

CITYMAP

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

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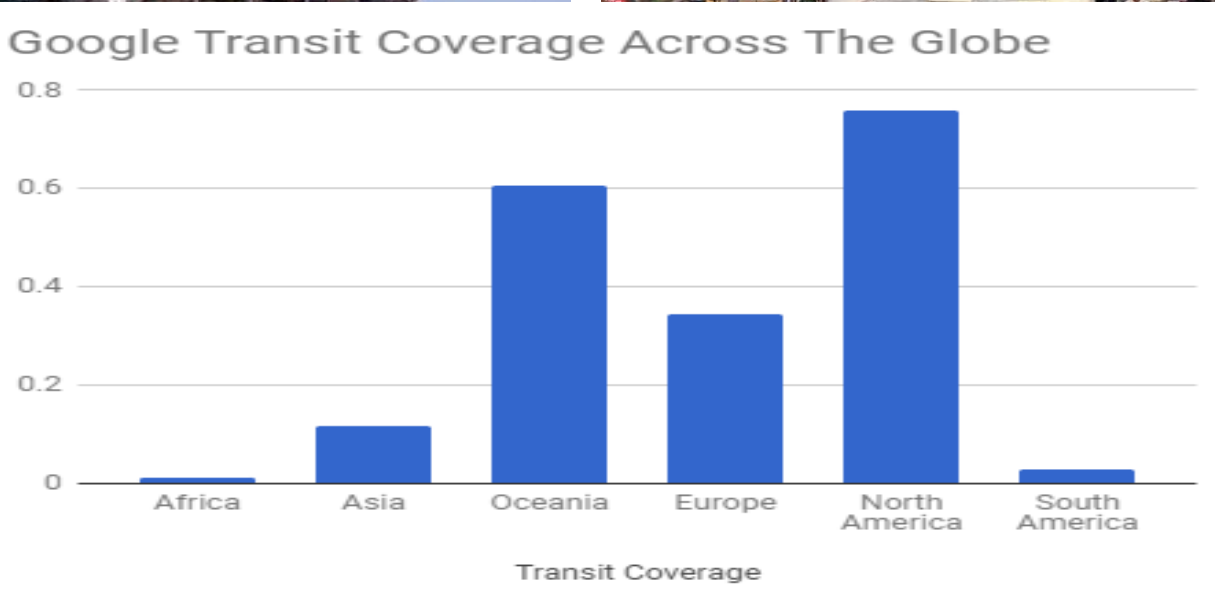


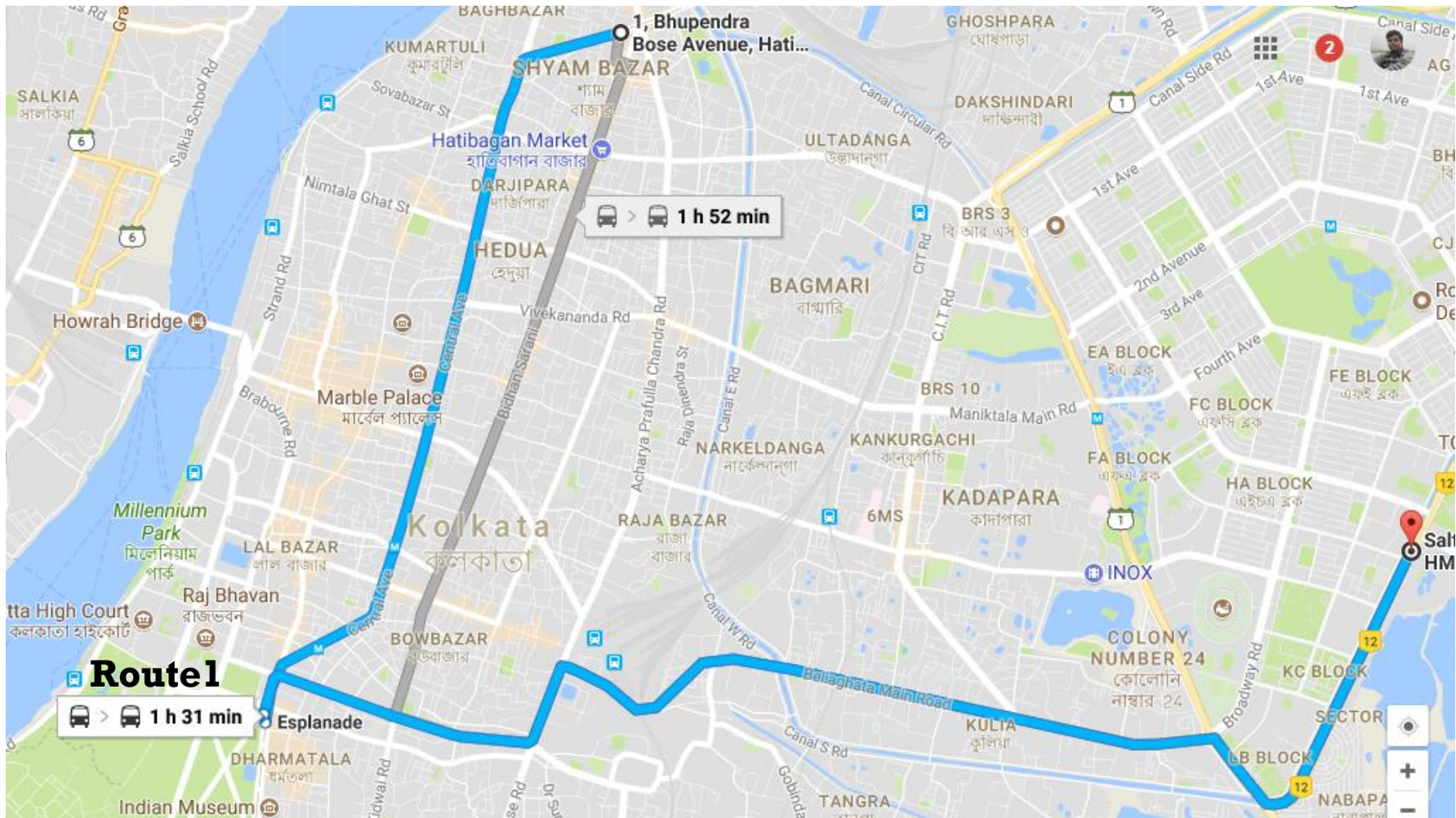
Indian Institute of Technology Kharagpur, India

ISSUES WITH PUBLIC TRANSPORT



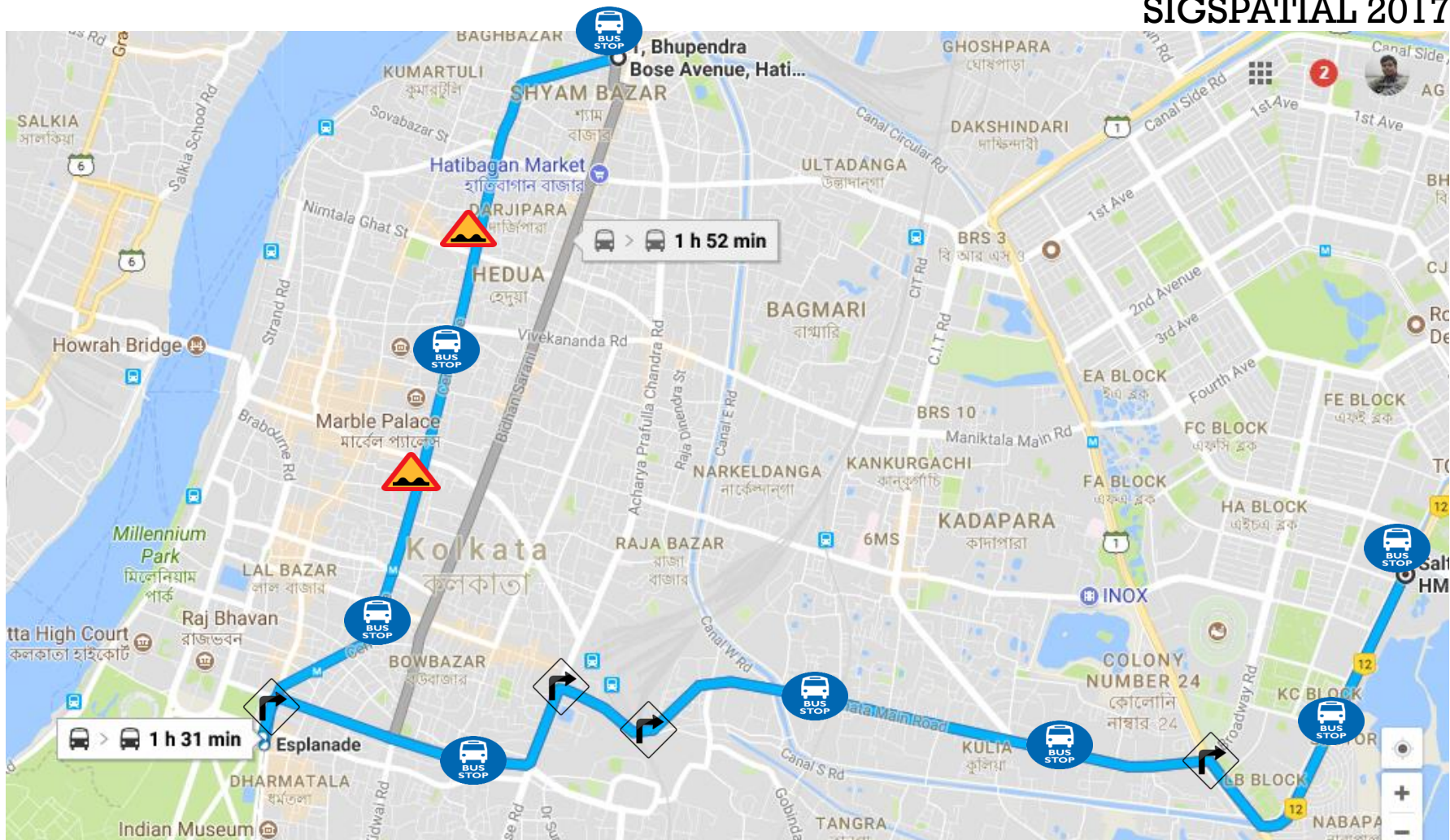
ISSUES WITH PUBLIC TRANSPORT





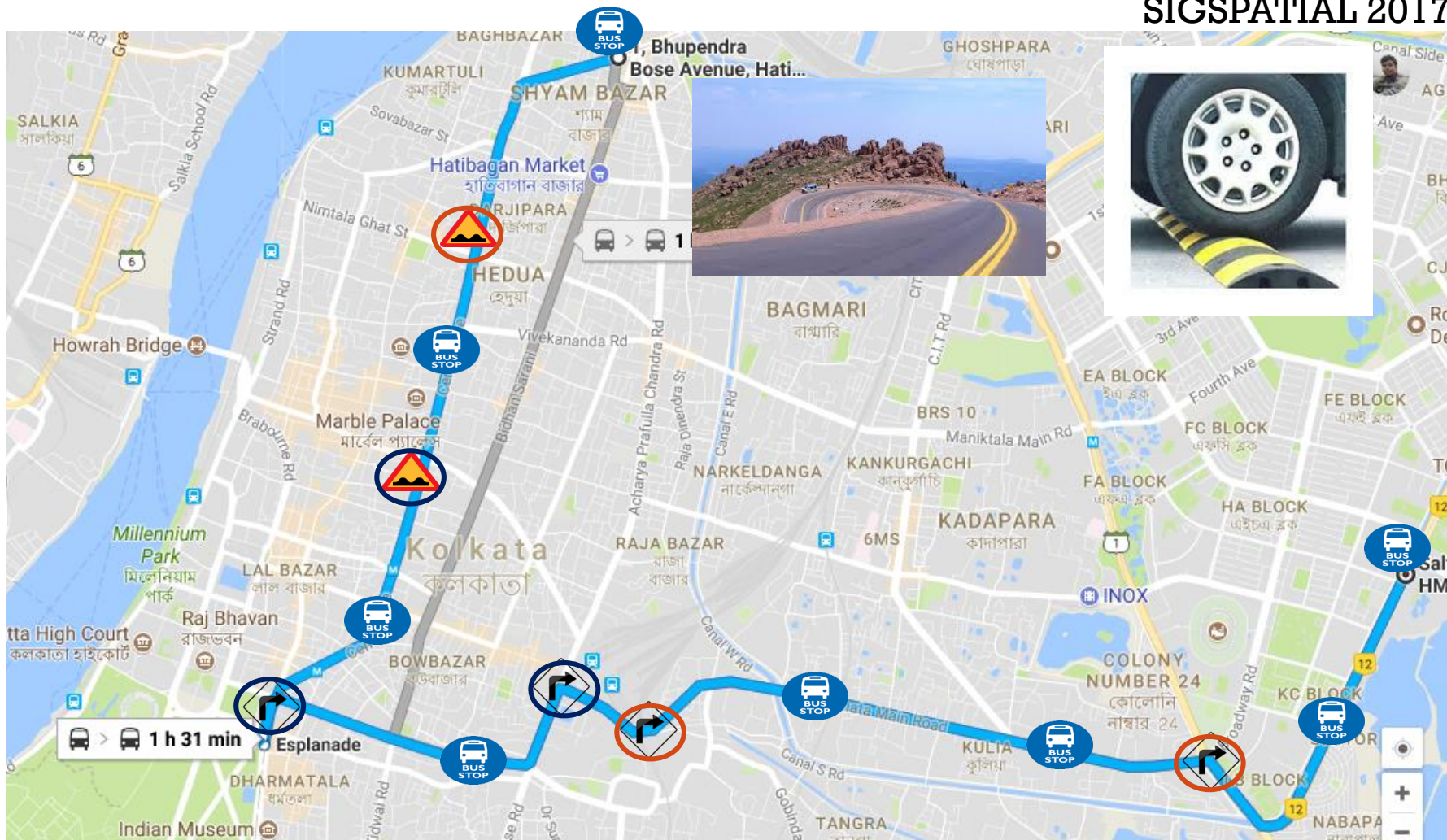
The map shows:

- 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



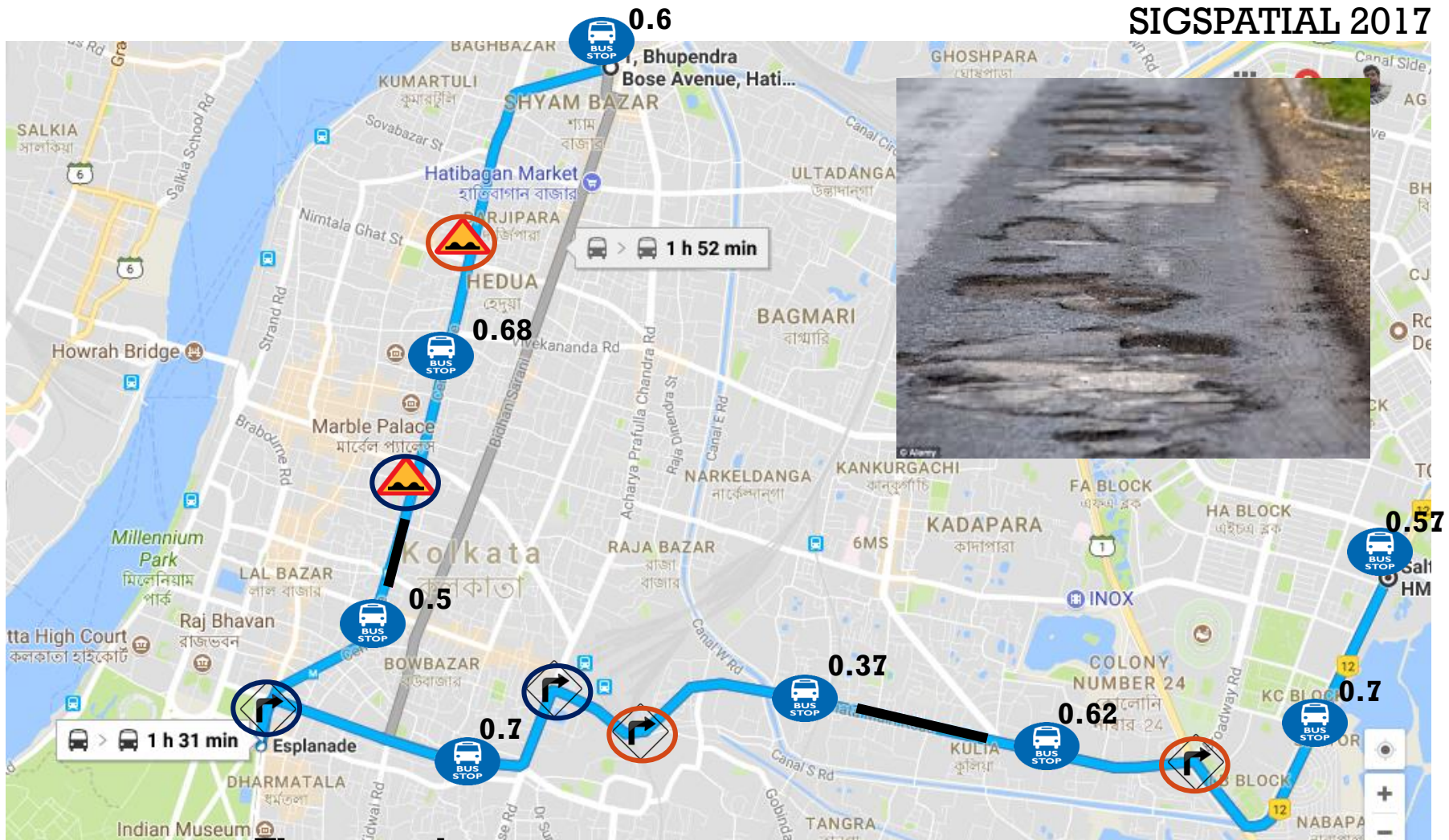
The map shows:

- The available bus route
- All the PoCs on the bus route
- Features linked with these PoCs like
 - Steep/Gentle turns or speed breakers



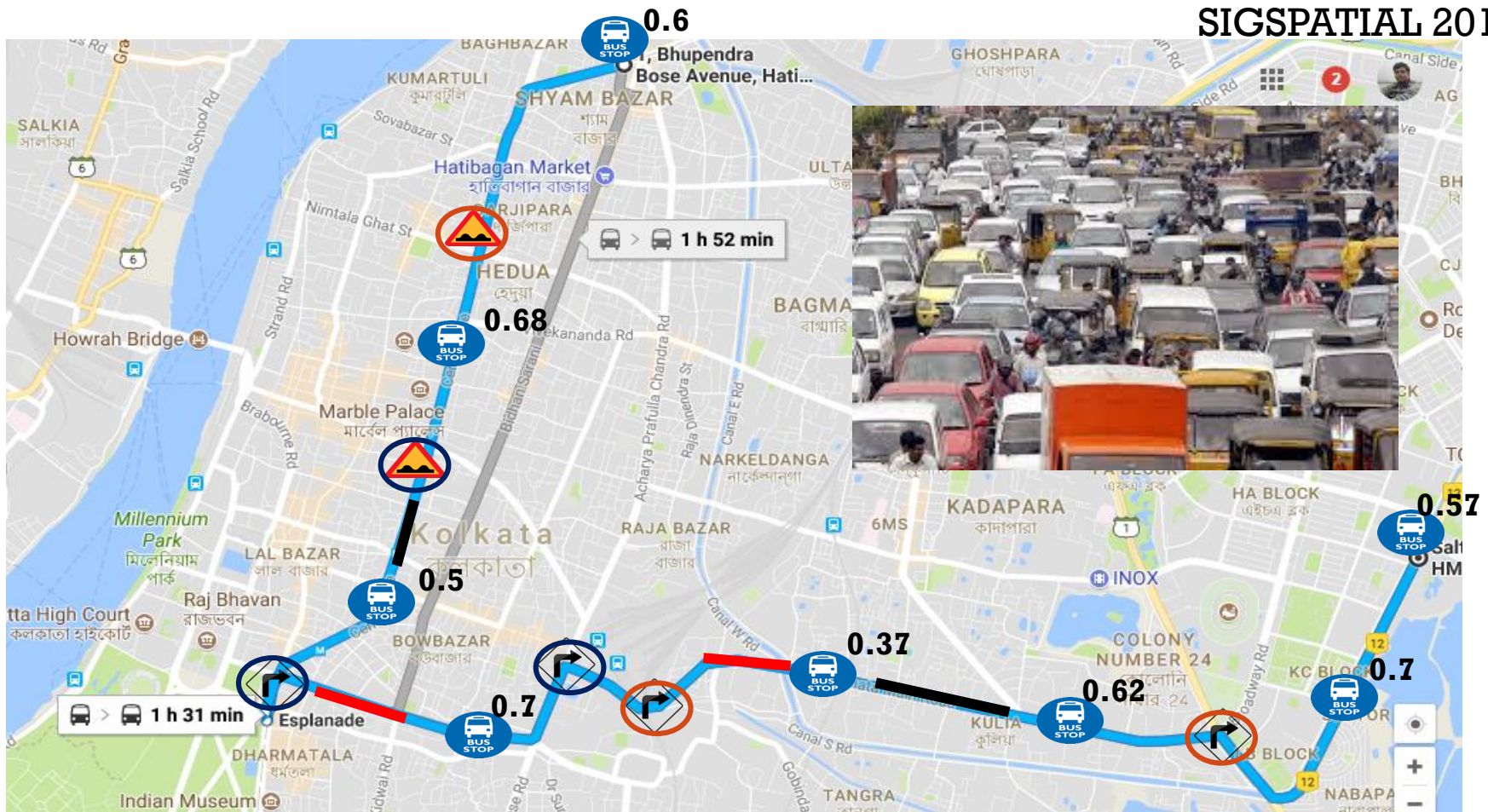
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- Other route features like **jerky road**



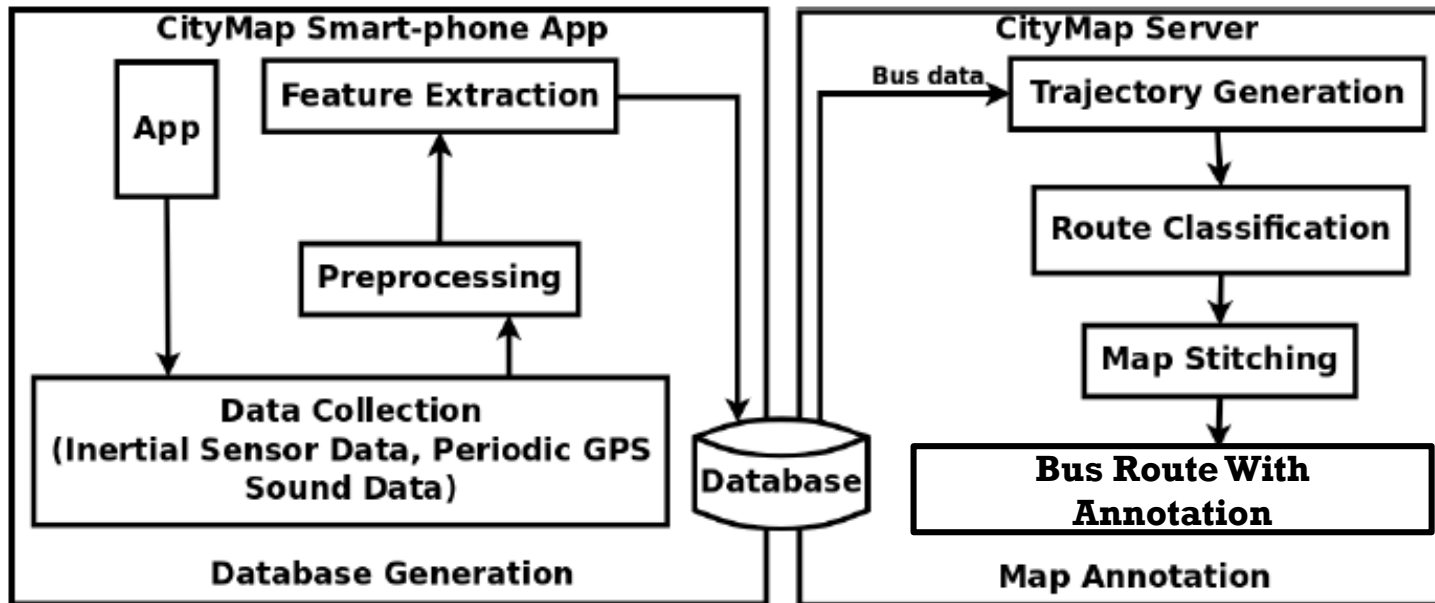
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- All the PoCs on the bus route
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 - Probability of getting a seat at a bus stop
- Other route features like **jerky road, congested patches**

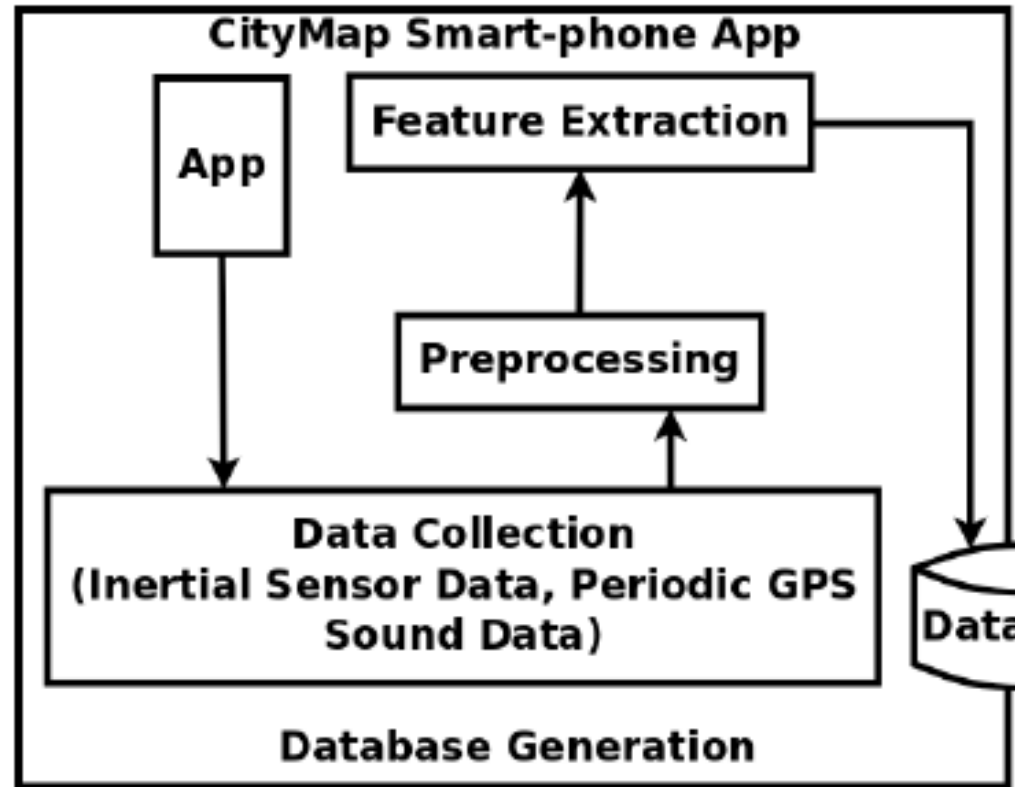
OBJECTIVE

- 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



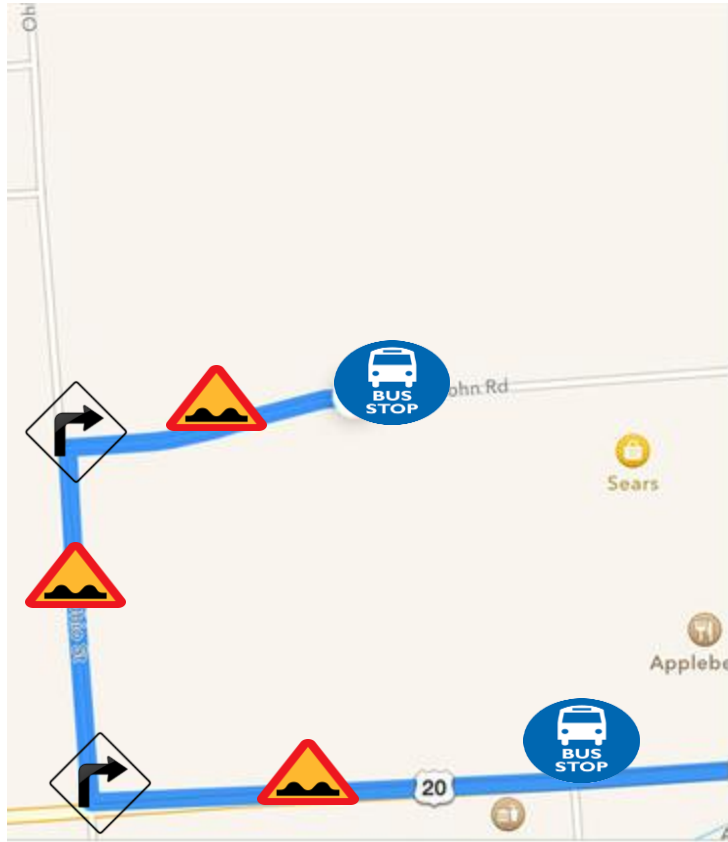
CHALLENGES: DATABASE GENERATION



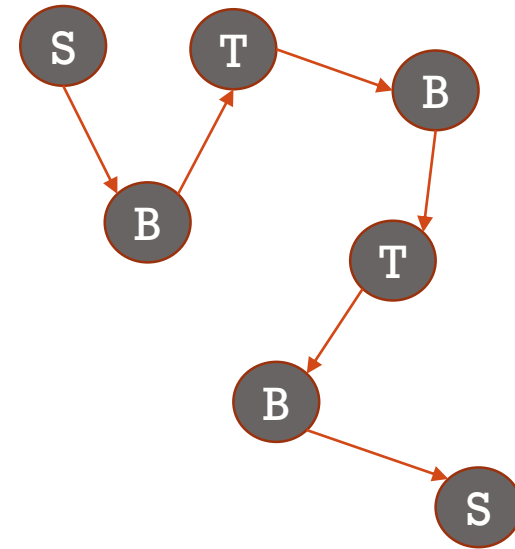
How to make the application energy efficient?

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

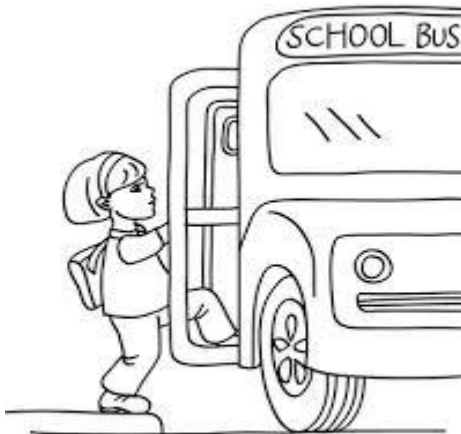
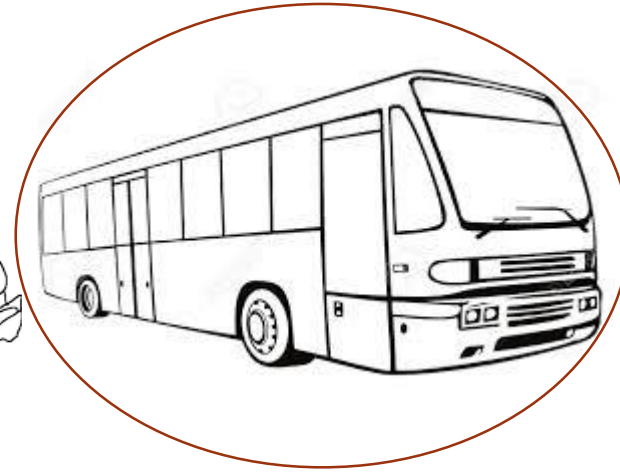
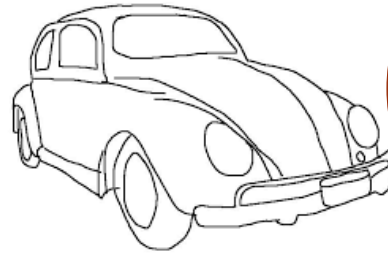
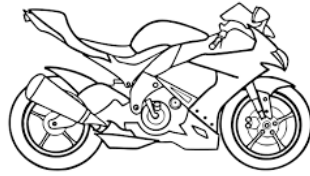
MANAGING ENERGY EFFICIENCY



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



SMART DATA LOGGING



Continue

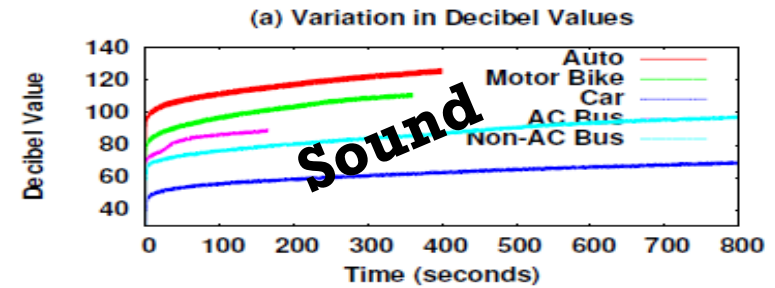
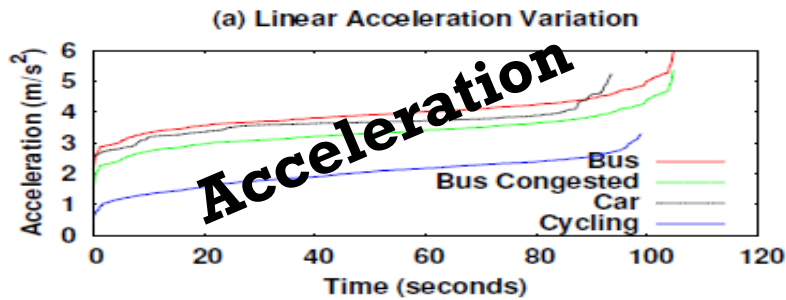


Start Logging

Stop Logging

SMART DATA LOGGING

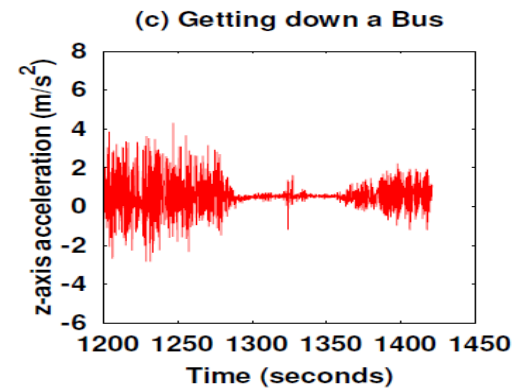
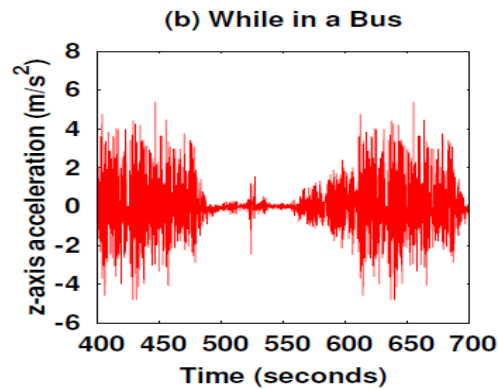
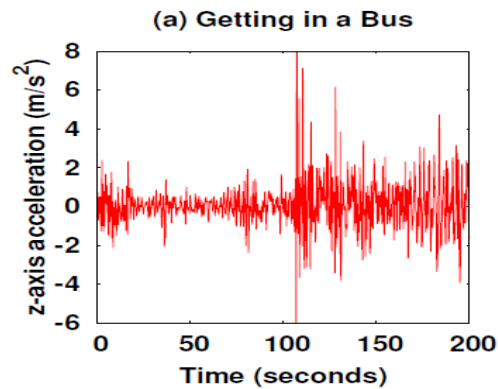
Identifying user in bus



Signature of the acceleration along y-axis for different modes

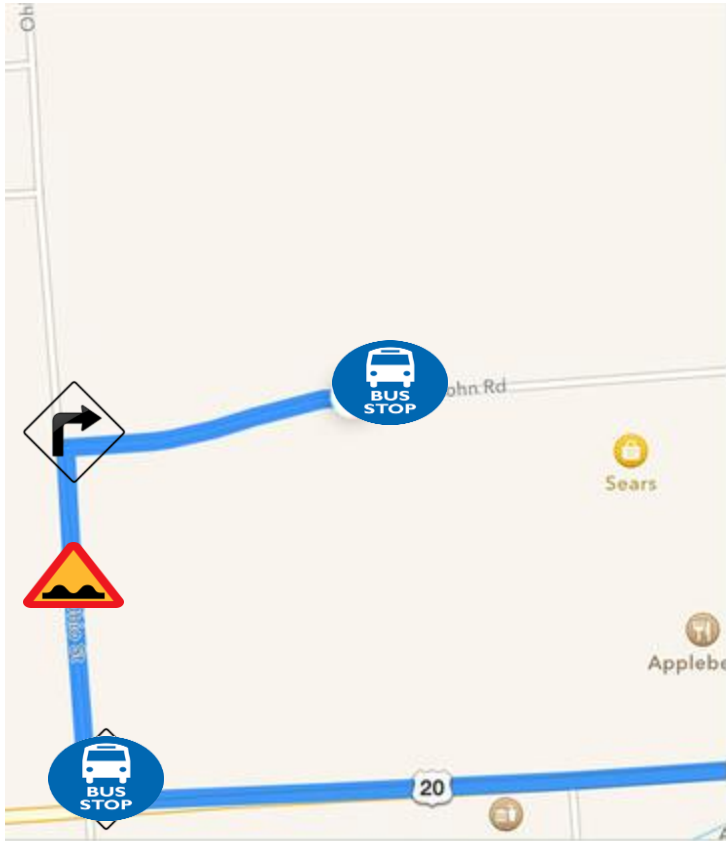
Variation in sound data for different motorized vehicles

Logging at bus stop



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

BUILD DATABASE



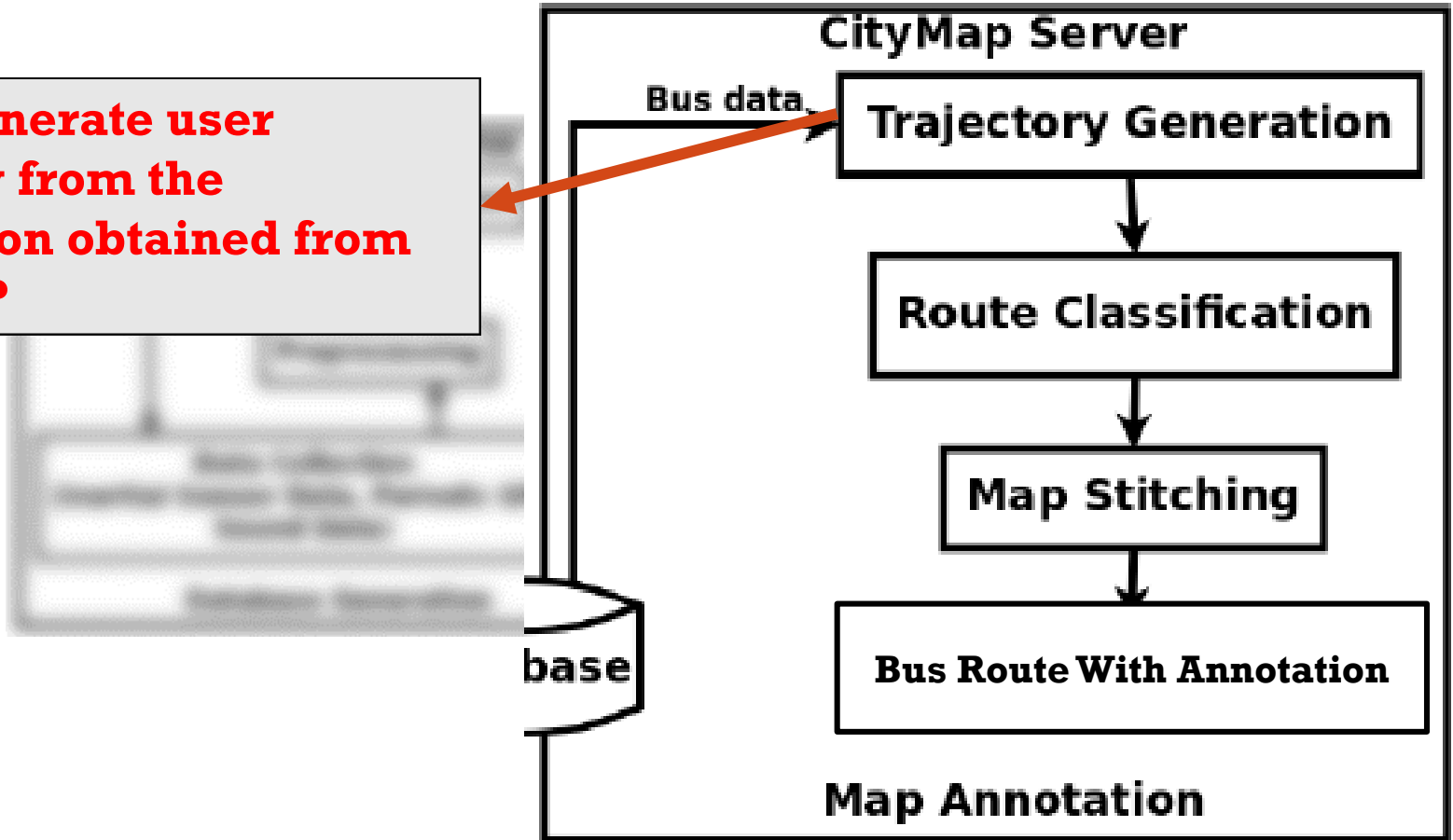
- **PoC information** in the database.

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.

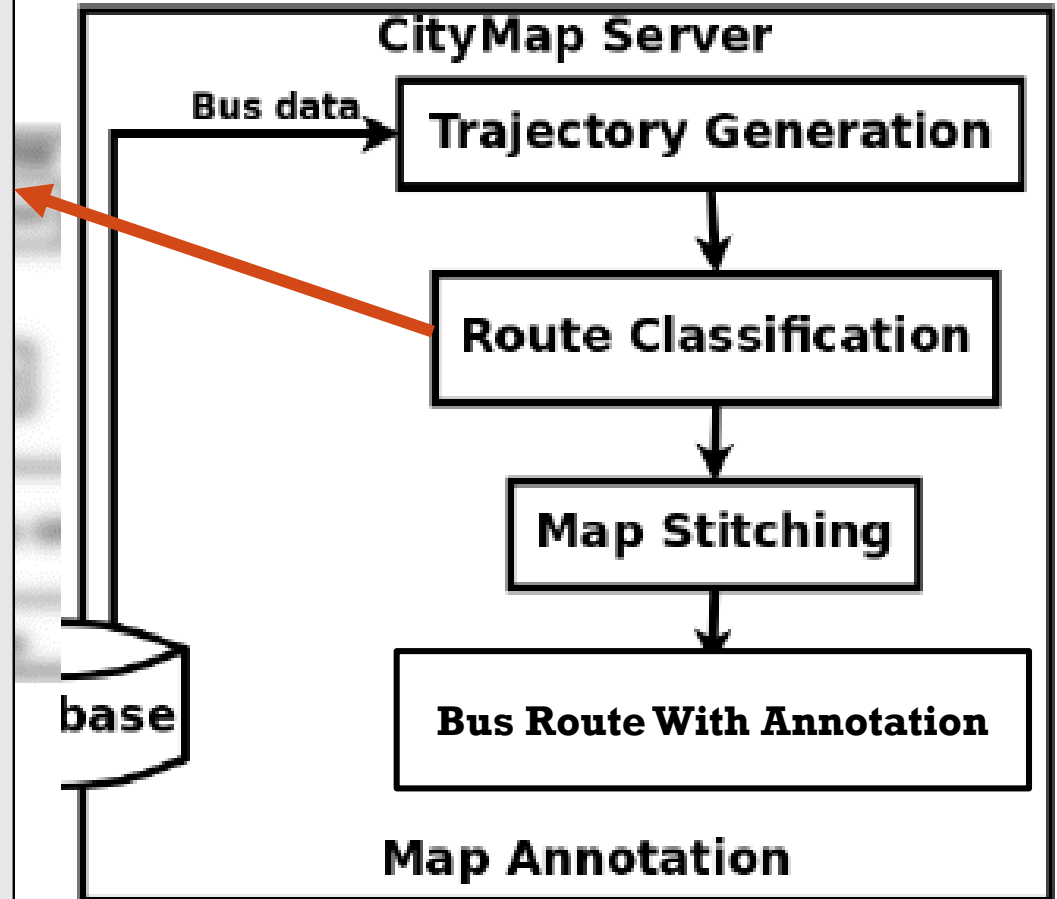
CHALLENGES: MAP ANNOTATION

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



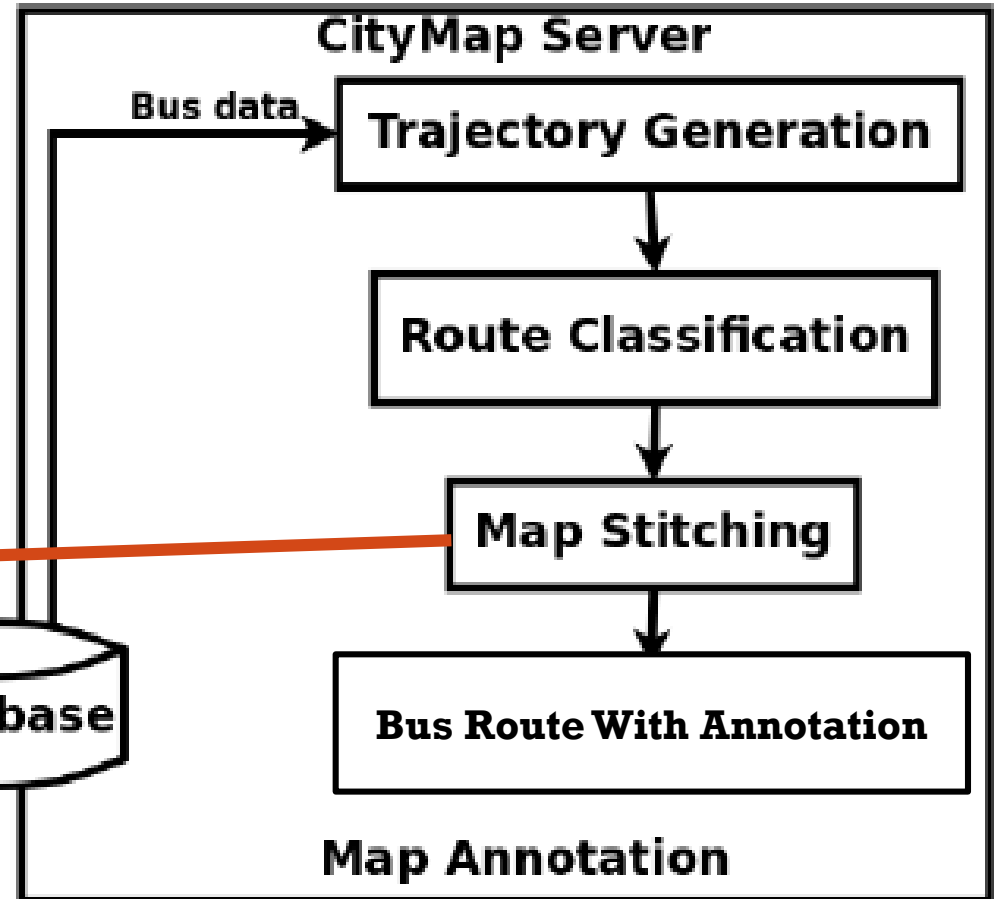
CHALLENGES: MAP ANNOTATION

- **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.**

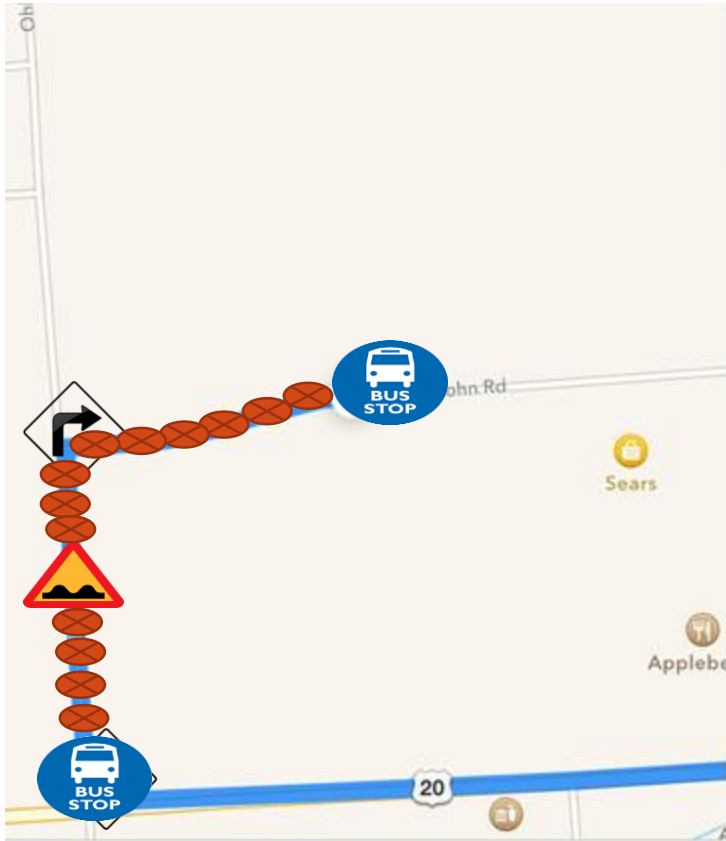


CHALLENGES: MAP ANNOTATION

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

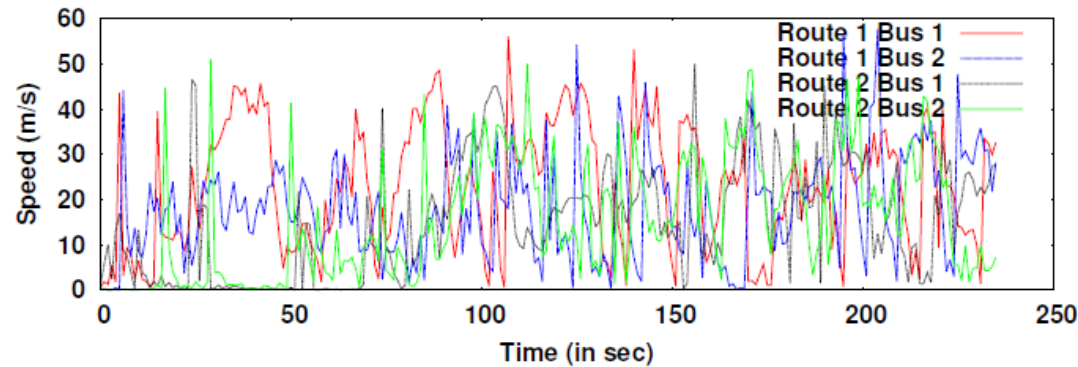


- Place detected **PoCs as anchor points** on the trajectory
- **Estimate intermediate GPS Coordinates** to generate complete trajectory of the user
 - Use **Vincenty's Formula** to estimate a point P'
 - Bring the point closer to the desired road, at P'' , using **Coordinate geometry approach**
 - Use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

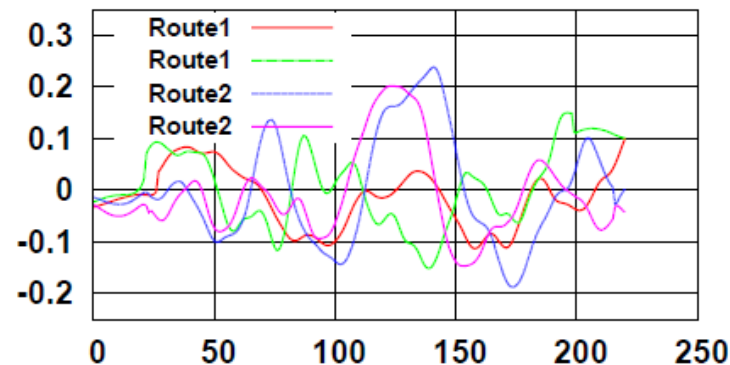
INCLUDING A ROUTE IN THE MAP

- 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



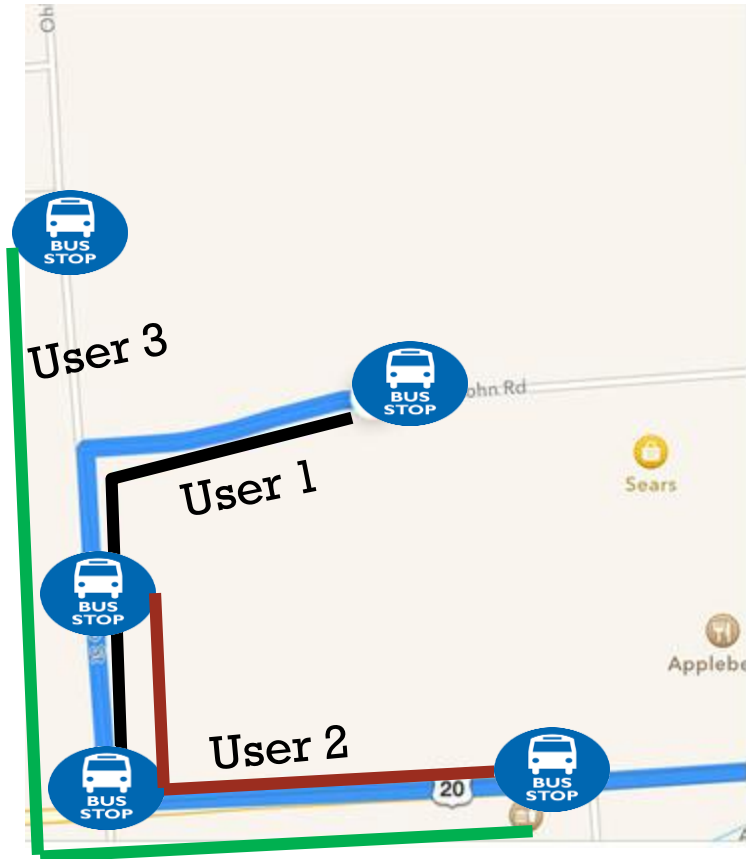
Variation of speed over two different routes for two different buses



Variation of speed after DWT for different data

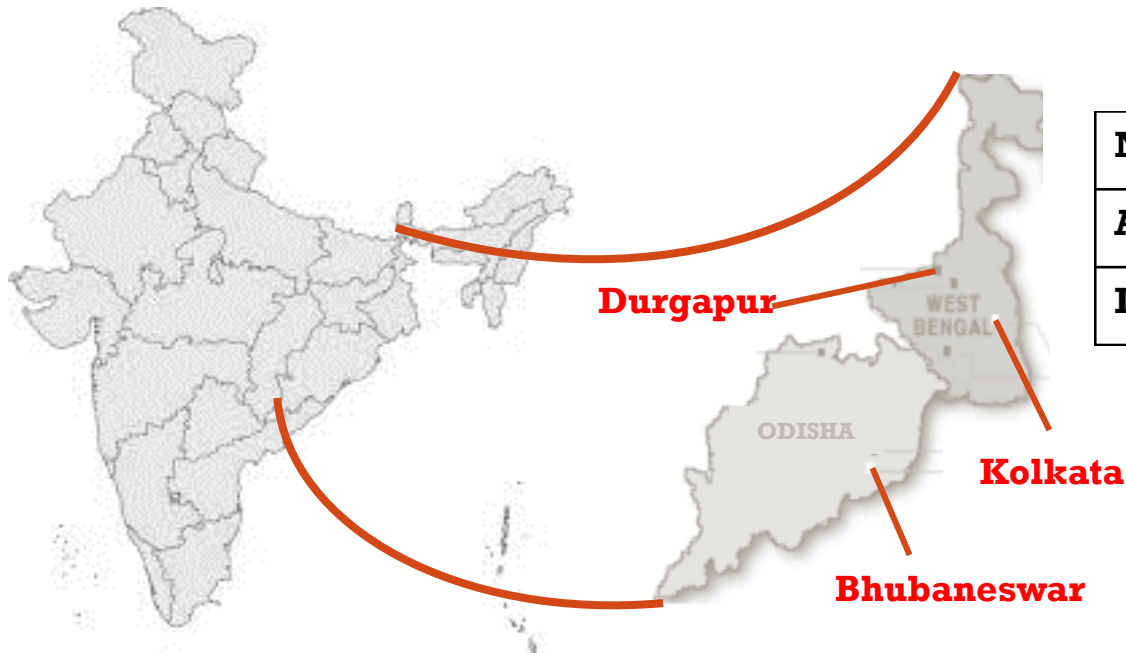
- Every bus route can be classified using a set of features like speed of vehicle, waiting time at bus stop, jerkiness of the bus
- We use **Discrete Wavelet Transform (DWT)** to cluster trajectories belonging to same bus route

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



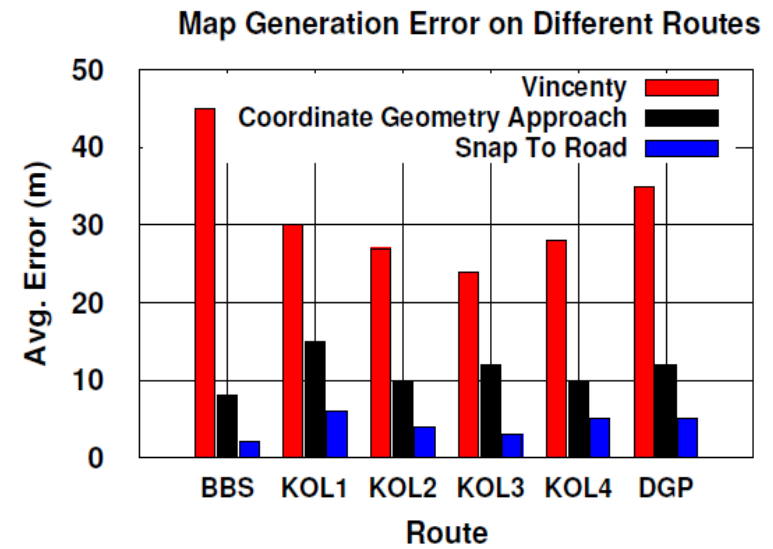
Volunteer Details

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

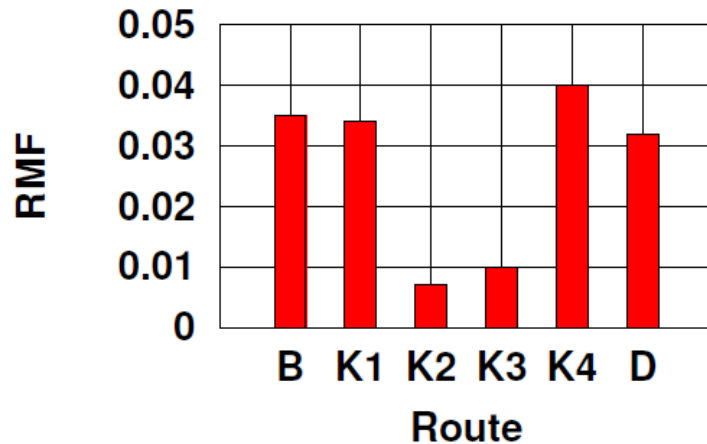


City	Route Number					
	BBS	306			207	
P		R	A	P	R	A
0.93		0.88	0.83	0.92	0.92	0.85
KOL	S9			S4		
	P	R	A	P	R	A
	1	0.9	0.9	0.96	0.96	0.93
DGP	A1			A2		
	P	R	A	P	R	A
	0.92	0.92	0.86	0.93	0.93	0.88

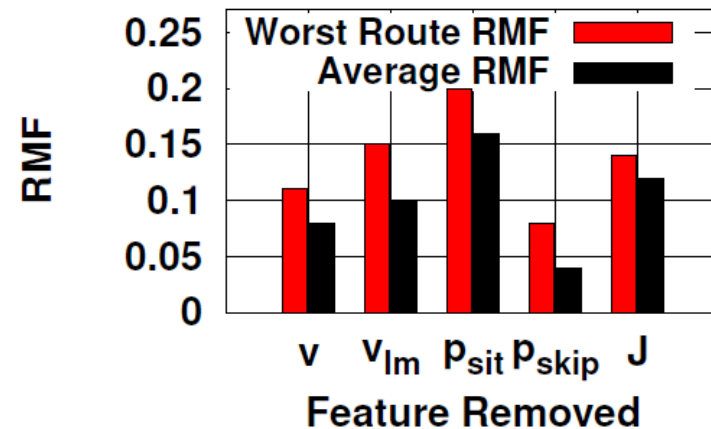
Accuracy of Bus Route Differentiation

EVALUATION: OVERALL SYSTEM

(a) Route Mismatch Fraction



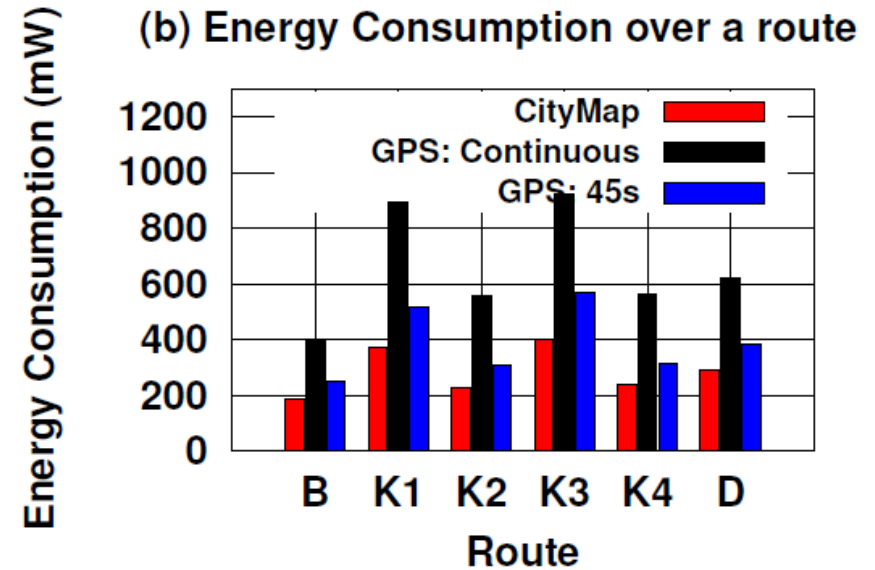
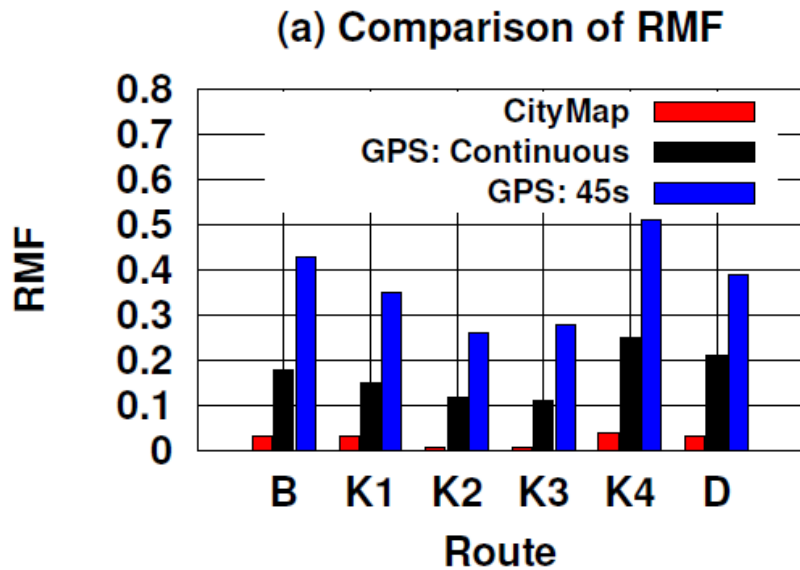
(b) Impact of a feature on the system



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

- 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.

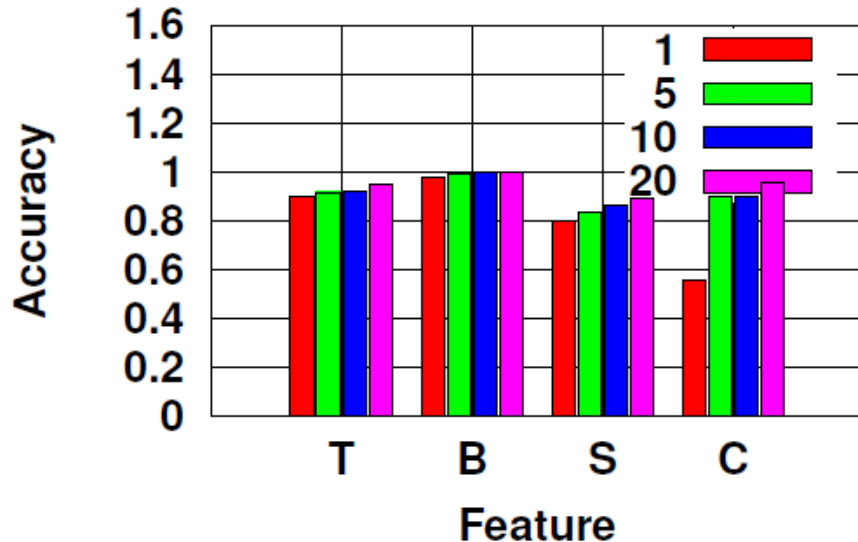
EVALUATION: COMPETING SYSTEMS



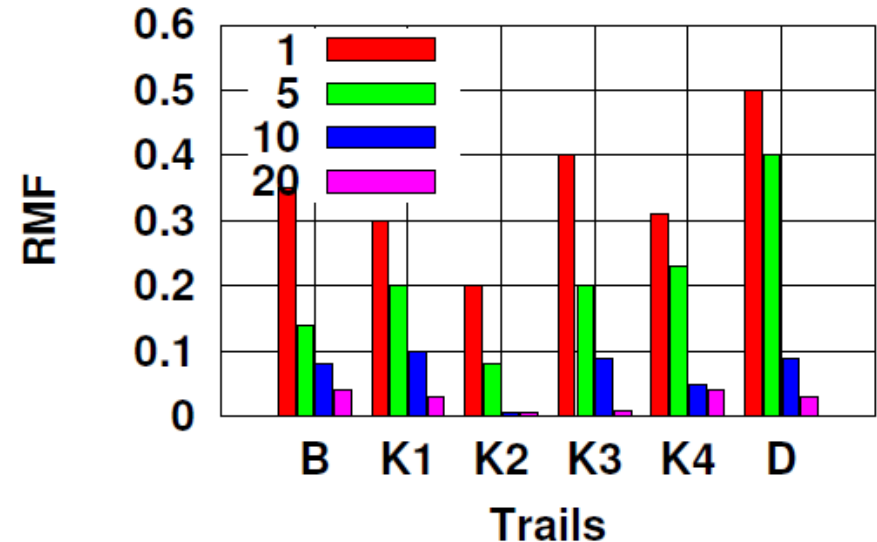
- Competing system only uses GPS information and hence fails in classifying overlapping segments
- With minimal GPS usage, CityMap consumes much less energy

EVALUATION: DATA ACCUMULATION IMPACT

(a) Impact on Annotations



(b) Impact on Map Matching



- 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



Source: M.G. Road
 Destination: City Centre
 Number of Speed Breakers = 2
 Number of Bus Stops = 12
 Number of Bad Road Patches = 0
 Available Buses:
 A-Zone:
 Type of Bus : Mini
 Avg Speed : G
 Speed Before Landmarks : Y
 Bus Stop skipping probability : Y
 Sitting probability : Y
 Jerkiness : Y

OK

This page says:

Source: Science City, Kolkata
 Destination: Jadavpur, Kolkata
 Number of Speed Breakers = 4
 Number of Bus Stops = 20
 Number of Bad Road Patches = 2
 Available Buses:
 S9:
 Type of Bus : Non-AC
 Avg Speed : G
 Speed Before Landmarks : Y
 Bus Stop skipping probability : G
 Sitting probability : R
 Jerkiness : R
 AC9:
 Type of Bus : AC
 Avg Speed : R
 Speed Before Landmarks : G
 Bus Stop skipping probability : G
 Sitting probability : G
 Jerkiness : G

(a)

(b)

OK

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!

CrowdMap

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Challenges

Multiple challenges had to be tackled to develop CrowdMap. We list here the major ones;

- Developing an intelligent data logging system
- Automatically sense route signatures or landmarks like speed breakers, turns, etc
- Generate the complete trajectory of the bus using only inertial sensor data
- Discover a unique bus route on the map

Contributions

We propose a crowdsourcing based solution, **CrowdMap** that tackles the problems discussed earlier. CrowdMap seamlessly discovers the bus routes, and embeds the annotated route information on the city map. The major contributions of CrowdMap are;

- A data collection module that uniquely identifies the user is in a bus and logs required data.
- Detects and tags landmarks
- Generates a trajectory of the route travelled by the user
- Annotate bus routes on map alongwith comfort level information



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 Available Buses:
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