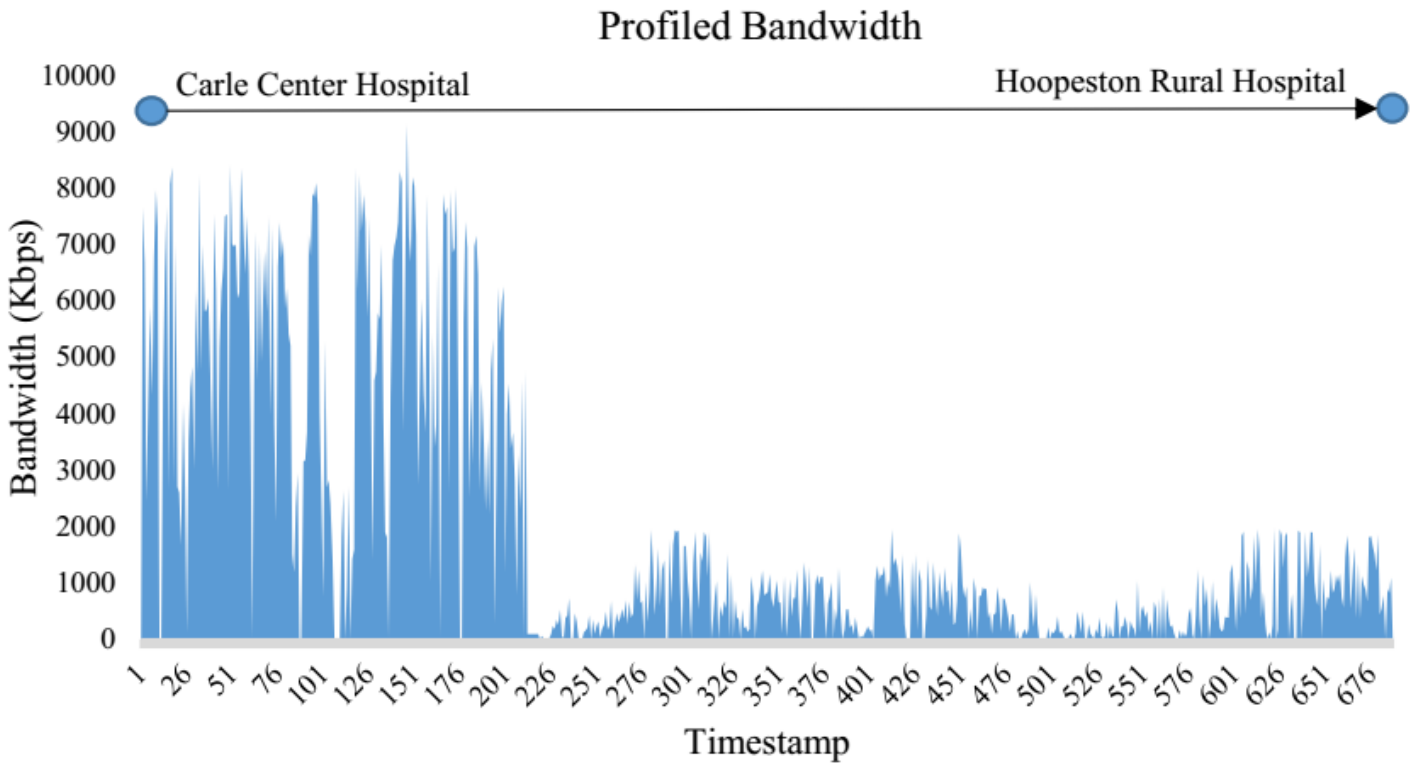
Timestamp	DL	UL	Longitude	Latitude	Acc.	Alt.	Vel.	Bearing
100	1192.1749	971.52216	40.459123	-88.070278	14	193.0	28.75	91.1
101	566.8956	932.59045	40.459017	-88.066069	13	189.0	30.0	90.7
102	834.95325	1560.9518	40.459028	-88.063833	11	195.0	30.75	90.6
103	1192.1749	971.52216	40.459123	-88.070278	14	193.0	28.75	91.1
104	878.0356	1117.8868	40.459036	-88.062363	11	197.0	30.75	90.3

Dataset Features

Our dataset is unique in the sense that:

- ✓ It specifically targets mobile healthcare communication in emergency ambulance services
- ✓ It includes profiling of a large rural environment and rural Illinois in specific with almost 54,000 samples
  - With a real clinical use-case and hospital collaboration
- ✓ In our dataset we profile a comprehensive and integrated set of fields as a single dataset
  - Prior datasets separately covered measurements of individual geo-communication information
- ✓ Traces are collected through profiling of 4 different mobile carriers as opposed to only one
  - Sprint, Verizon, T-Mobile, AT&T

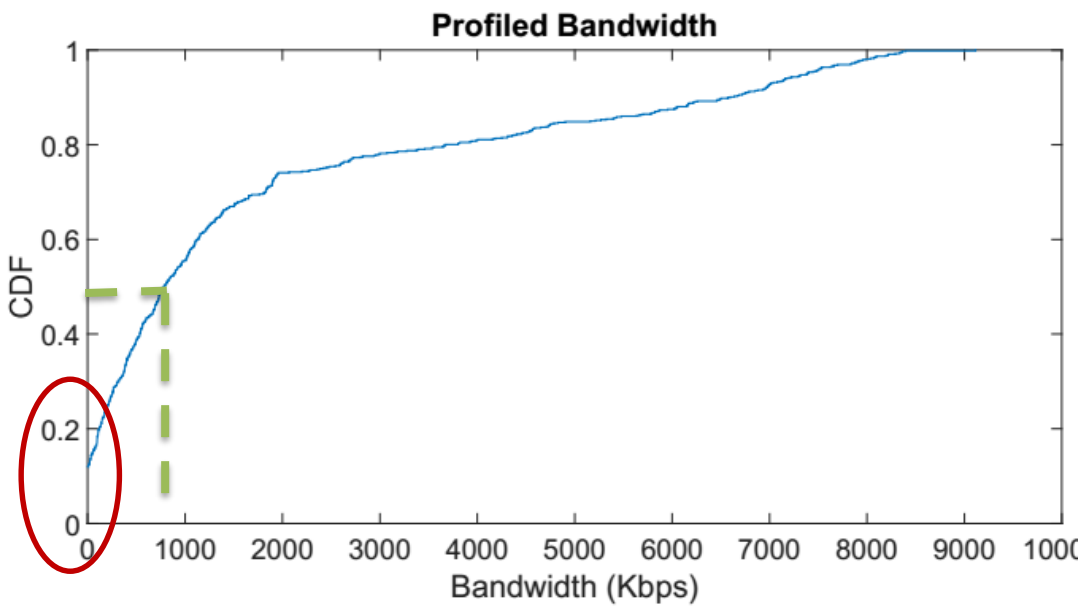
Samples of Traces: Bandwidth

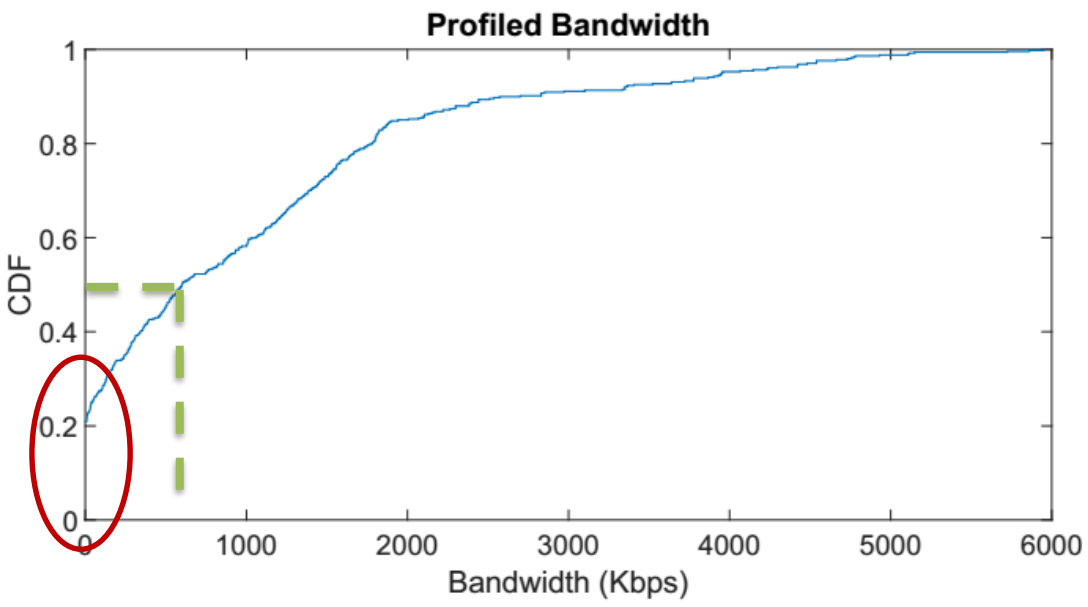


- A sample of profiled bandwidth rates along a route from Hoopeston rural hospital to Carle center hospital
  - Sprint cellular network (Downlink)
  - Total distance of 53 miles
- Profiled data validates both the *variability* and *limitation* of bandwidth during ambulance transport

Samples of Traces: Bandwidth

- CDF of bandwidth traces for two samples (Sprint- downlink)

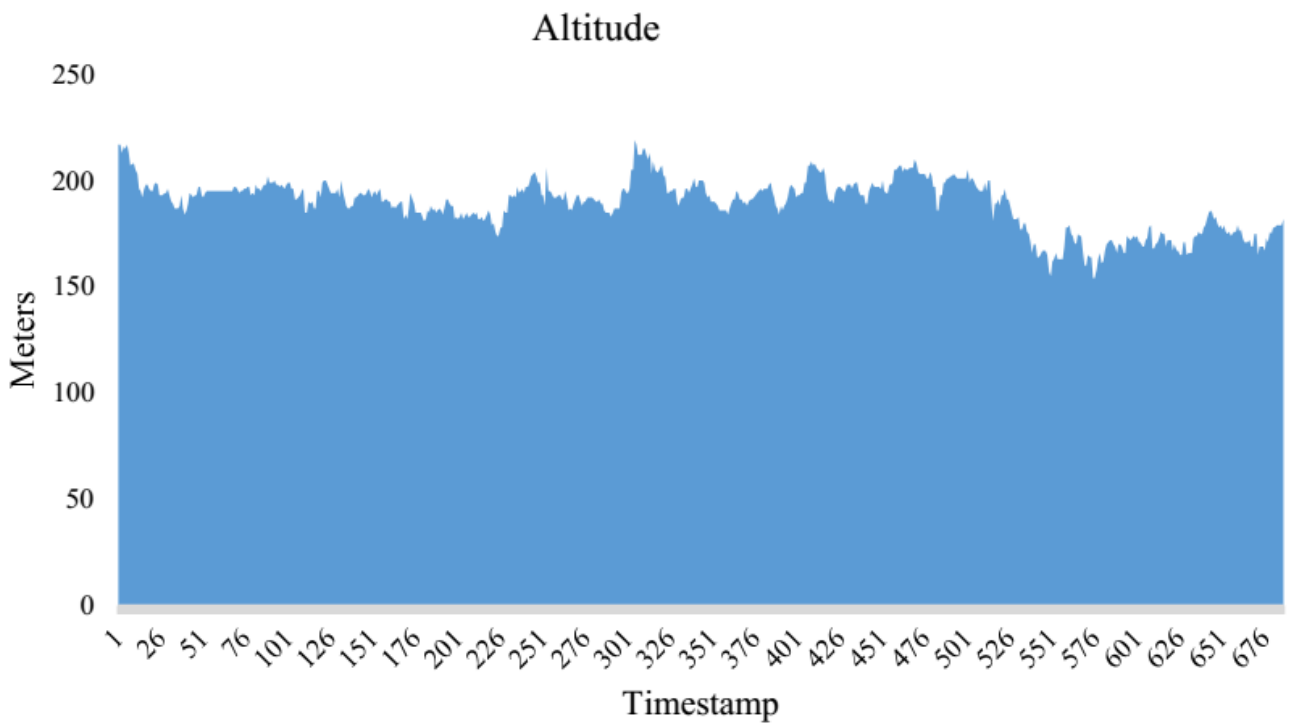




More than *half* of both routes suffer bandwidth rates of less than 1000 Kbps

Almost %17-%23 of the traces showing no data coverage (0 Kbps)

Samples of Traces: Altitude



- Altitude distribution (meters) from Hoopeston rural hospital to Carle center hospital
  - Total distance of 53 miles
- Low altitude variance
  - Interestingly proving the fact that Illinois is mostly hill-less plains, in fact the second flattest state on mainland!

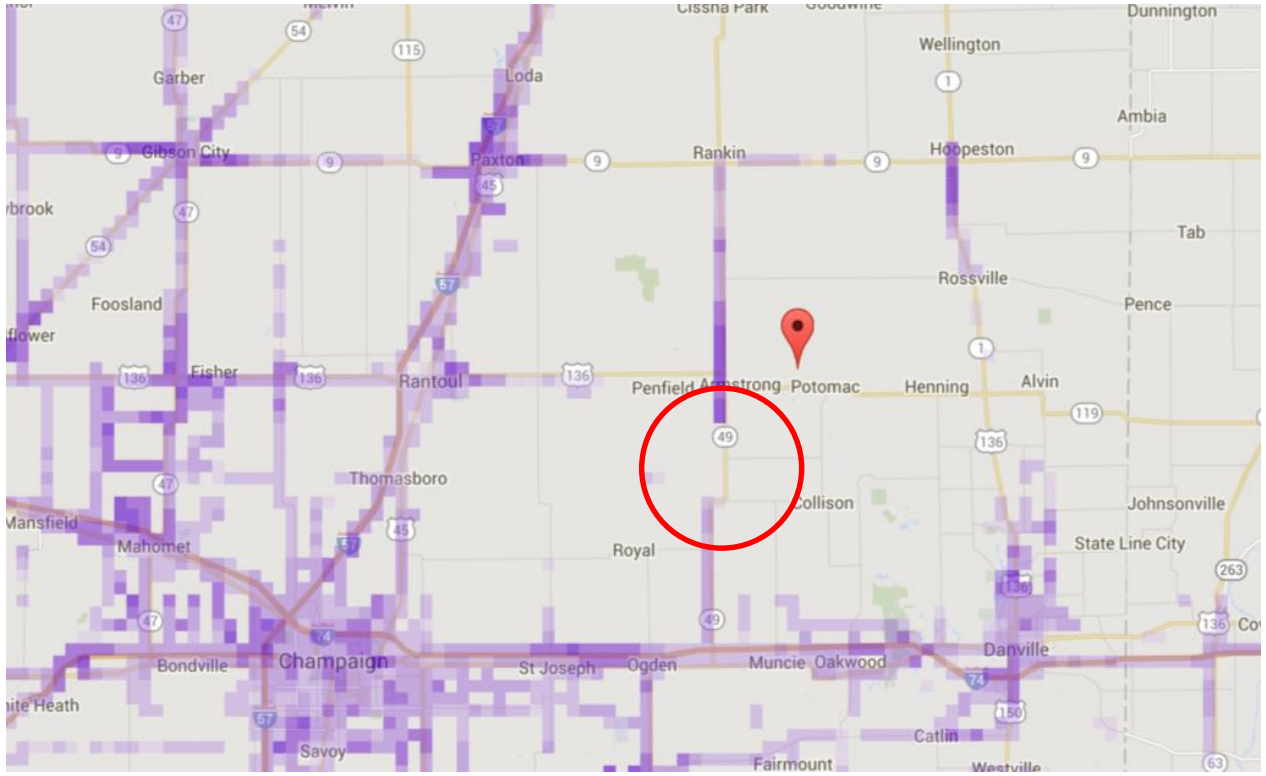
Dataset Features (2)

Insights from our dataset can help improve the effectiveness of patient care through:

- Not only:
  - ✓ Adaptive transmission of various clinical data in response to:
    - Bandwidth conditions
    - Patients' physiological state
- But also:
  - ✓ Adaptive selection of best transport routes when real-time monitoring is needed
    - Some routes suffer poor communication
  - ✓ Adaptive adjustment of ambulance velocity

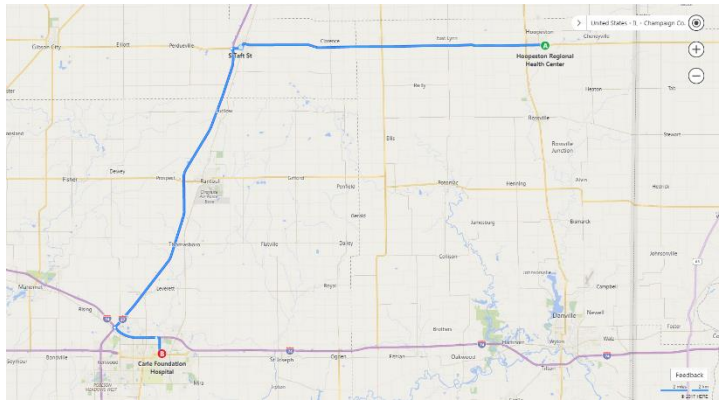
Other Use-Cases: Physiology-Aware Routing

- Continuous remote monitoring of patients can get crucial
  - Continuous infusions and real-time tracking of BP based on patient condition and response for medications such as *nitroprusside*
  - Maintaining excellent control of oxygenation depending on the disease
- Communication breakage in parts of routes

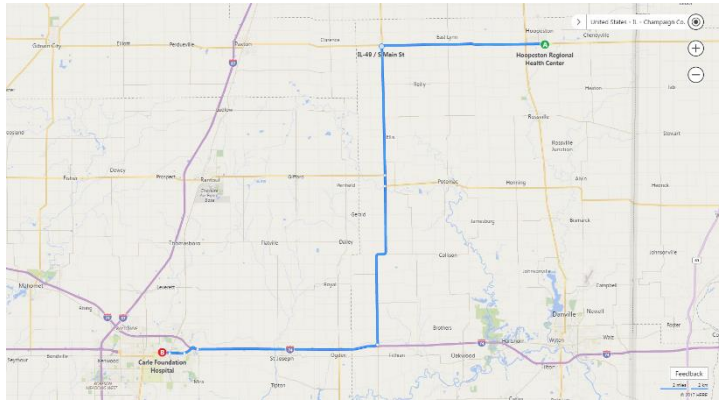


Other Use-Cases: Physiology-Aware Routing

- Ischemic stroke:
  - Precise management of BP, TPA, and supporting oxygen if brain condition deteriorates
  - Ambulance takes the **longer** route, but high-fidelity bandwidth

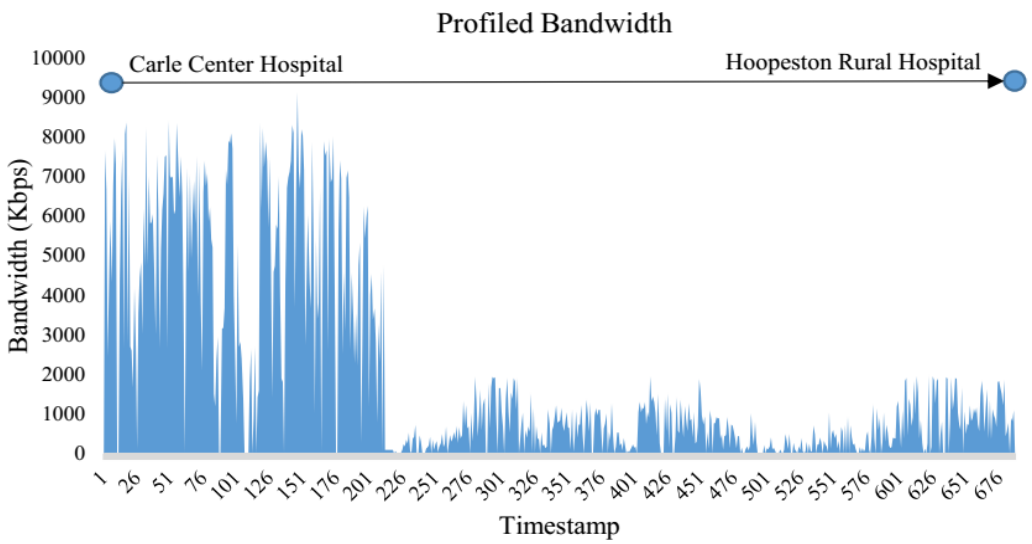


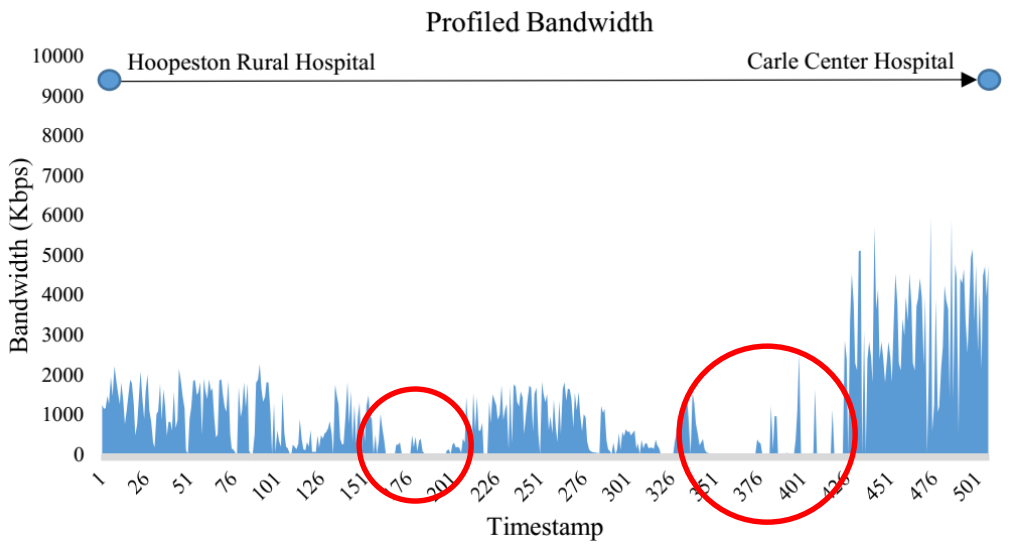
- Hemorrhagic stroke:
  - Brain hemorrhage : There is a burst blood vessel (aneurysm) in the brain.
  - Time is most critical. Ambulance takes the **shorter** route

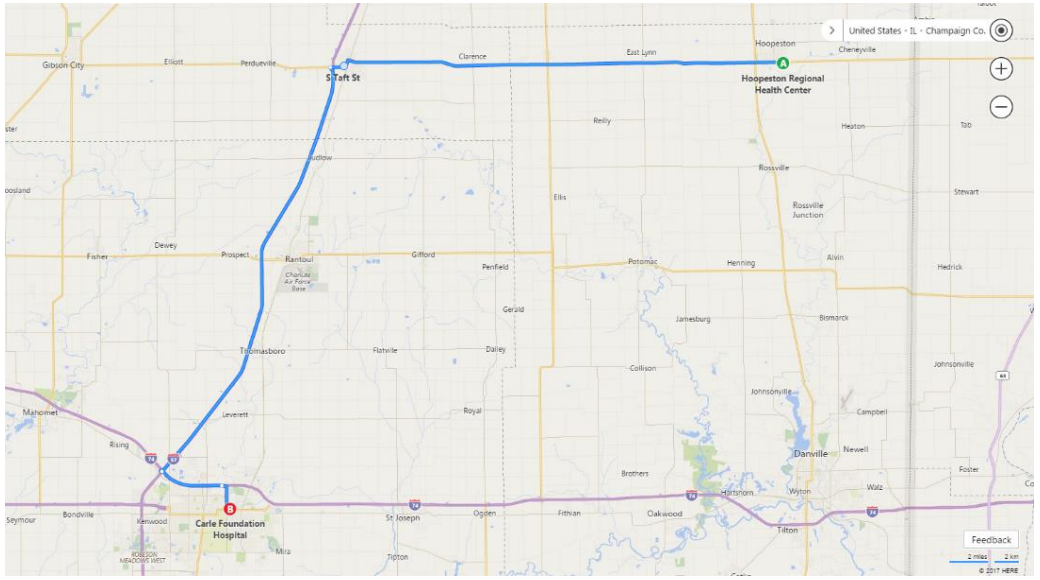


➢ Trade-off between travel time and continuous communication coverage
  - Depending on the patient status, continuous monitoring of vital signs might be more important than picking the shortest path.
  - Ambulance might arrive a bit later, but doesn't want to miss continuous monitoring

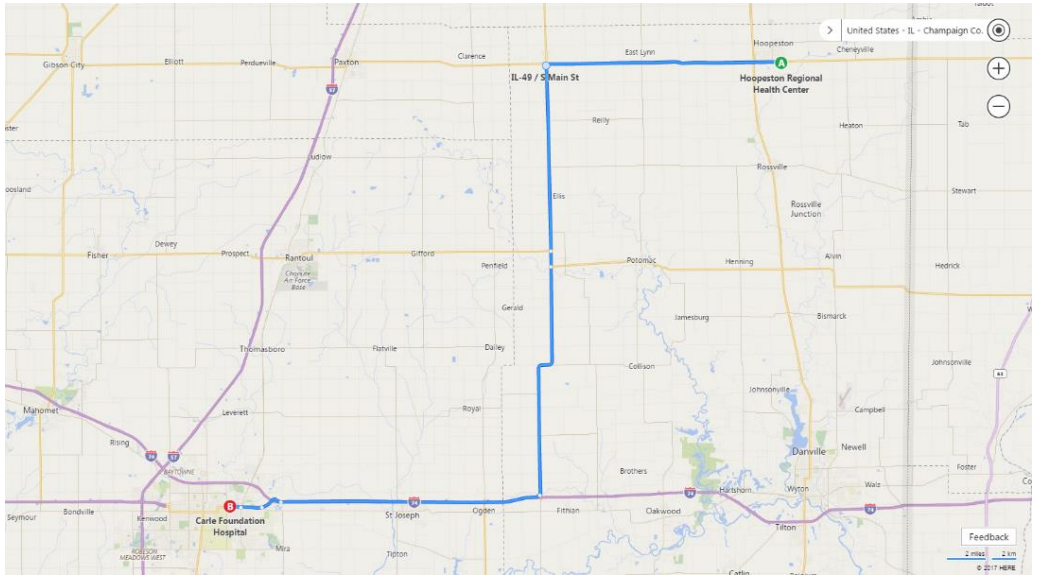
Other Use-Cases: Physiology-Aware Routing







Longer route (~47 mins)



Shorter route (~33 mins)

Broader Impact and Intellectual Merit

Broader Impact

- Our dataset is aimed to improve effectiveness of emergency care for people in rural areas
- Our real-world geo-communication dataset can be used in many other domains
  - From research in mobile networks and multimedia streaming to disaster response scenarios or military
- Available for research community to use

Intellectual Merit

- Enhancing emergency healthcare services in hospital networks covering a large rural area
- To demonstrate the potential to decrease the mortality rate of acute diseases especially strokes given its 3-hour window (or any other disease)
  - Stroke requires additional expertise possible only through real-time remote patient supervision over networks

The End!

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