# CITYMAP

## Smart-phone based Spatio-temporal Sensing for Annotated Transit Map Generation

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# ISSUES WITH PUBLIC TRANSPORT



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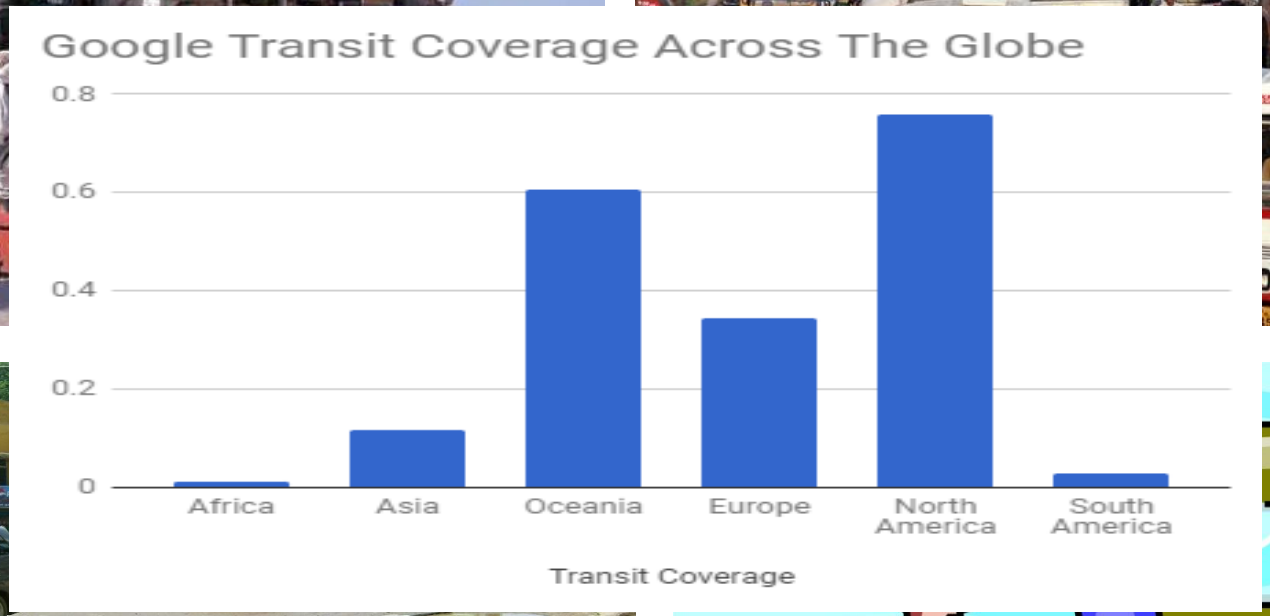
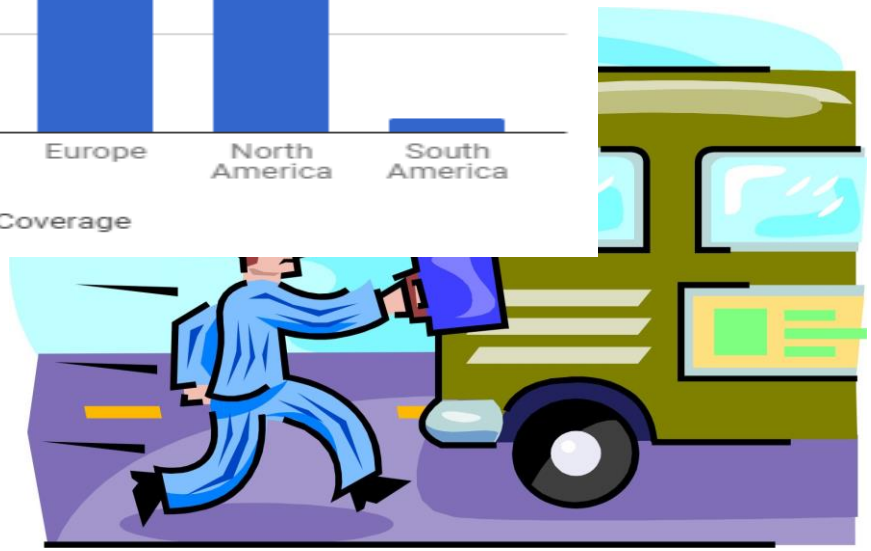
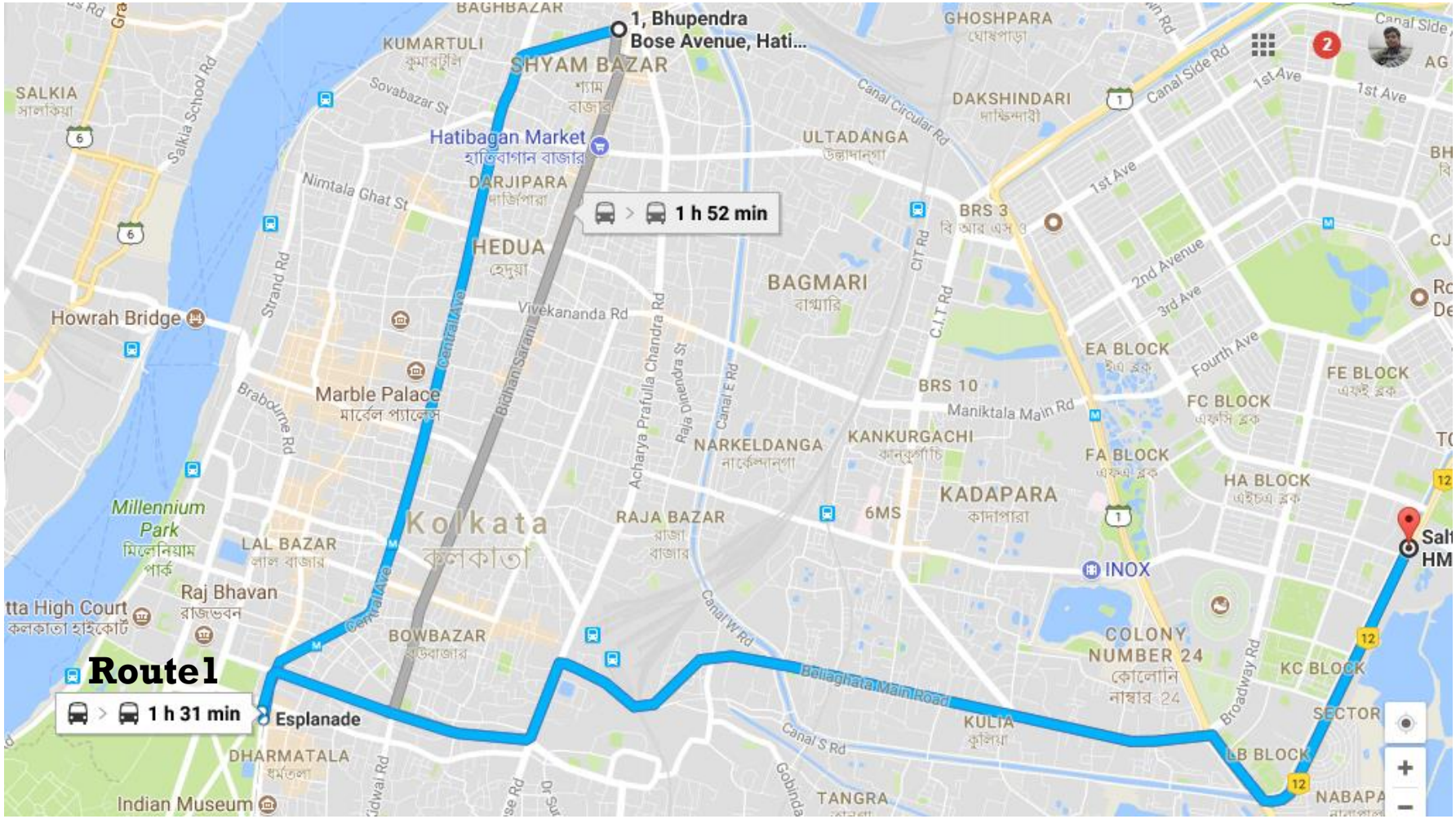
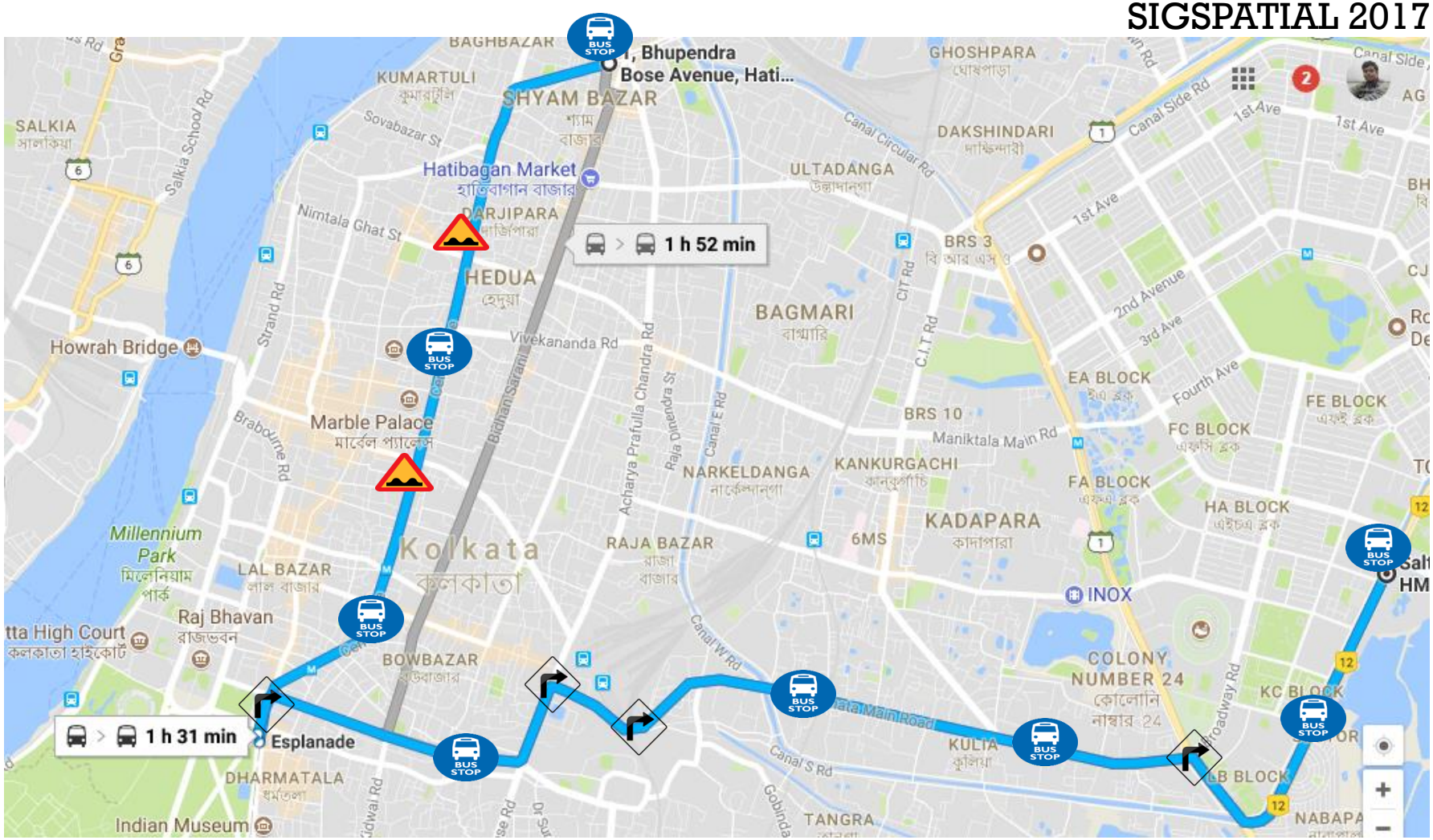




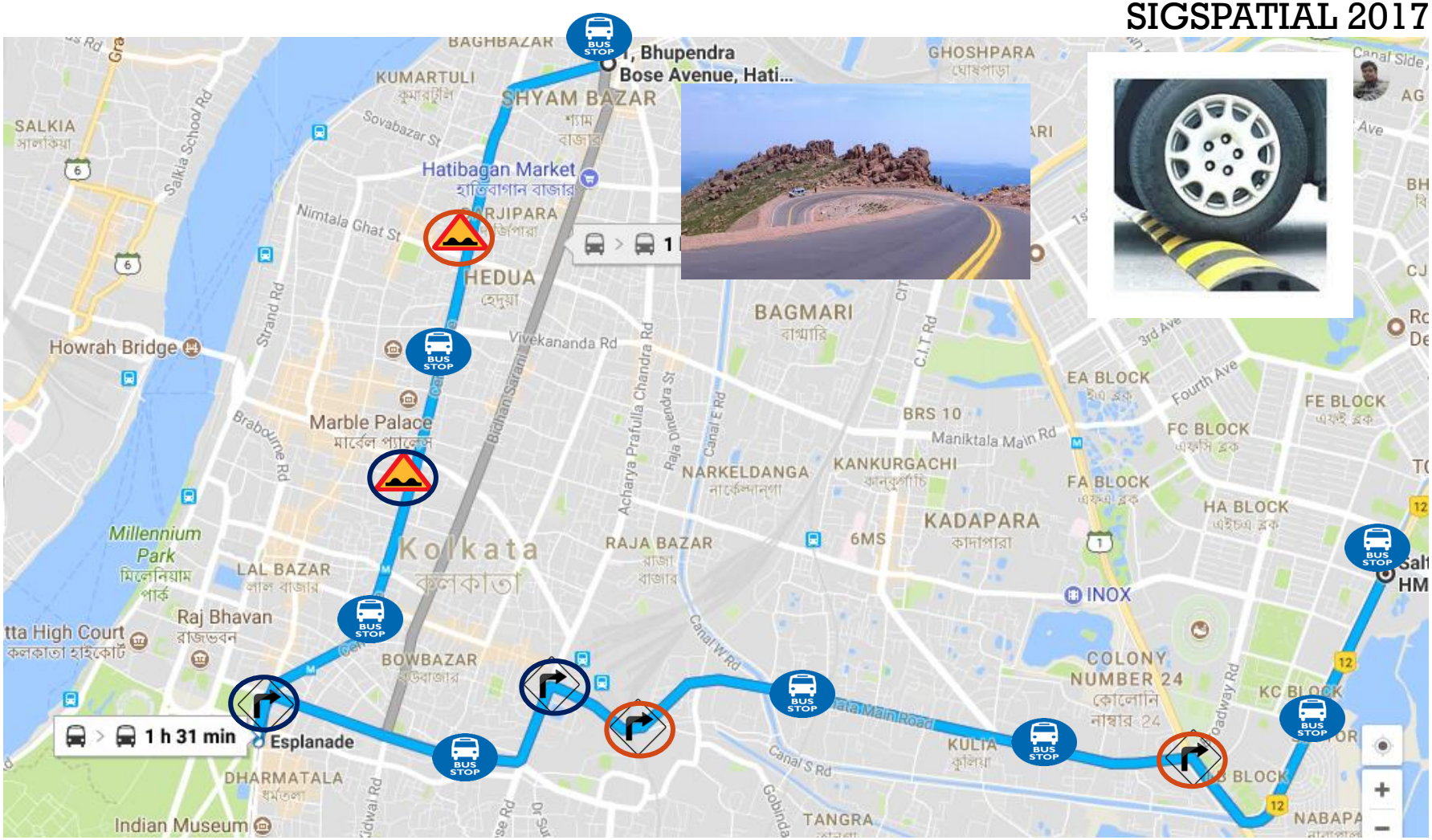

The map shows:

- The available bus route




The map shows:

- The available bus route
- All the speed breakers, turns, bus stops, termed as **Points of Concern (PoCs)** on the bus route

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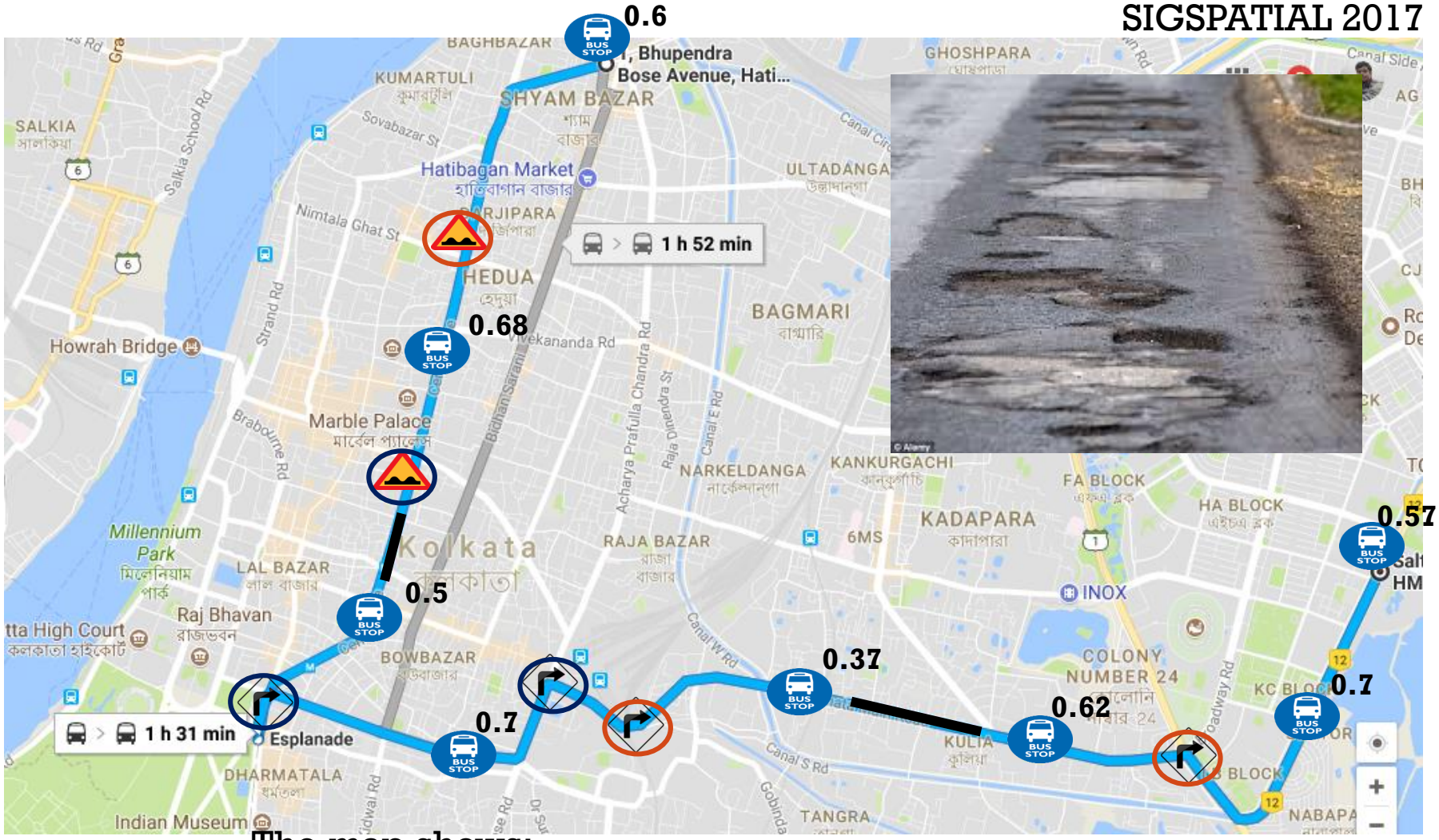


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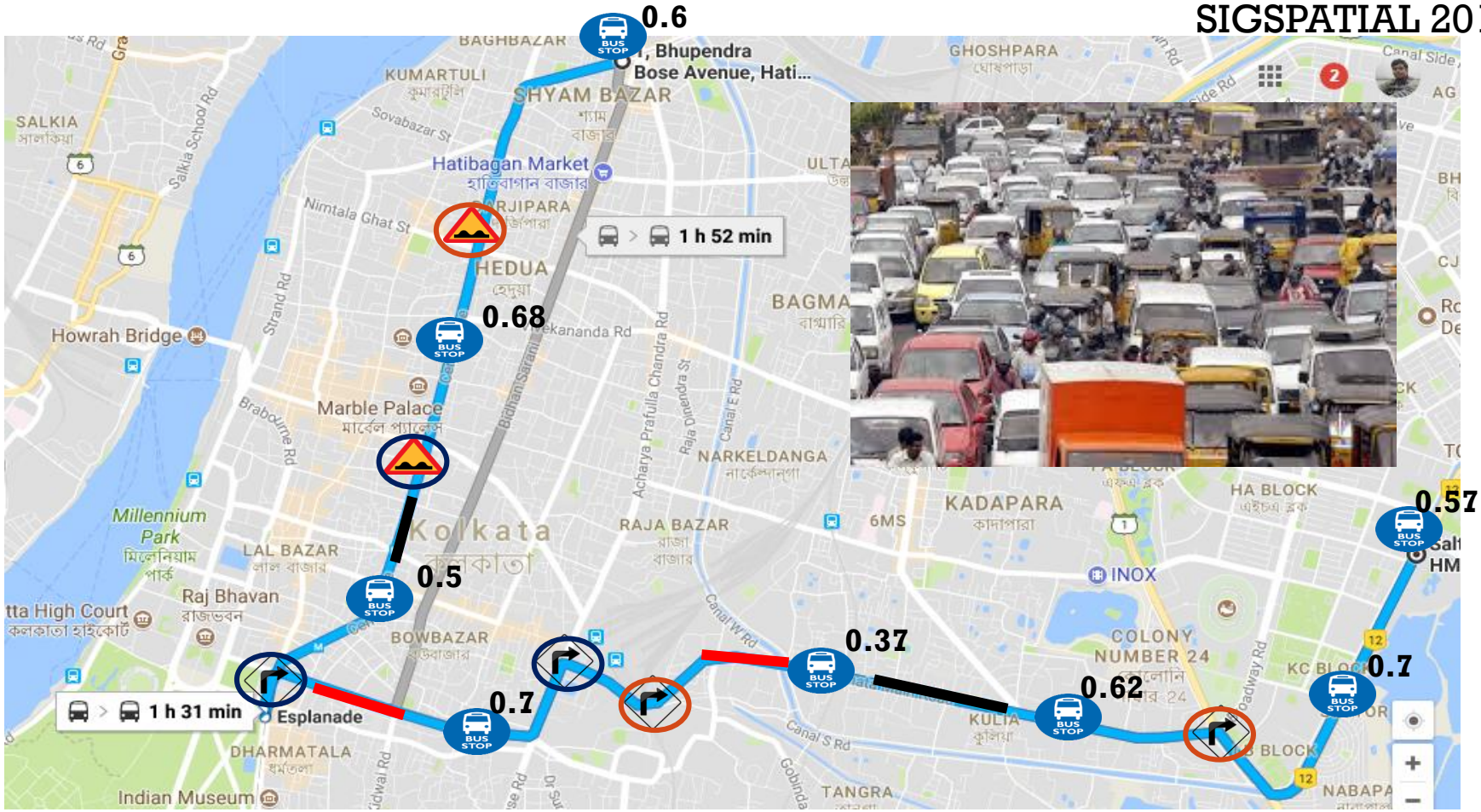
- Other route features like **jerky road**

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- All the PoCs on the bus route
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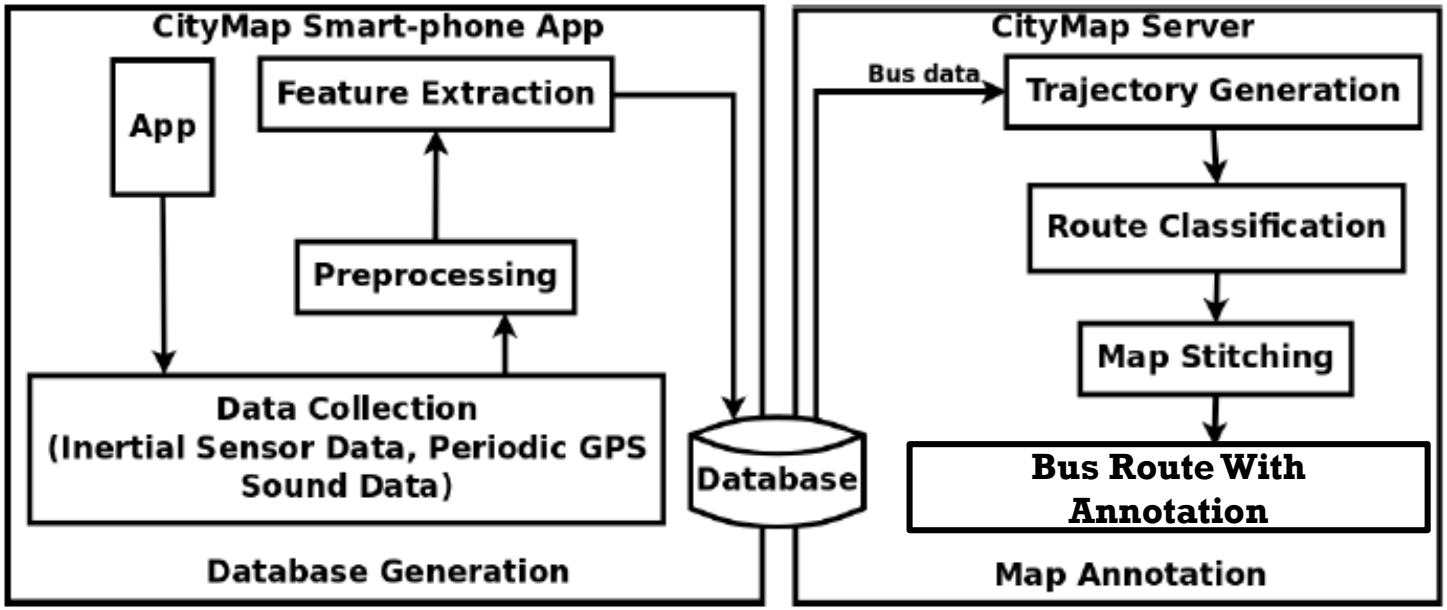
  - Steep/Gentle turns or speed breakers
  - Probability of getting a seat at a bus stop
- Other route features like **jerky road, congested patches**

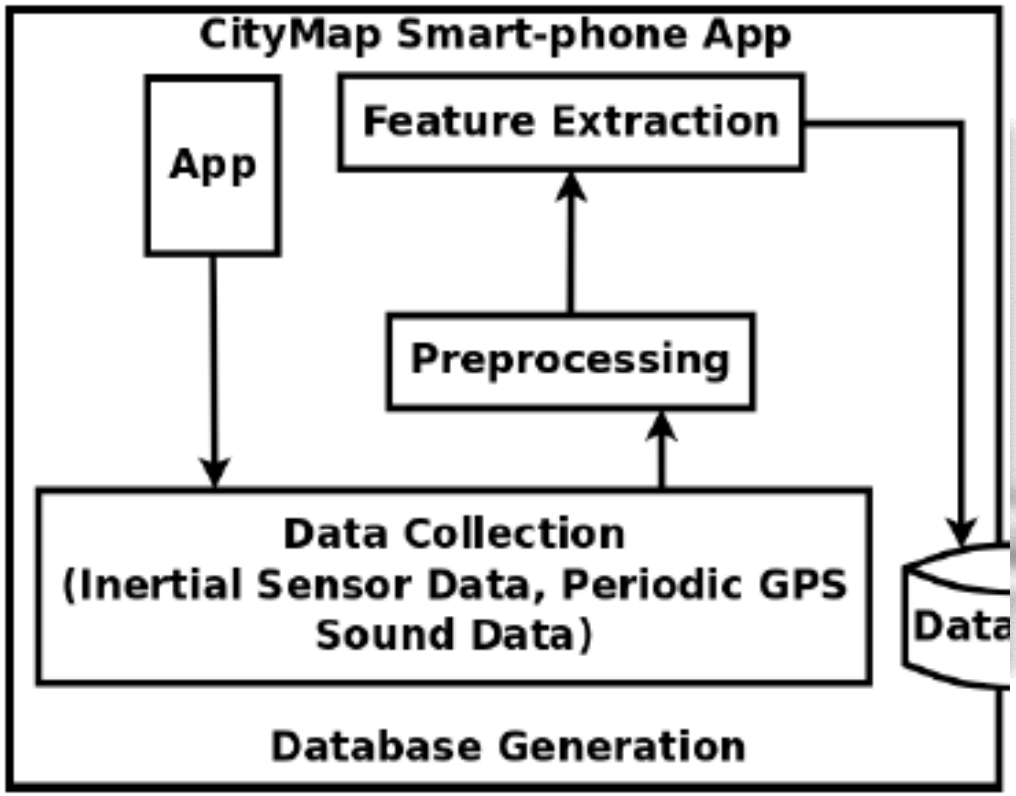
# OBJECTIVE

- A system which
  - Generates a complete annotated transit map of a city.
  - Annotations on the bus route:
    - PoCs like speed breaker, turns, bus stops.
    - Features linked to PoCs like
      - Type of turn (sharp/gentle)
      - Type of speed breaker (steep/gentle)
      - Probability of getting a seat at a bus stop
    - Jerky bus route segment
    - Congestion level in a bus route segment
  - **Smartphone based crowdsourcing application**

# SYSTEM ARCHITECTURE



# CHALLENGES: DATABASE GENERATION

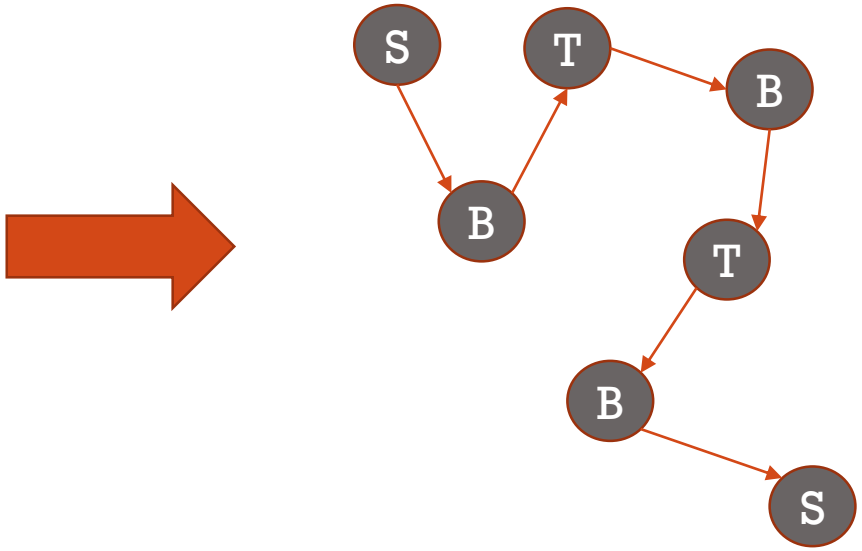



**How to make the application energy efficient?**

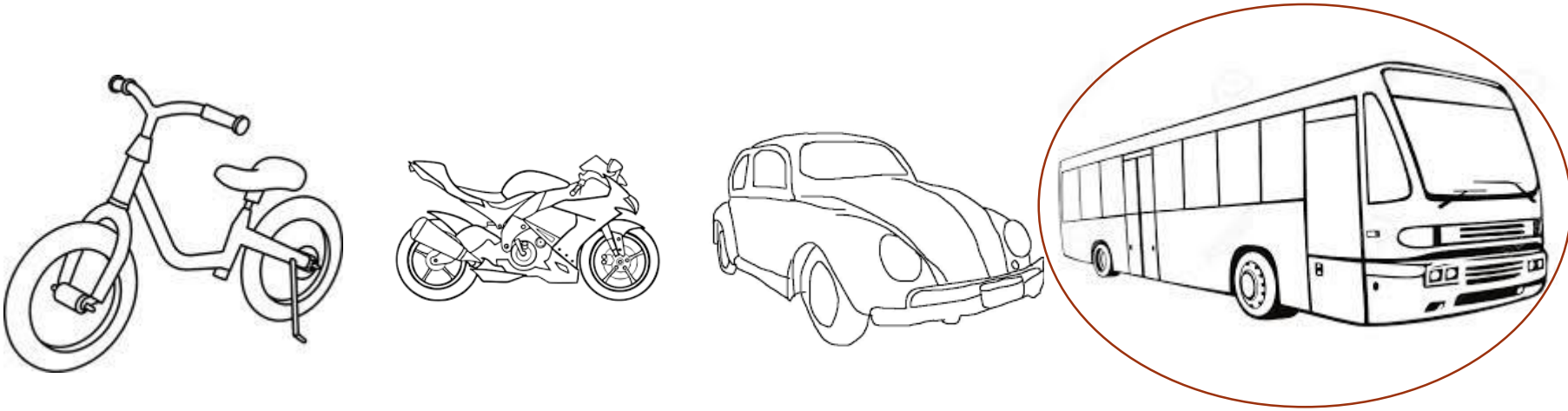
**How to develop a zero intervention and intelligent data logging application?**

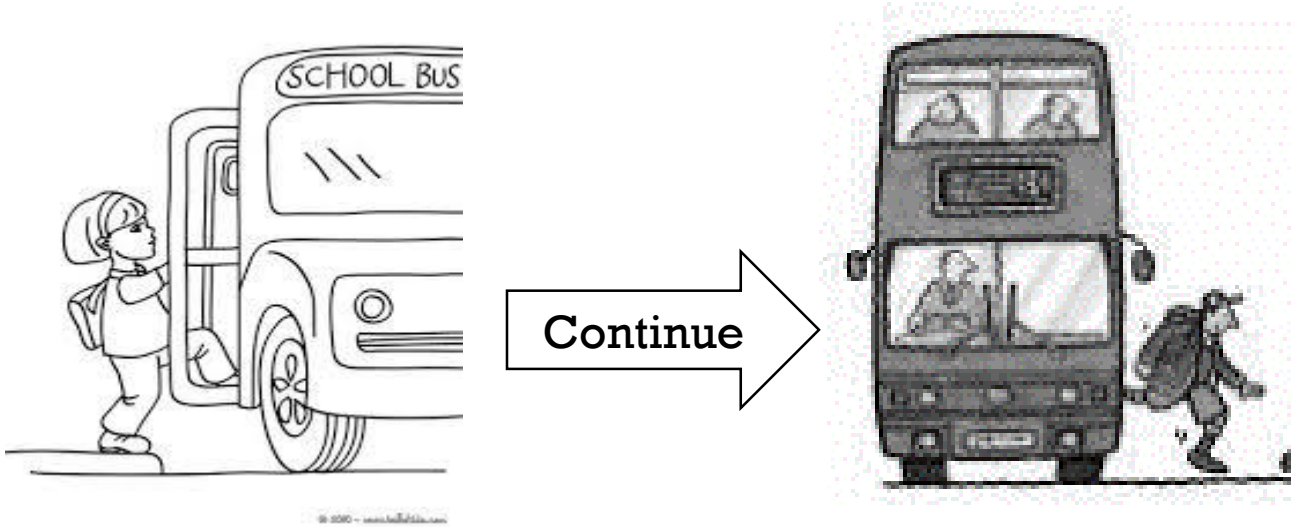
# MANAGING ENERGY EFFICIENCY


The application should **consume low energy** being a continuous data collection app.



# SMART DATA LOGGING



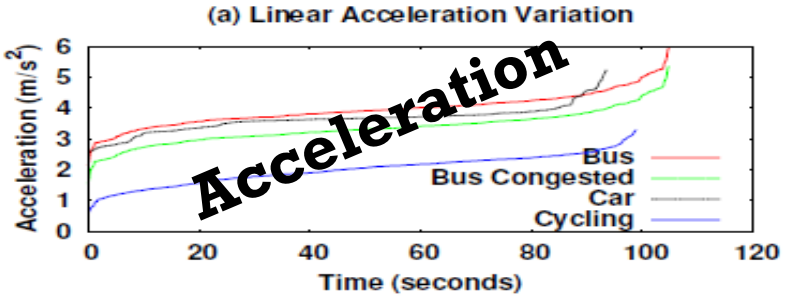



Start Logging

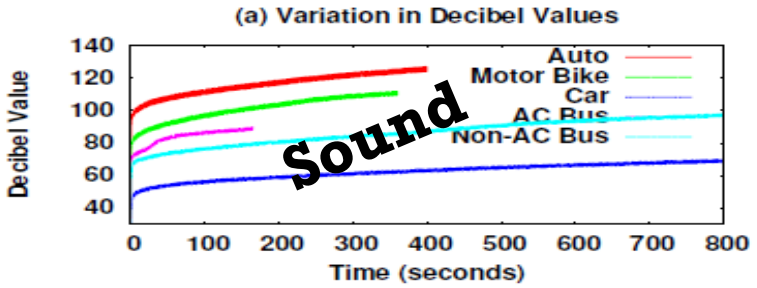
Stop Logging

# SMART DATA LOGGING

## Identifying user in bus

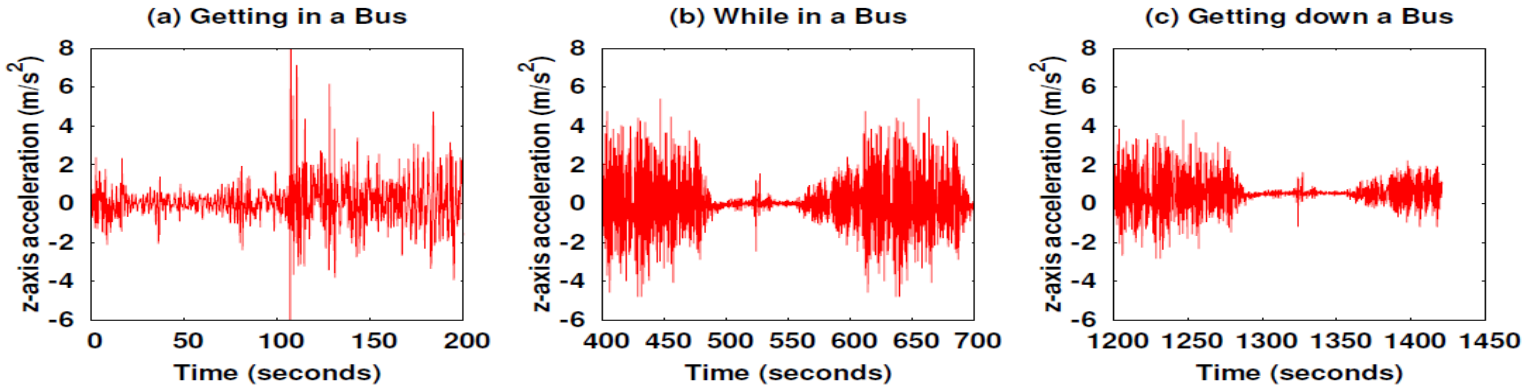



Signature of the acceleration along y-axis for different modes



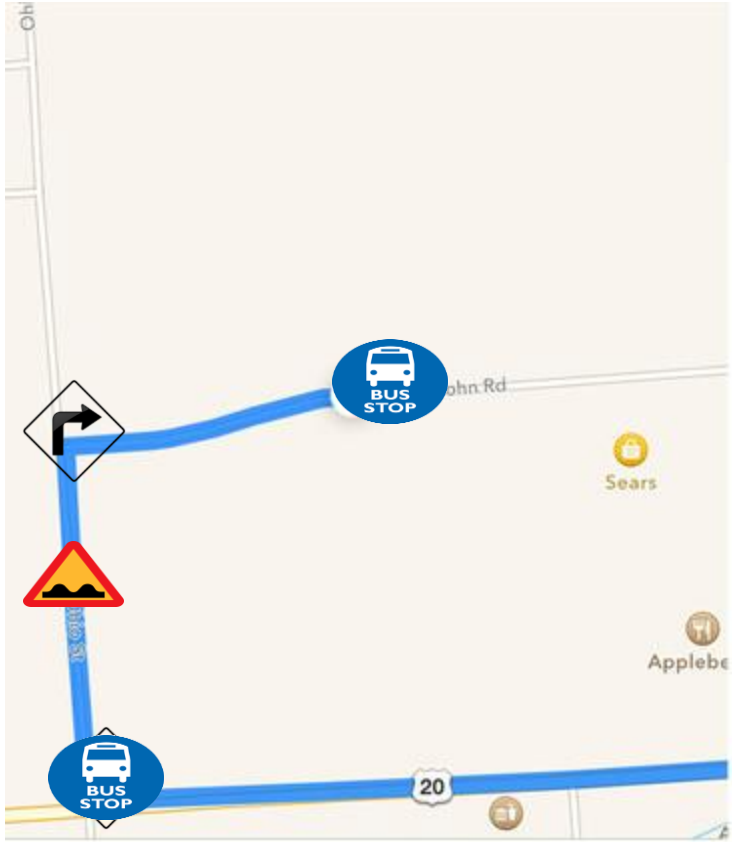

Variation in sound data for different motorized vehicles

## Logging at bus stop




Vertical acceleration values to identify the events when the user is traveling by a bus

# BUILD DATABASE



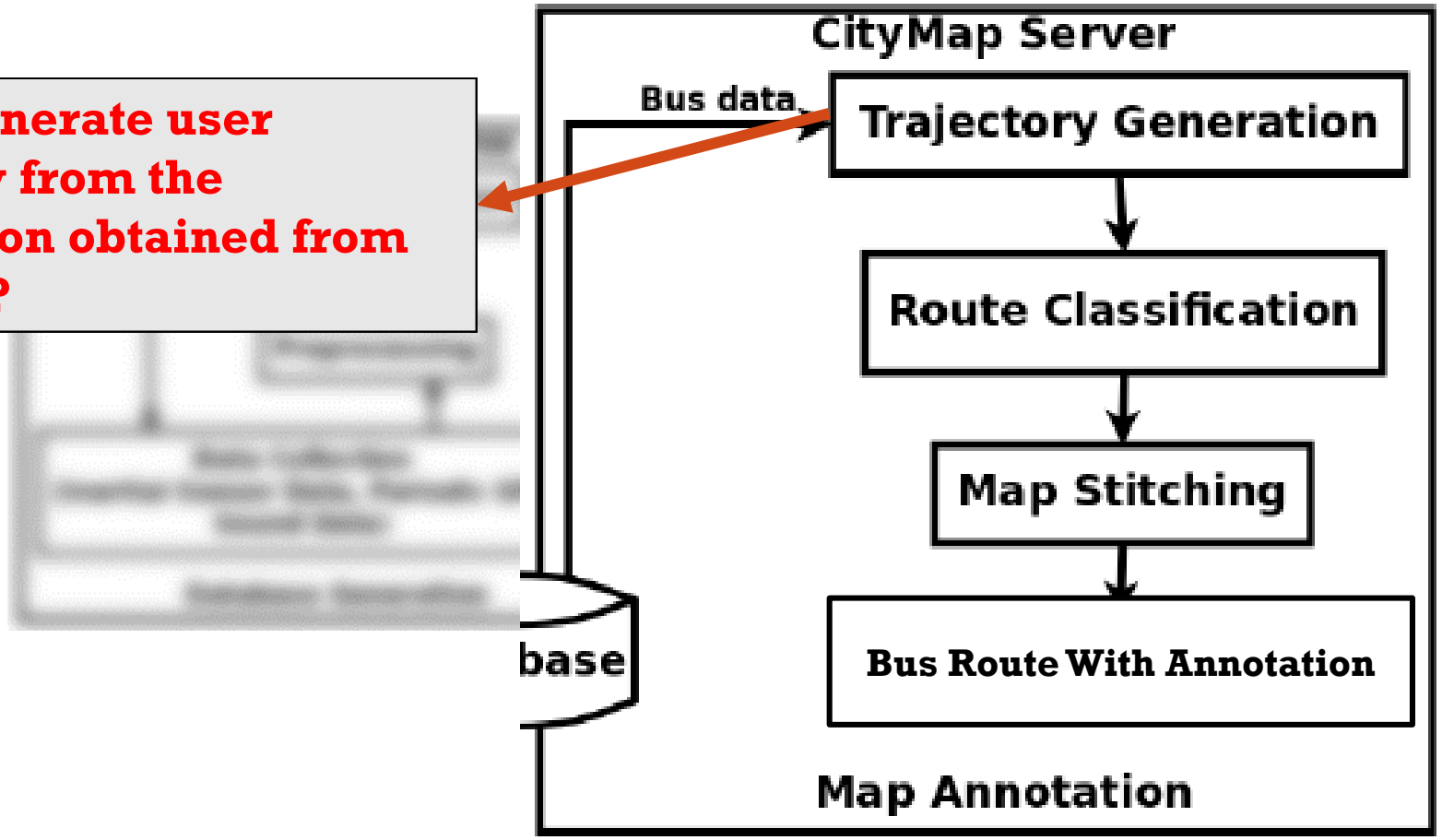

- **PoC information** in the database.

| PoC | GPS Coord |
|---|---|
| Bus Stop 1 | C1 |
| Turn1 | C2 |
| Speed Breaker 1 | C3 |
| Bus Stop 2 | C4 |
| Bus Stop 3 | C5 |

- Data from inertial sensors for every sample in between each PoC.

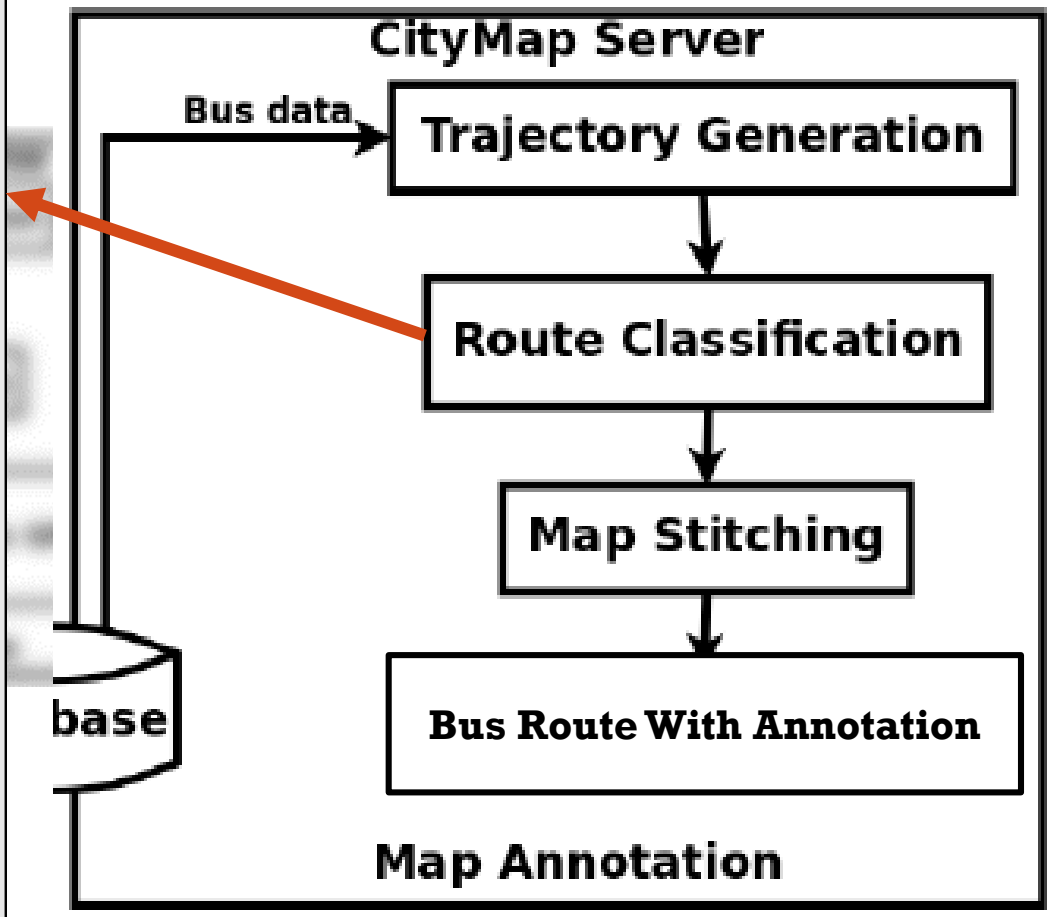
# CHALLENGES: MAP ANNOTATION

**How to generate user trajectory from the information obtained from database?**



# CHALLENGES: MAP ANNOTATION

- **Bootstrapping initial bus route data.**
- **Data collected from a commuter is never tagged by him, hence we need to decide which bus route did he actually travel on.**
- **We also need to shortlist one bus route when two bus routes have overlapping segments and the commuter travels on this part.**



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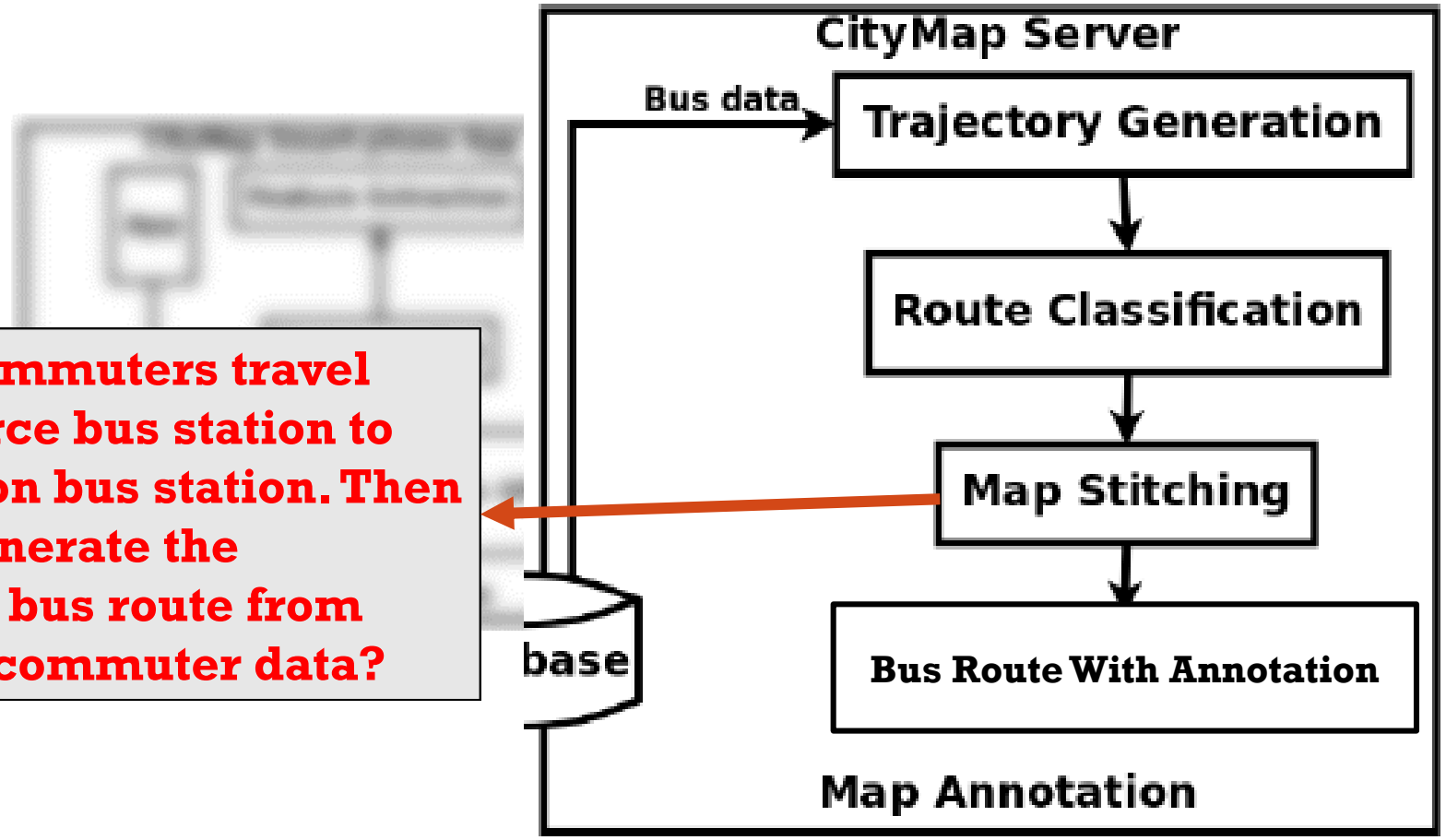
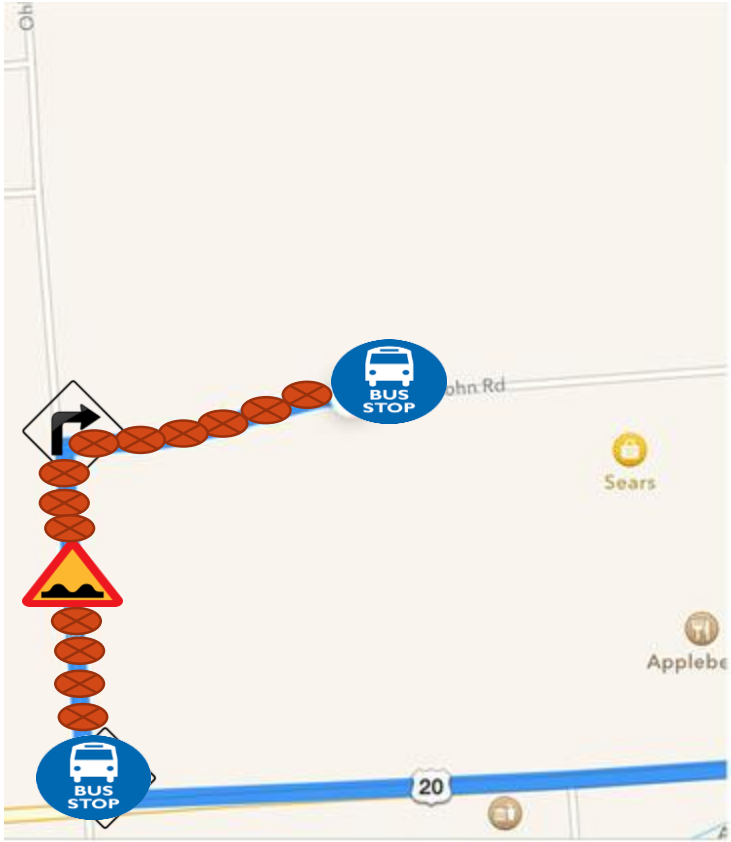



**Not all commuters travel from source bus station to destination bus station. Then how to generate the complete bus route from multiple commuter data?**

# PoC TO TRAJECTORY

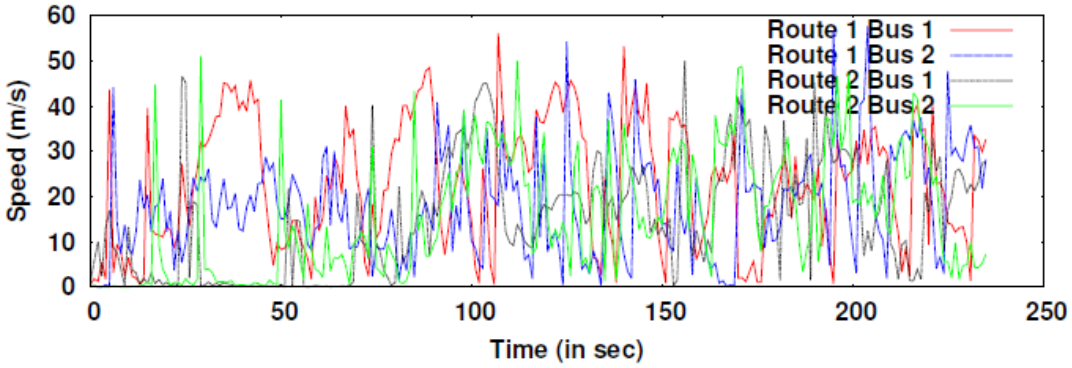



- Place detected **PoCs as anchor points** on the trajectory
- **Estimate intermediate GPS Coordinates** to generate complete trajectory of the user
  - Use **Vincenty's Formula** to estimate a point P'
  - Bring the point closer to the desired road, at P'', using **Coordinate geometry approach**
  - Use **Snap-to-Road API** to drag point to road

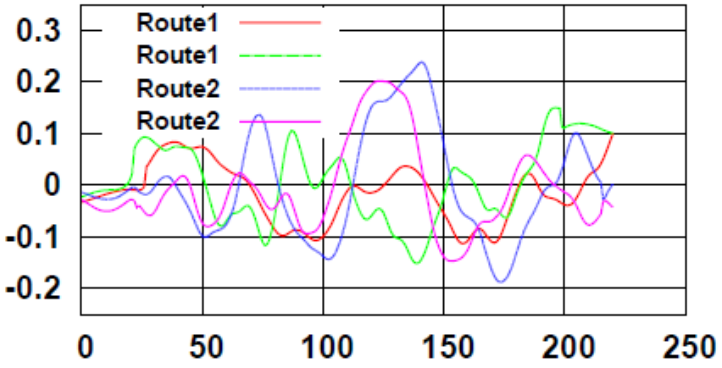
# INCLUDING A ROUTE IN THE MAP

- Each instance of the route data would have a set of features linked to it.
- We try to cluster the data into clusters based on correlation between these features.
- The clusters which have a **high confidence clustering** are used and the rest discarded.
- The **cluster head** is taken as the representative for the route.
- A minimum of **20 instances** is required for a route to be considered as a cluster head.

# NOISE REDUCTION



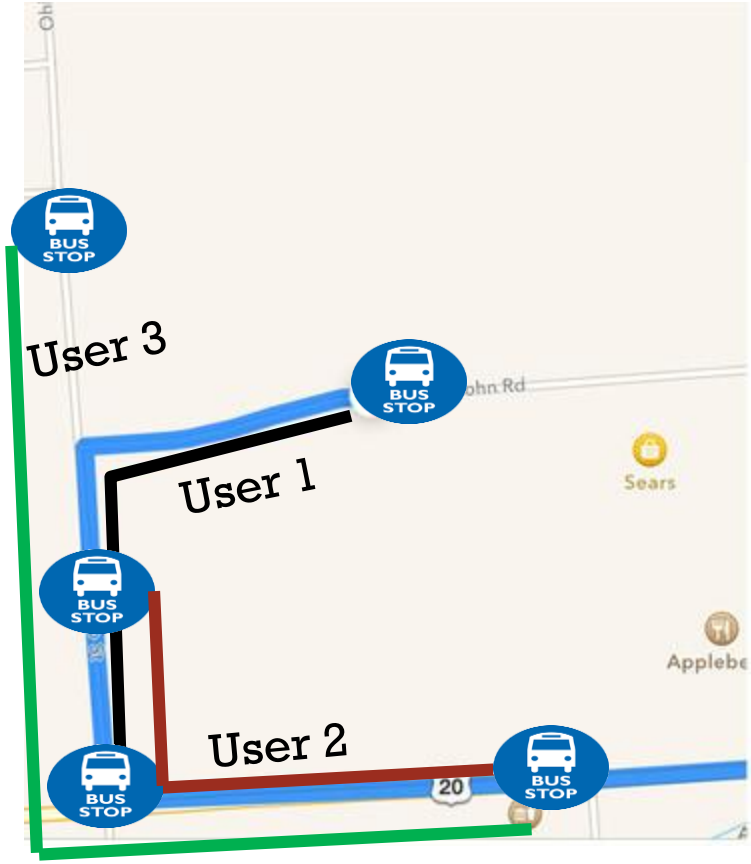

Variation of speed over two different routes for two different buses




Variation of speed after DWT for different data

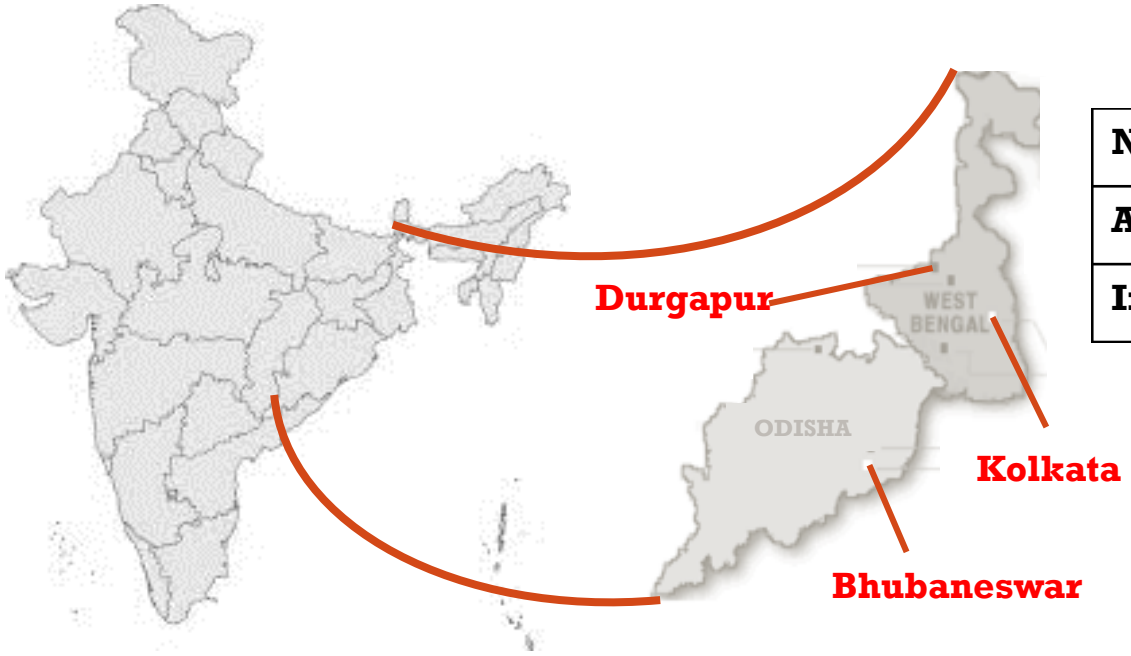
- Every bus route can be classified using a set of features like speed of vehicle, waiting time at bus stop, jerkiness of the bus
- We use **Discrete Wavelet Transform (DWT)** to cluster trajectories belonging to same bus route

# MAP STITCHING FOR COMPLETE ROUTE




- Users in different buses on same bus route may not cover the complete route. The relevant trajectories need to be stitched together to generate complete route.
- **Caveat:** There may be **overlapping routes**.
- **Solution:** Stitch only if the correlation coefficient between route and trajectory features is high.

# EXPERIMENTS



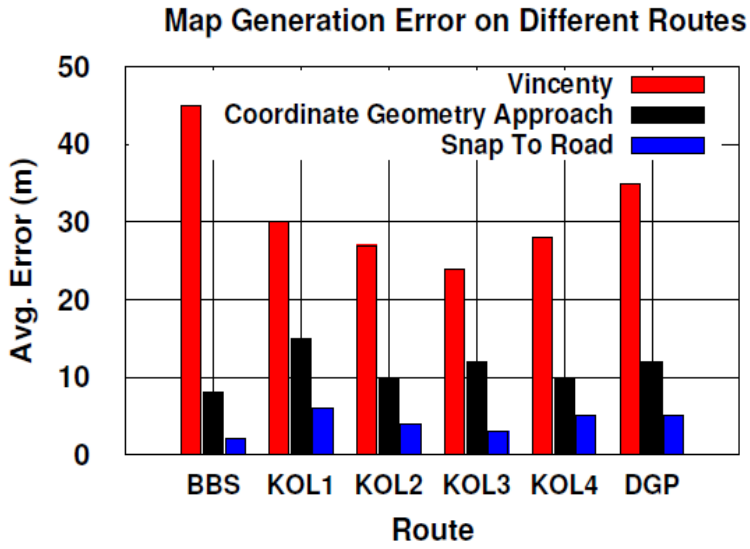

## Volunteer Details

| | |
|---|---|
| **No. of Volunteers** | 30 (K), 10 (B), 10 (D) |
| **Age Group** | 18-25 yrs |
| **Incentive** | 1500 INR/month |

- Experiments were carried on by **50 volunteers** on **11 routes** in **3 cities** for a period of **around 3 years**.
- The volunteers travelled at different bus routes, with the application installed in their mobiles.
- They tagged the ground truth data like, location of PoCs, congested patches, bus route travelling on, broken roads, etc, along with continuous GPS data for the first 3 months.

# EVALUATION: MAP GENERATION AND ROUTE DIFFERENTIATION

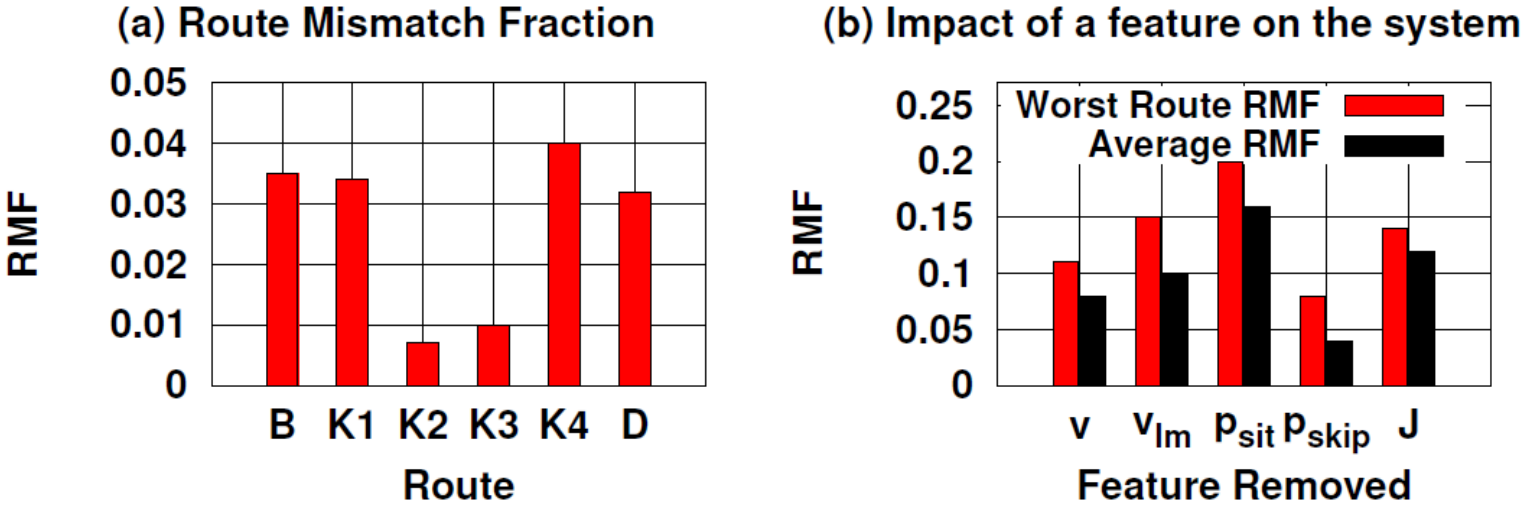
| Route Name | Route Length | Daily Avg Travel Time |
|---|---|---|
| K1 | 17 km | 3.12 hrs |
| K2 | 14 | 2.76 |
| K3 | 20 | 4.32 |
| K4 | 10 | 0.48 |
| B | 19 | 1.2 |
| D | 22 | 3.84 |




| City | Route Number | | | | | |
|---|---|---|---|---|---|---|
| BBS | 306 | | | 207 | | |
| | P | R | A | P | R | A |
| | 0.93 | 0.88 | 0.83 | 0.92 | 0.92 | 0.85 |
| KOL | S9 | | | S4 | | |
| | P | R | A | P | R | A |
| | 1 | 0.9 | 0.9 | 0.96 | 0.96 | 0.93 |
| DGP | A1 | | | A2 | | |
| | P | R | A | P | R | A |
| | 0.92 | 0.92 | 0.86 | 0.93 | 0.93 | 0.88 |

**Accuracy of Bus Route Differentiation**

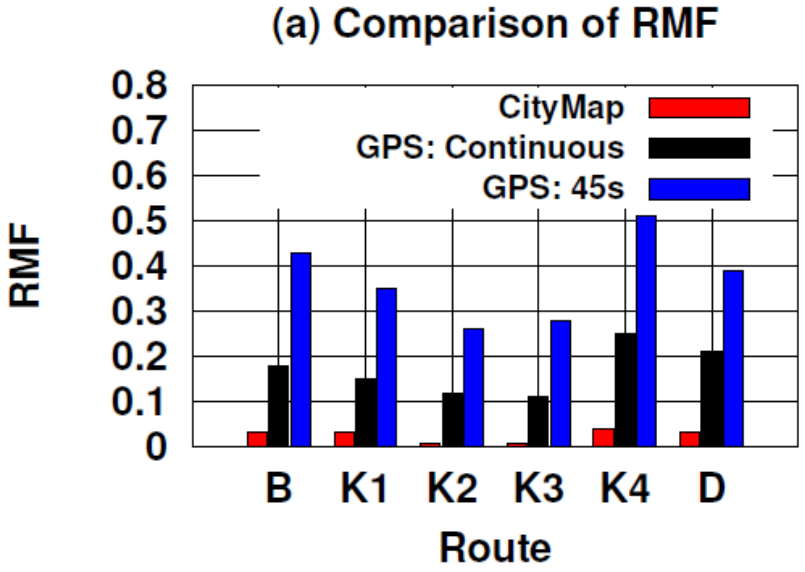
# EVALUATION: OVERALL SYSTEM

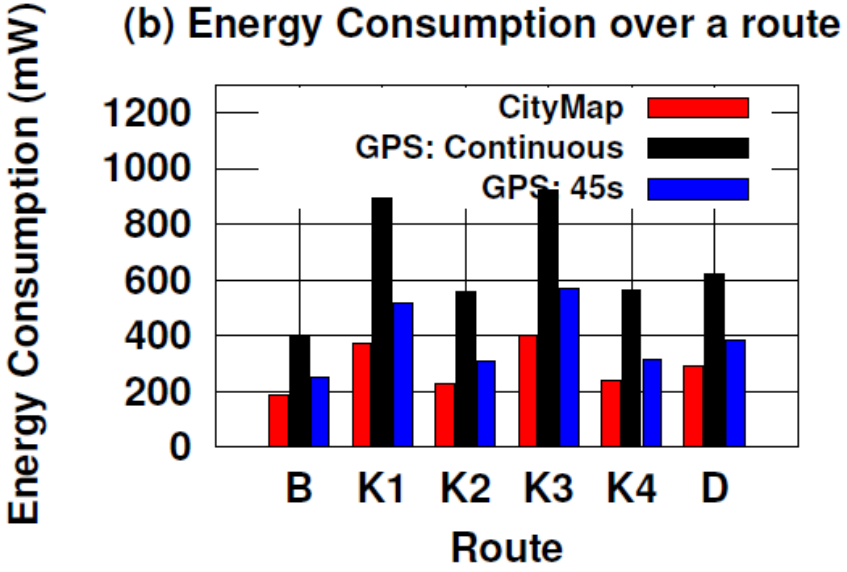



$$RMF = \frac{Erroneously\ matched\ route\ length}{total\ route\ length}$$

- Low RMF values in K2 and K3 is because of high landmark density compared to others.
- $p_{skip}$ impacts value of RMF the least.
- $p_{sit}$ impacts value of RMF the most.

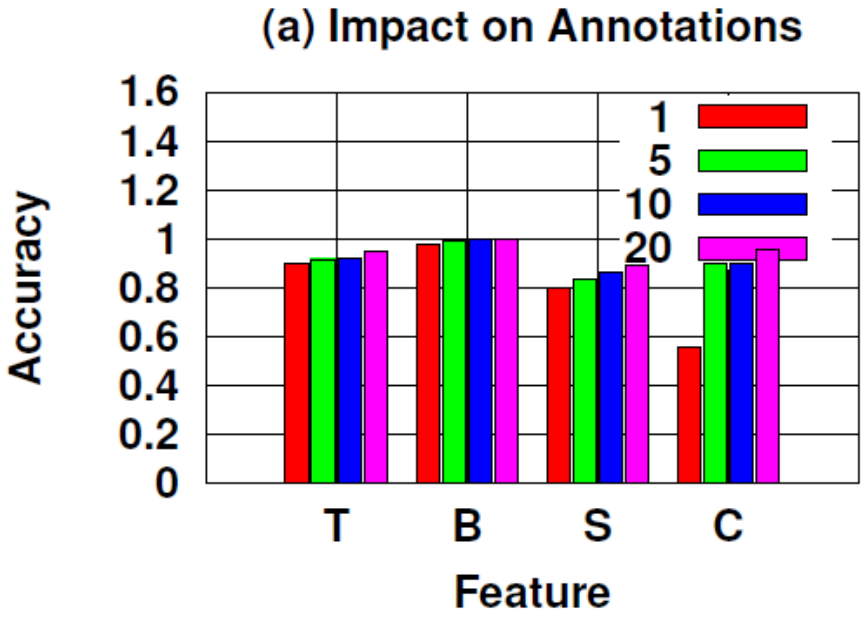
# EVALUATION: COMPETING SYSTEMS

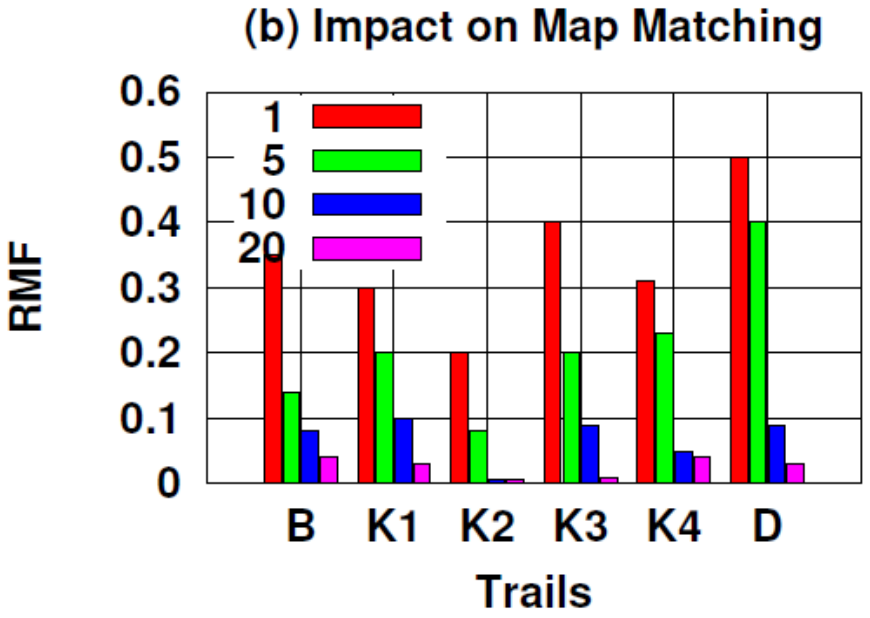



- Competing system only uses GPS information and hence fails in classifying overlapping segments
- With minimal GPS usage, CityMap consumes much less energy

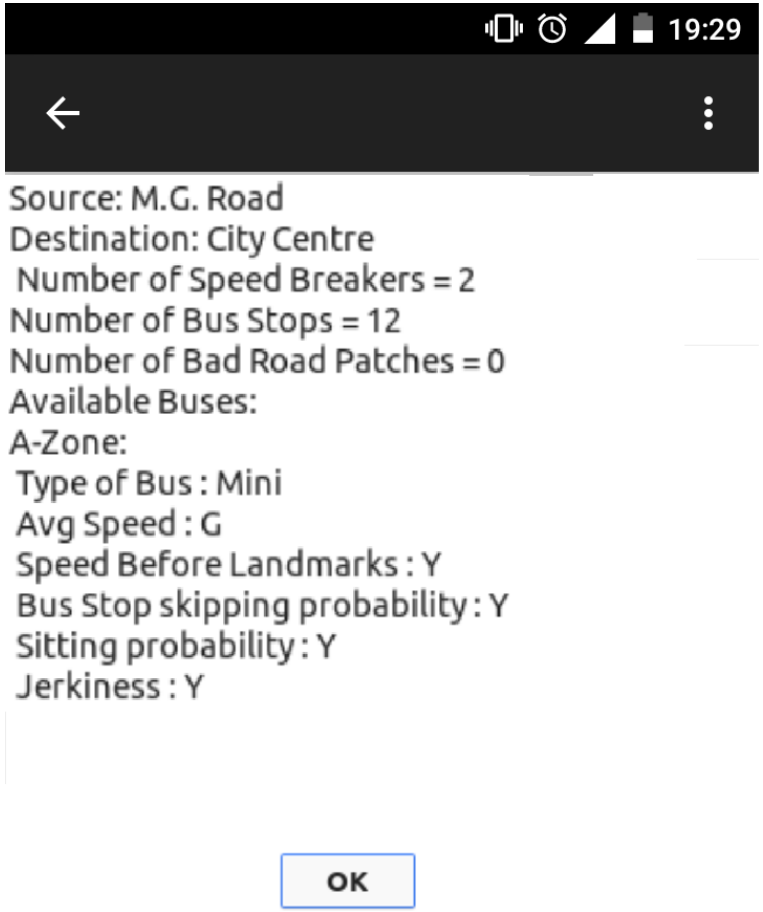
# EVALUATION: DATA ACCUMULATION IMPACT

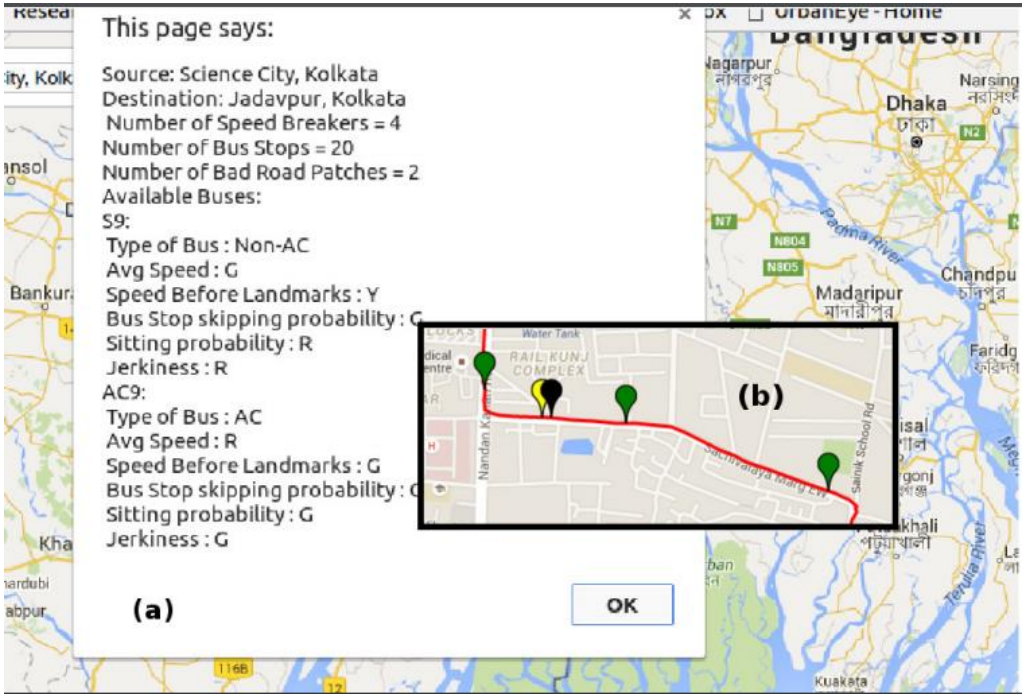



- Increasing the data collection period improves the results for both annotations and map generation.
- Continuous data collection for a period of 20 days decreases the errors many folds after which the algorithm stabilizes.

# ROUTE SUMMARIZATION APPLICATION



# CONCLUSION

- **CityMap** is the first of its kind implementation for **city transit map generation using smartphone sensors.**

- **CityMap** effectively annotates bus routes along with other route and road features with more than **90% of accuracy**.

- The generated map can be utilized as an infrastructure for a large set of public transit based applications like
  - Navigation application
  - Route Recommendation application
  - Dynamic Rerouting application

# THANK YOU!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