Fighting Chaotic Road Congestion

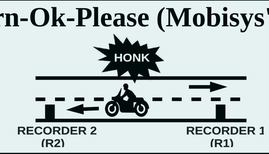
Rijurekha Sen, Pankaj Siriah, Bhaskaran Raman,
Swaroop Roy, Swanand Kulkarni, Puru Kulkarni
CSE, IIT Bombay

techvista PUNE 2011

Microsoft Research india

RoadSoundSense

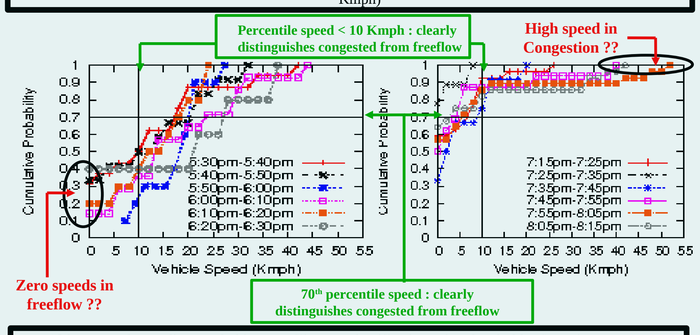
Horn-Ok-Please (Mobisys'10)



(1) f1 = (v * f0) / (v + vs) (2) f2 = (v * f0) / (v – vs)
(3) vs = ((f2 – f1) * v) / (f2 + f1)

Developed heuristics for
a) Recorder Synchronization b) Honk Detection
c) Honk Matching d) Frequency Extraction

Extensive in-campus and on-road experiments to test speed accuracy (Worst error 5 Kmph, average error 1.24 Kmph)



18 hours road recordings to do binary traffic state classification using thresholds of metrics
a) 70th percentile speed b) percentile speeds < 10 Kmph
c) number of honks d) duration of honks

RoadSoundSense (submitted to SECON'11)

Implementability Issues

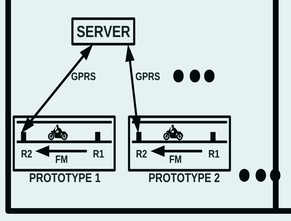
- Can **computation intensive acoustic signal processing** be implemented on **embedded sensor platform**?
- Can the sensing and processing be done in **near real-time**?
- Will the **cost** be low enough?

Usability Issues

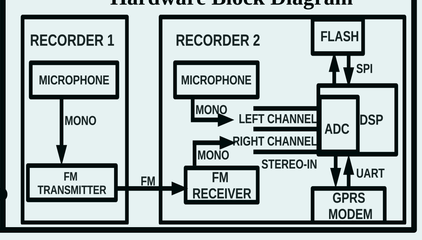
- Will the system be able to detect congestion on a **wide variety of roads**?
- Will the **traffic classification model** vary from road to road?
- What will be the **training overhead** of our system on a new road?
- Can we do without training using **unsupervized learning**?

In this work, we seek answer to the above questions

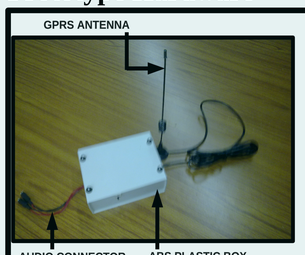
System Architecture



Hardware Block Diagram

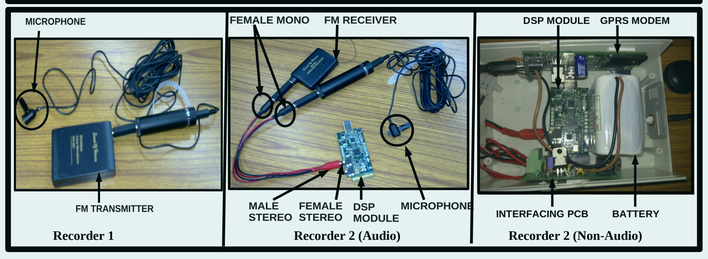


Prototype Hardware

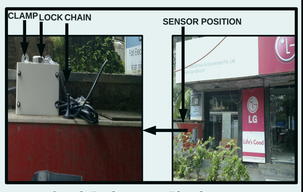


Item	Unit Price ($)	Quantity	Cost ($)
DSP module	50	1	50
GPRS modem	50	1	50
FM tx-rx	15	1	15
Microphone	5	2	10
Interfacing PCB	5	1	5
Battery	20	1	20
Enclosure	5	1	5
Flash	3	1	3
Connectors	0.4	5	2
Total			160

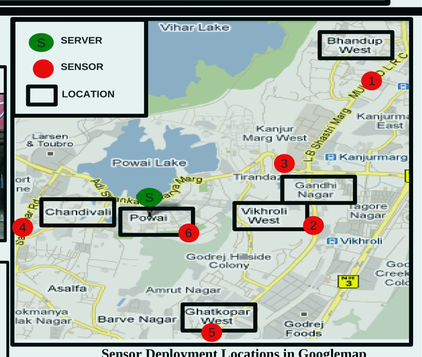
Prototype Cost Breakup



Deployment



Sample Deployment at Bhandup



Sensor Deployment Locations in Googlemap

Choice of locations

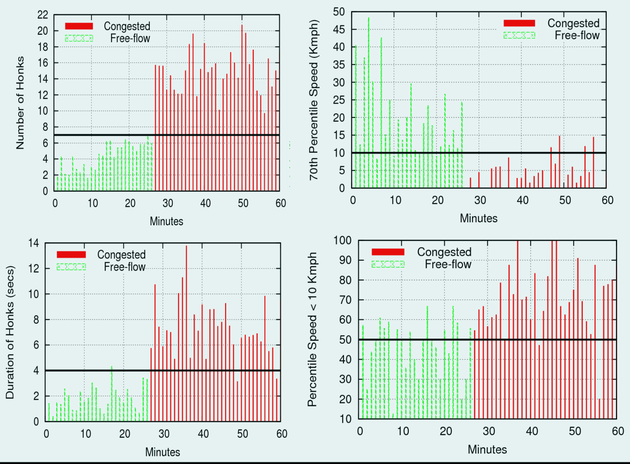
- Not very near to traffic signal
- Not very far from traffic signal
- Not after traffic signal
  - 150-200m before traffic signal
- Near important road junctions or railway stations to ensure congestion in peak hours
- 5-6Km from IIT to reduce trip time from lab to each location

No.	Location	Road bi-directional	Road width (each way)	Vehicle type
1	Bhandup	Yes	10m	All
2	Vikhroli	Yes	10m	All
3	Gandhinagar	Yes	25m	All
4	Chandivali	Yes	15m	All
5	Ghatkopar	Yes	10m	All
6	Powai (Hiranandani)	Yes	8m	Light

Deployment Location Details

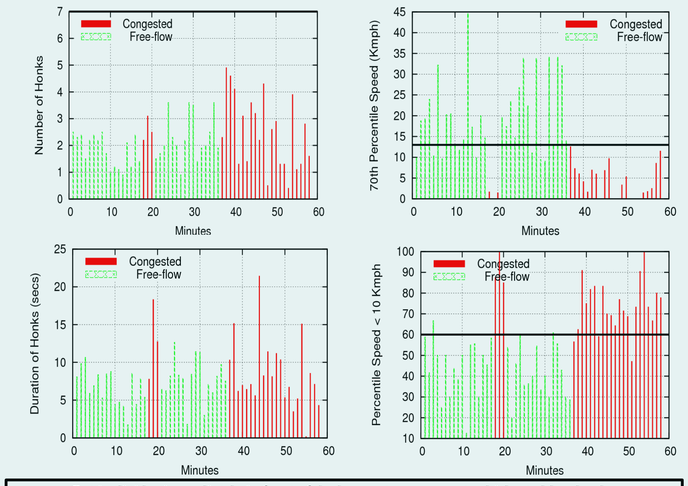
http://www.cse.iitb.ac.in/~riju/rss-videos/

Gandhinagar



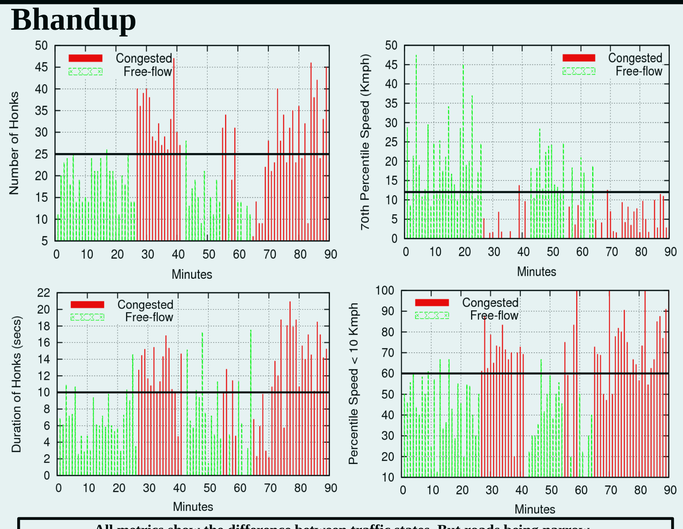
25 m wide road causes many times increase in vehicle number in congestion from free-flow, increasing honk-based metric values, which suffice in congestion detection.
Speed-based metrics, more complex to compute, are unnecessary.

Vikhroli



Cut in divider immediately in front of deployment causes most vehicles to blow honks, even in free-flow, to alert the road crossing pedestrians. Honk-based metrics are unduly inflated.
Only speed based metrics should be used.

Bhandup



All metrics show the difference between traffic states. But roads being narrow, honks from opposite direction get recorded, giving inflated values of honk-based metrics.
Thus speed-based metrics should be given more weightage.

Automation: Machine Learning Tools

- **Separate training set** for each road -- 90 instances for Bhandup, 58 instances for Vikhroli, 60 instances for Gandhinagar, Chandivali, Ghatkopar, Powai (Hiranandani)
- **6 attributes for each instance** – 4 honk-based metrics and 2 speed-based metrics
- **1 class label for each instance**, congested or free-flow, based on manual observation

Classification Models

Bhandup (Accuracy 93.2%)	*Vikhroli (Accuracy 98.3%)*	*Gandhinagar (Accuracy 100%)*
*+ 1.38 * numhonks1*	*+ 0.71 * numhonks1*	*+ 1.45 * numhonks1*
*+ 0.38 * duration1*	*- 0.21 * duration1*	*+ 0.97 * duration1*
*- 0.17 * numhonks2*	*+ 0.15 * numhonks2*	*+ 1.59 * numhonks2*
*+ 1.19 * duration2*	*- 0.57 * duration2*	*+ 0.91 * duration2*
*- 2.94 * 70speed*	*- 2.71 * 70speed*	*- 0.58 * 70speed*
*+ 2.25 * 10speed*	*+ 2.71 * 10speed*	*+ 0.49 * 10speed*
- 1.73	*- 0.94*	*- 1.98*

Attribute weights using binary Sequential Minimal Optimization (SMO) SVM model with linear kernels

- **Weights assigned to the attributes are in accordance with manual observation**
- **Minimum accuracy obtained in 10 fold cross-validation is 92.7% for Powai (Hiranandani)**

Unsupervized Learning:

K-means clustering, with cluster to classes evaluation, gives 65.52% accuracy for Vikhroli
For other roads accuracy is 85-100%

Temporal Variation in Traffic

Time	State	Time	State	Time	State
10:30am	F	11:00am	F	11:30am	C
12:00noon	C	12:30pm	F	–	–
4:00pm	F	4:30pm	F	5:00pm	F
5:30pm	C	6:00pm	C	6:30pm	C
7:00pm	C	7:30pm	C	8:00pm	C
8:30pm	C	9:00pm	C	9:30pm	C

Table 3.4. Traffic State at Bhandup on Dec 1, 2010

Seven hours manual ground truth collection on Dec1, 2010

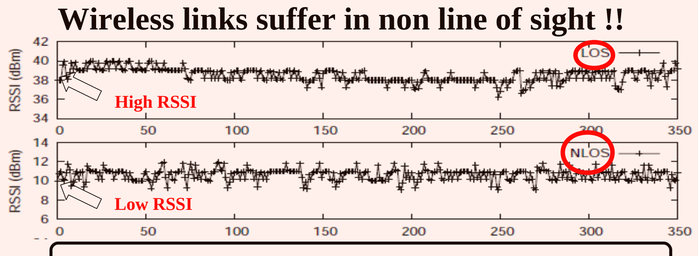
Observations

- Six days deployment at Bhandup, Dec1 – Dec3, Dec6 – Dec8, 2010
- Power optimization possible by duty cycling prototype at non-peak hours
- Time series analysis of per minute data necessary to reject outliers
- Time series analysis of per minute data suitable for detecting slow traffic intermediate between free-flowing and congested or vice versa.

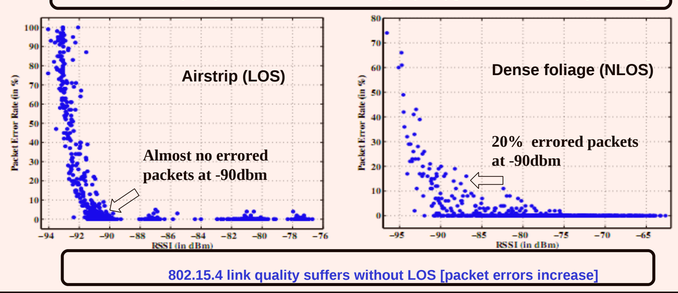
Horn-Ok-Please + RoadSoundSense

WirelessAcrossRoad

Wireless links suffer in non line of sight !!

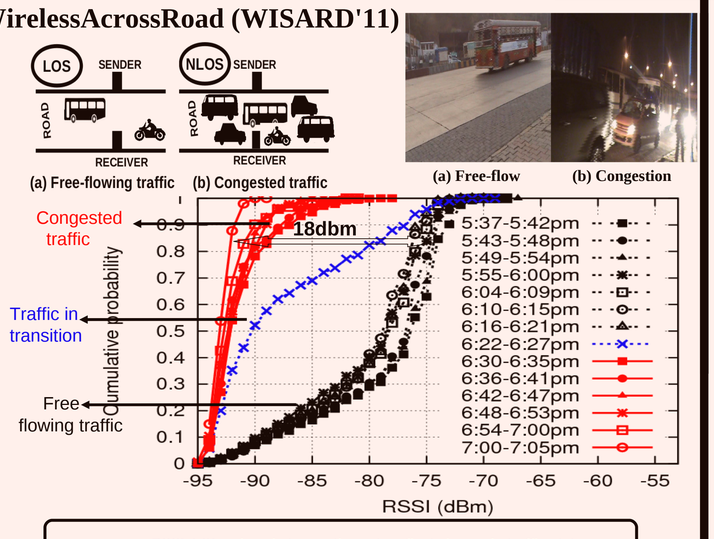


802.11b link quality suffers without line of sight (LOS) [Decrease in RSSI by 25 dbm]



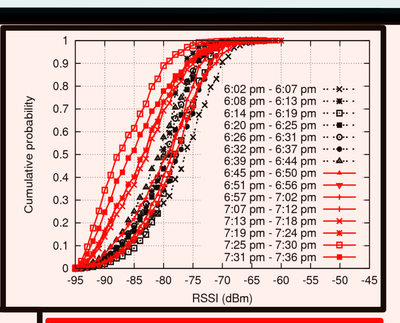
802.15.4 link quality suffers without LOS [packet errors increase]

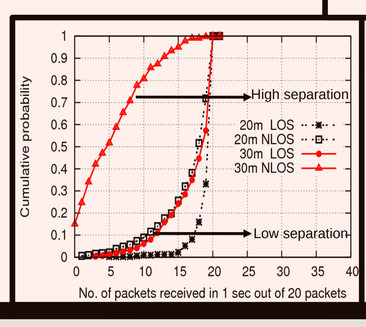
WirelessAcrossRoad (WISARD'11)



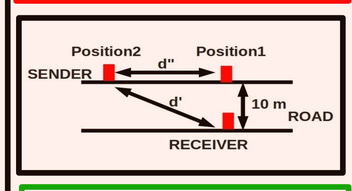
RSSI, LQI and packet reception rate reflect change in traffic state.

Technique on narrow road



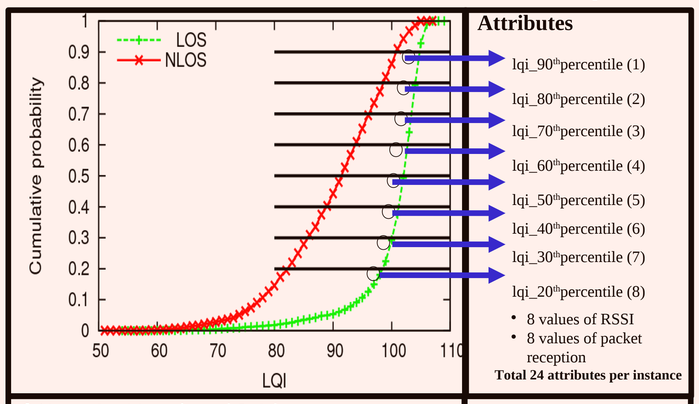


No separation between LOS and NLOS



Alternative mote positioning solves the issue

Decision-Tree Based Classification

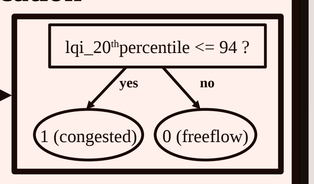


- 1 instance in training set from each 5 min log
- **24 attributes** per instance
- 1 **class label** per instance -> 0 (free-flow), 1 (congestion)
- Class label assigned based on **manual observation**

WEKA open source package for machine learning tools

Decision-Tree Based Classification

- **9 hours 20 mins** data for narrow road -> 112 logs of 5 mins each
- **112 instances** with attributes and class label
- **Randomly order** instances, input to WEKA first **102 as training** data and last **10 as test** data, a decision tree model output by WEKA
- Repeat procedure **50 times**



Results

# of train_test cases	Decision tree model	Average accuracy (s.d)	# of false positives	# of false negatives
34	lqi_20thpercentile <= 94 : 1	97.64% (4.96)	7	1
8	rssi_20thpercentile <= -91 dBm : 1	90% (0)	0	8
3	rssi_30thpercentile <= -89 dBm : 1	90% (0)	3	0
3	lqi_20thpercentile <= 93 : 1	90% (0)	0	3
2	rssi_40thpercentile <= -87 dBm : 1	90% (0)	2	0

Simple threshold based classifier
based on rule (lqi_20thpercentile <= 94 : 1) will *probably* suffice

Comparison with state of the art

	Dual loop detector	Magnetic sensing	Image sensing	GPS in public transport	Smartphones	Acoustic sensing	RF sensing
Handles non-laned traffic	no	no	yes	yes	yes	yes	yes
Cost (infrastructure/computation)	high	low	high	low	low	low	low
Disruption while installation/ maintenance	yes	yes	no	no	no	no	no
Needs commuters' participation	no	no	no	no	yes	yes	no
Commuters incur cost	no	no	no	no	yes	no	no
Commuters have privacy issues	no	no	no	no	yes	no	no
Proliferation in developing countries	low	low	low	low	moderate	–	–

Table 2.1. Comparison table of our techniques with state of the art in road sensing

Publications

- Rijurekha Sen, Vishal Sevani, Prashima Sharma, Zahir Koradia, Bhaskaran Raman, "Challenges In Communication Assisted Road Transportation Systems for Developing Regions", NSDR'09, a workshop in SOSP'09, Big Sky, Montana, USA, 11 Oct 2009.
- Rijurekha Sen, Bhaskaran Raman, Prashima Sharma, "Horn-Ok-Please", Mobisys'10, San Francisco, USA, Jun 15-18, 2010.
  Swaroop Roy, Rijurekha Sen, Swanand Kulkarni, Purushottam Kulkarni, Bhaskaran Raman, Lokendra Singh, "WirelessAcrossRoad: RF based Road Traffic Congestion Detection", WISARD'11, a workshop in Comsnets'11, Bangalore, India, Jan 4-5, 2011.
- [**under submission**] Rijurekha Sen, Pankaj Siriah, Bhaskaran Raman, "RoadSoundSense: Acoustic Sensing Based Road Congestion Monitoring in Developing Regions", SECON'11, Salt Lake City, Utah, USA between June 27-30, 2011.

Conclusion