A Lightweight Framework for Meeting Group Identification Using Smartphones

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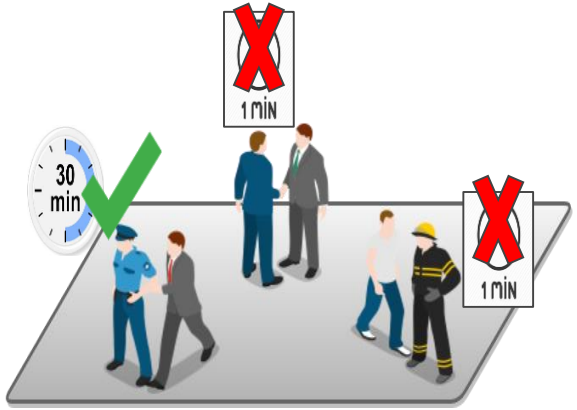
1. *Snigdha Das*, Soumyajit Chatterjee, Sandip Chakraborty, Bivas Mitra, “GroupSense: A Lightweight Framework for Group Identification using Smartphones," IEEE Transaction on Mobile Computing.
2. *Snigdha Das*, Soumyajit Chatterjee, Sandip Chakraborty, Bivas Mitra, “An Unsupervised Model for Detecting Passively Encountering Groups from WiFi Signals," in Proceedings of IEEE GlobeCom, Abu Dhabi, UAE, Dec 9-13, 2018.

What is a Meeting Group?

Colocation

Context



Colocation Time

Motivation

- Understanding the **user behaviour**, studying group is essential[JLMB15]
- **Team formation** among the **individuals** are the key factors behind **organizational efficiency**
- **Performance** of students in institution impacted by the groups
- Pre-defined vs instantaneous groups

[JLMB15] Kasthuri Jayarajah, Youngki Lee, Archan Misra, and Rajesh Krishna Balan. "Need accurate user behaviour?pay attention to groups!" In Proceedings of the ACM conference on Pervasive and Ubiquitous Computing, pages 855{866, 2015.

Challenges in Meeting group detection

Colocation

- Conceptualized as **localization** problem
  - Retrieving **highly precise location** information is challenging

- For **informal group** capture, deployment of **fixed infrastructure** is an **overhead**
- Capturing the **indoor** scenario with the only **GPS** is a challenging due to the **low coverage**
- **Pre-trained** information almost unavailable for **instantaneous** group members

Objective

- Developing a Framework for Group Identification using Smartphones
- Lightweight
- Unsupervised—able to detect instantaneous groups

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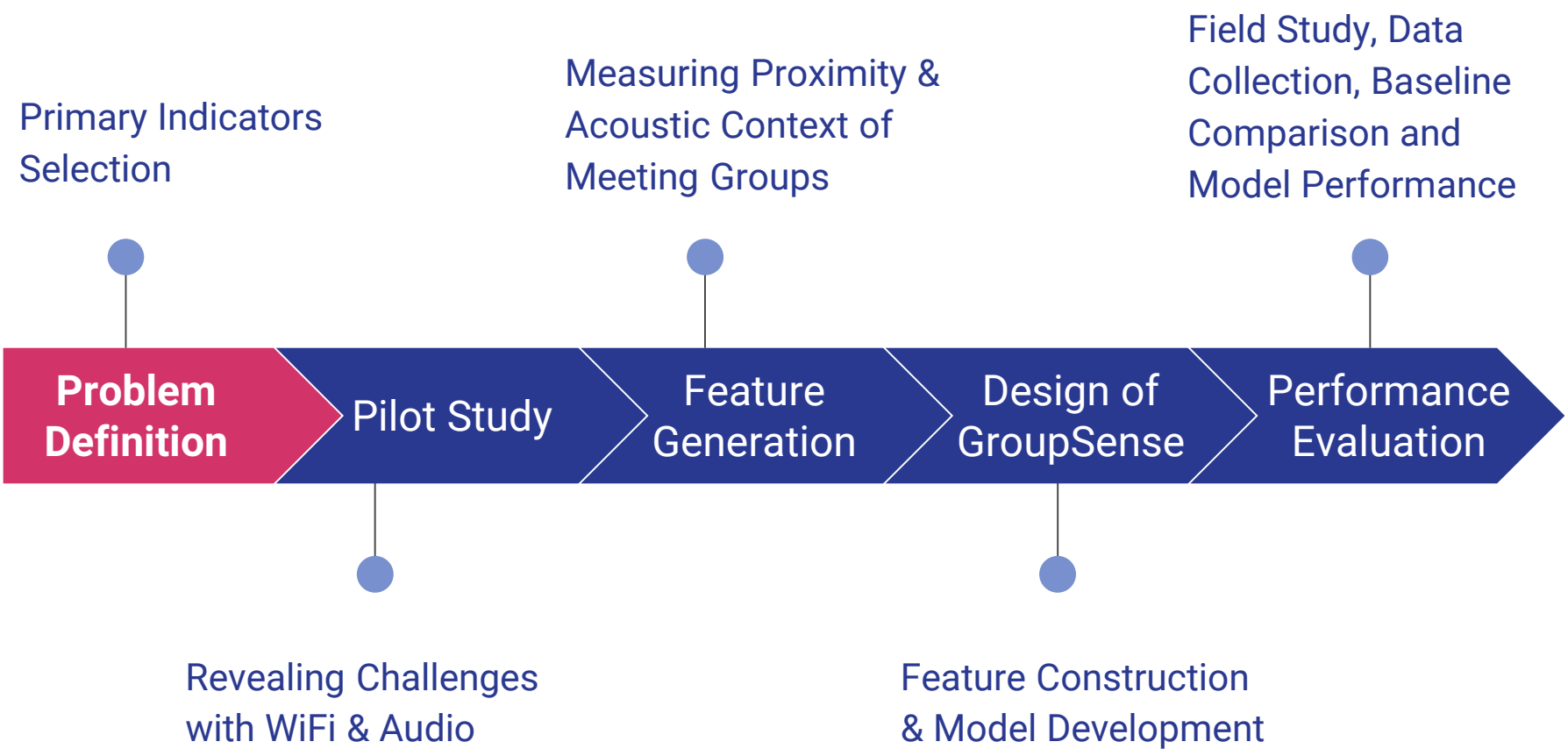
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Measuring Proximity & Acoustic Context of Meeting Groups
Field Study, Data Collection, Baseline Comparison and Model Performance
Problem Definition
Pilot Study
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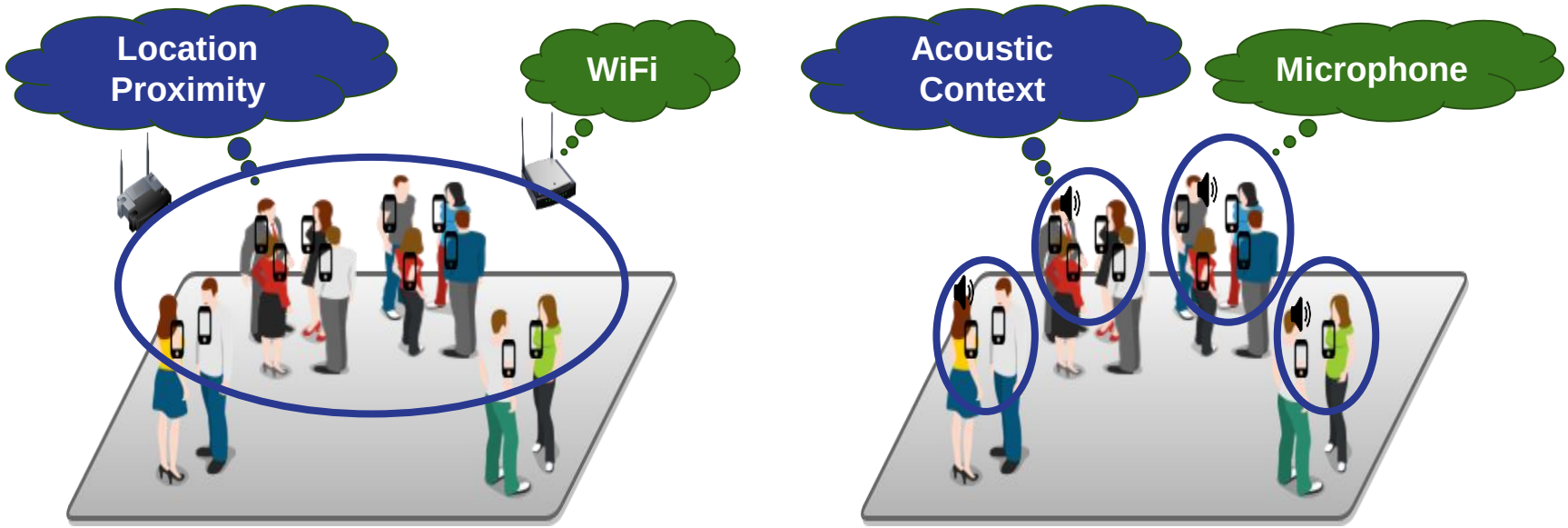
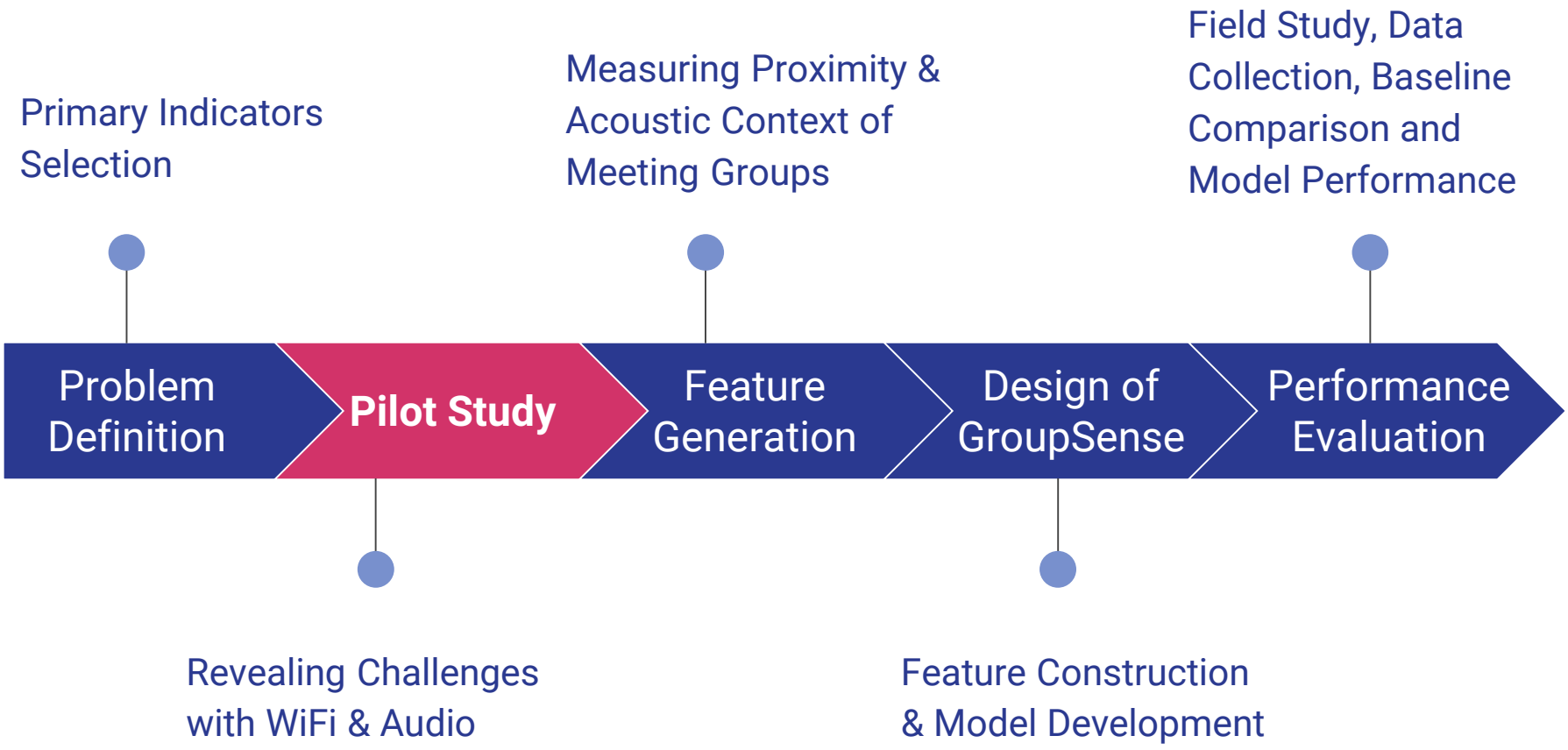
Meeting Group: Primary Indicators Selection

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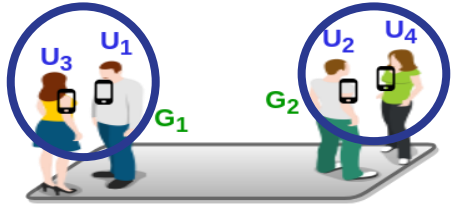
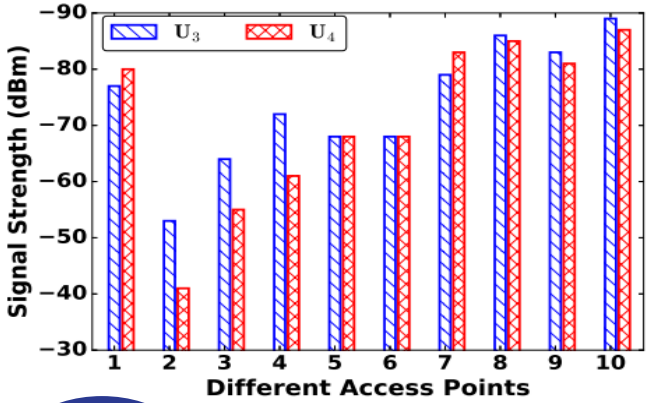
Pilot Study: Setup

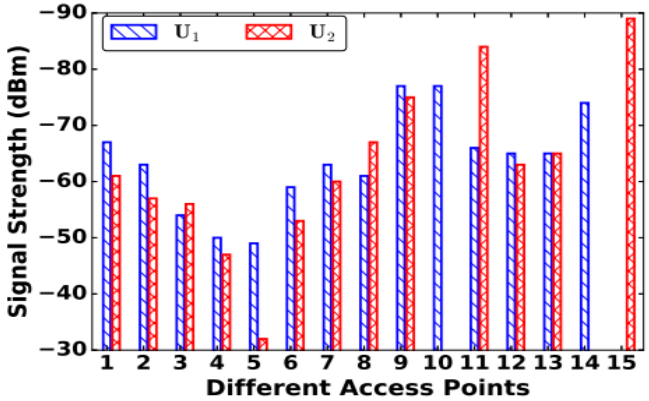
# of participants	6
Study duration	2 weeks
Sensor used	WiFi and Microphone
Devices used	2 Moto X, 1 Moto G 2nd Gen, 2 OnePlus3, 1 Samsung Note5
Group Duration	> 15 minute

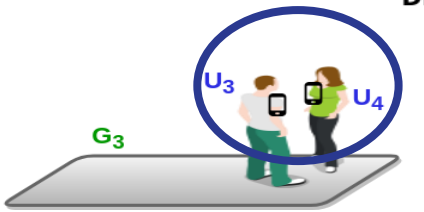
Group ID	Member IDs	Location	Primary Speaker
G_1	U_1,U_3,U_4	SMR Lab	U_4
G_2	U_2,U_5,U_6	Class C-118	U_2
G_3	U_1,U_2,U_3,U_4	Cafeteria	U_3
G_4	U_2,U_5	SMR Lab	U_5
G_5	U_1,U_2,U_3,U_4	Way to Cafeteria	U_4
G_6	U_1,U_2,U_3	Outdoor Roadside	U_1
G_7	U_4,U_5,U_6	Outdoor Roadside	U_4

WiFi as Proximity Indicator



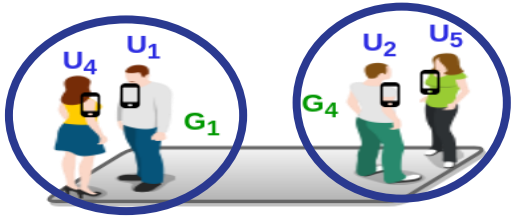


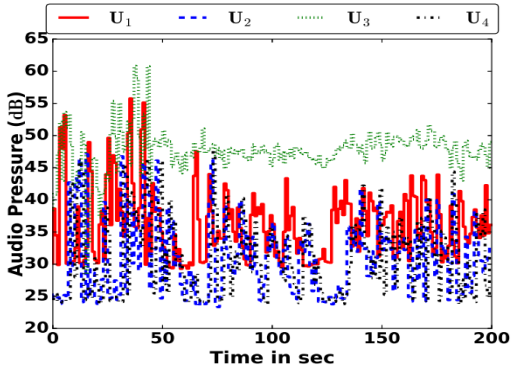


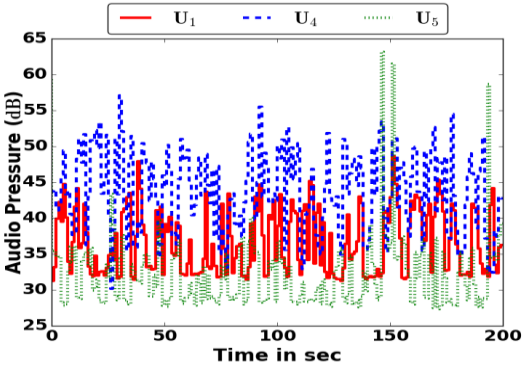


WiFi Similarity & Dissimilarity in **Same & Different Group**

Microphone as Context Indicator

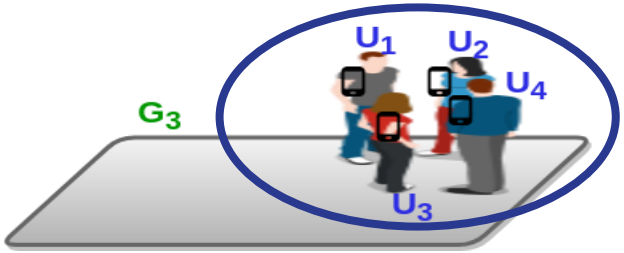






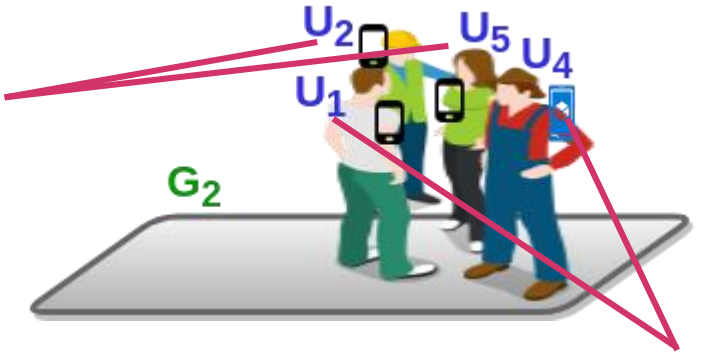
U4 and U1 exhibit similarity

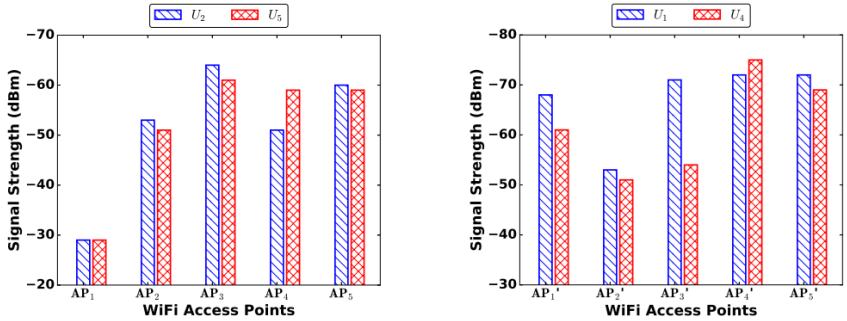
No clear discrimination between U1 and U5



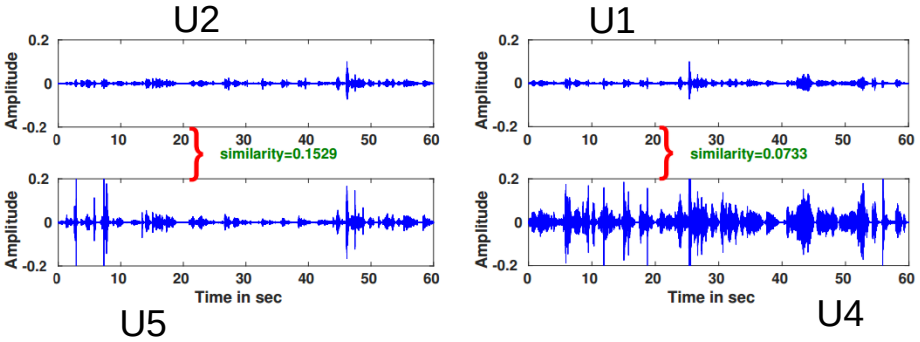
Audio Similarity & Dissimilarity in **Same & Different Group**

Device Heterogeneity





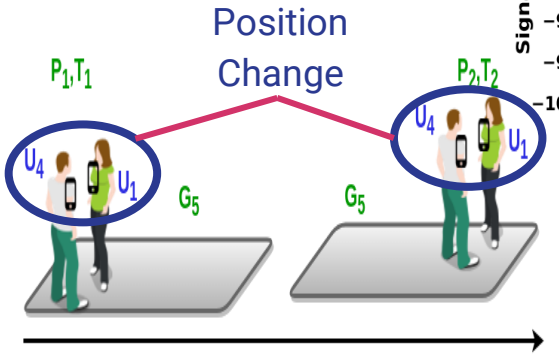
WiFi Similarity & Dissimilarity
in **Same & Different Build**

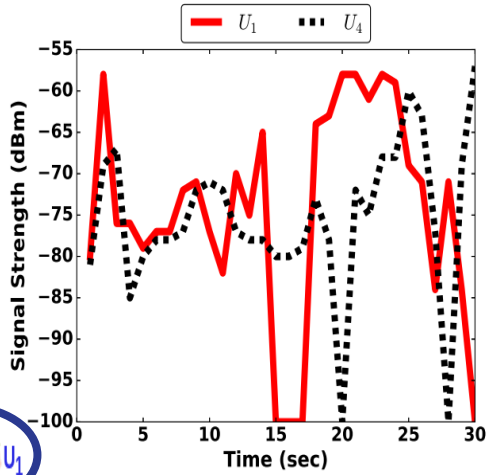


Audio Similarity & Dissimilarity
in **Same & Different Build**

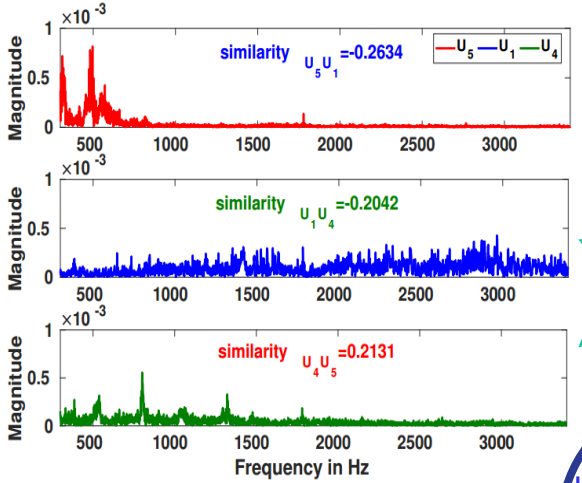
User Mobility & Environmental Noise

Clear discrimination between U1 and U5



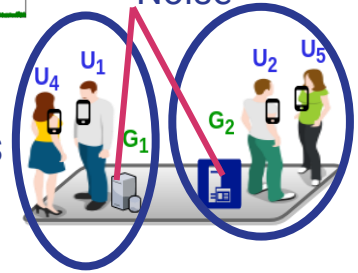


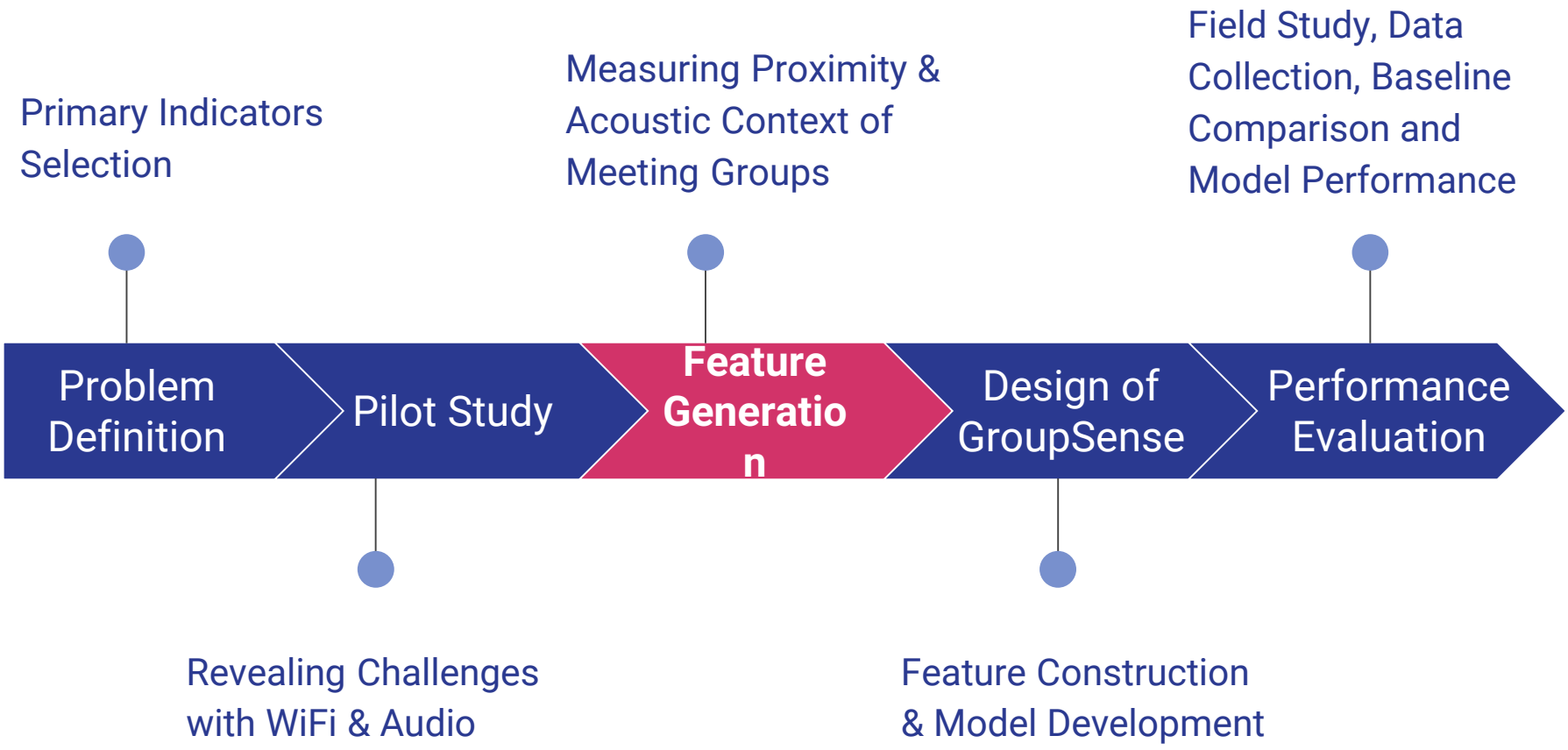
Effect of **Mobility** on WiFi RSSI



Deviations of Frequencies in Presence of **Noise**

Environmental Noise

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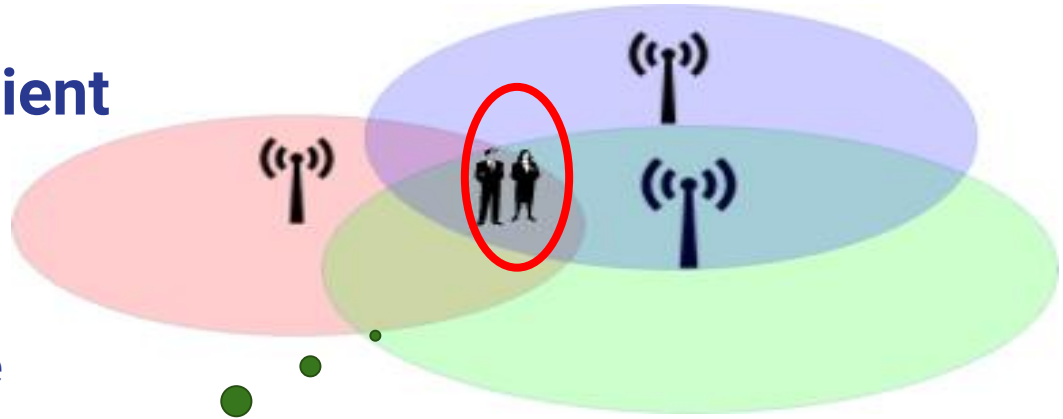
Measuring Proximity

➢ **Overlapping WiFi APs**
using **Jaccard Coefficient**

$$\mathcal{J}_{ij}^{t} = \frac{|\mathbb{B}_i^t \cap \mathbb{B}_j^t|}{|\mathbb{B}_i^t \cup \mathbb{B}_j^t|}$$

$$\mathbb{B}_i^t = \{\mathcal{B}_{i_1}^t, \mathcal{B}_{i_2}^t, \ldots, \mathcal{B}_{i_m}^t\}$$

vector of WiFi APs scanned by the subject u_i at time t



Higher coefficient index implies nearby subjects

Measuring Proximity

- **Overlapping WiFi APs** using **Jaccard Coefficient**

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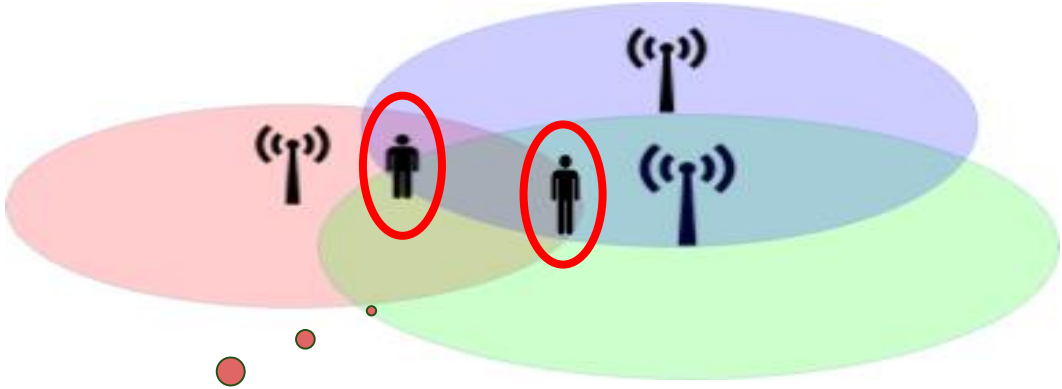


Overlooks the signal strength

Measuring Proximity

➢ WiFi **Signal Strength**

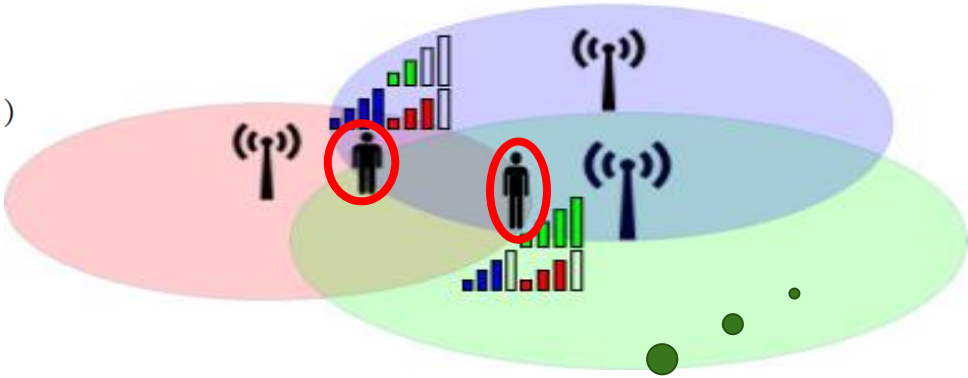
Gain factor

$$g_{ij}^t = \frac{1}{|\mathbb{I}_{ij}^t|} \sum_{(\mathcal{SS}_{i_k}^t, \mathcal{SS}_{j_k}^t) \in \mathbb{I}_{ij}^t} ((\mathcal{SS}_{i_k}^t - \mathcal{SS}_{i_1}^t) - (\mathcal{SS}_{j_k}^t - \mathcal{SS}_{j_1}^t))$$

$$\mathbb{SS}_i^t = \{\mathcal{SS}_{i_1}^t, \mathcal{SS}_{i_2}^t, \ldots, \mathcal{SS}_{i_m}^t\}$$

vector of signal strength of WiFi APs scanned by the subject u_i at time t

$\mathbb{I}_{ij}^t$: set of **overlapping APs** scanned by the subjects u_i, u_j



Device independent feature

Measuring Proximity

➢ **Proximity** Feature

$$\mathcal{F}_{ij}^{t} = \frac{\mathcal{J}_{ij}^{t}}{g_{ij}^{t}}$$

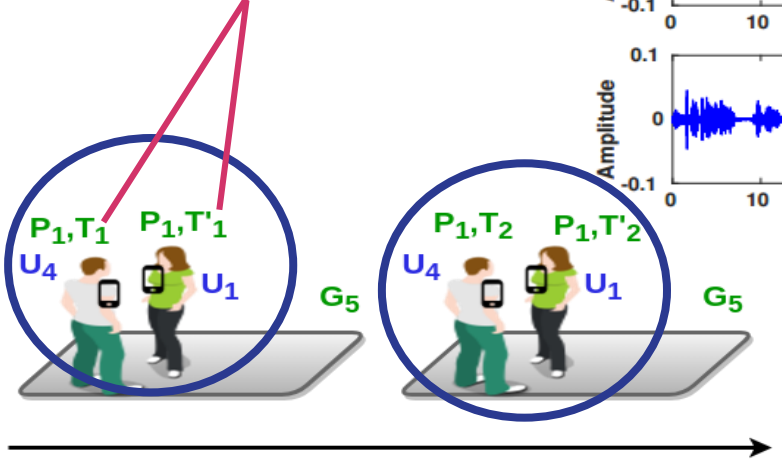
➔ ***Jaccard similarity*** improves with the higher degree of shared APs

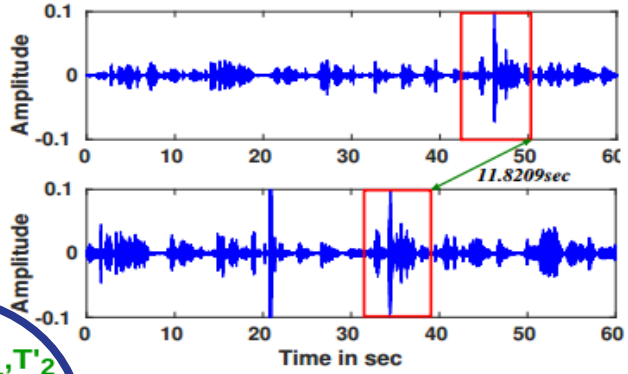
➔ ***Gain factor*** reduces with the proximity of the subjects

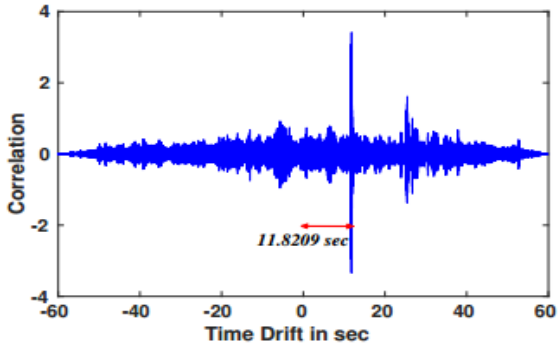
Measuring Acoustic Context

➢ **Time Drift** Adjustment

Time difference $|T_1-T'_1|$



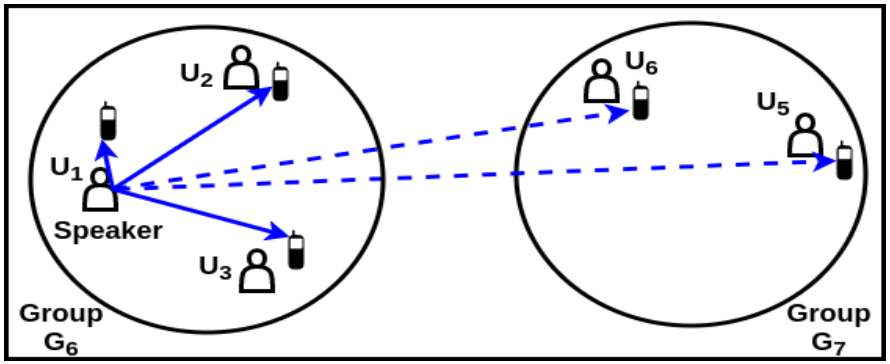


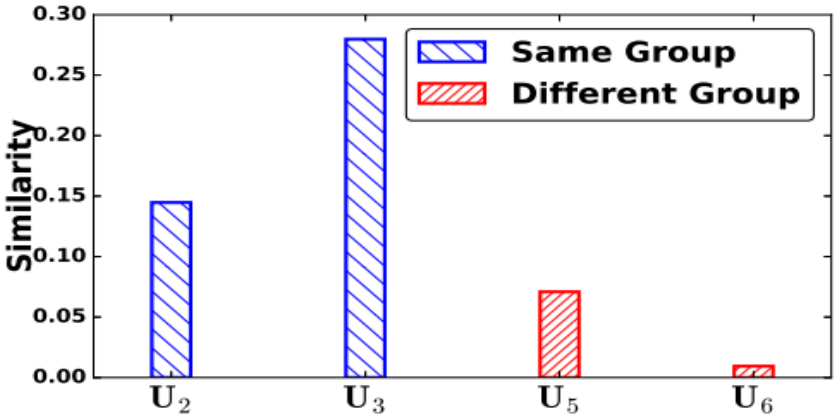


Measuring Acoustic Context

➢ Audio **Tone** Extraction (complex cepstrum)

$$\mathrm{CCEP}(\mathcal{S}) = \mathrm{IFT}(\log(\mathrm{FT}(\mathcal{S})) + j2\pi\ell)$$

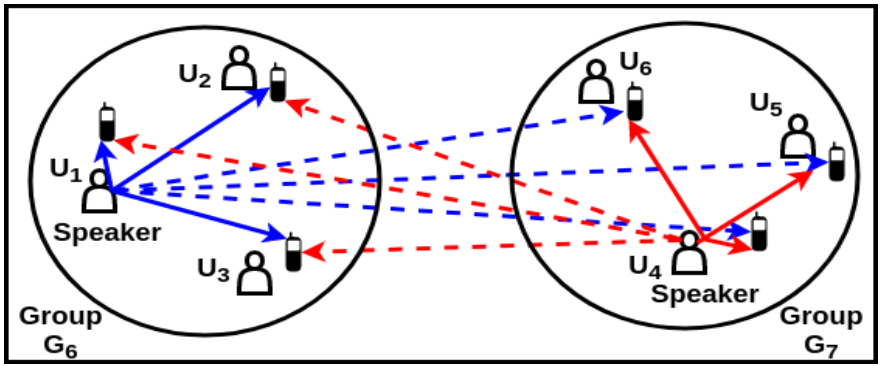


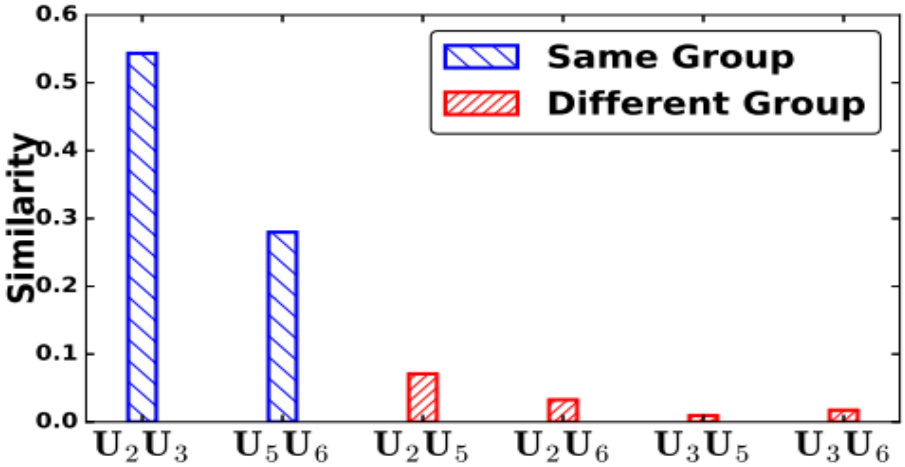


Single Speaker Multiple Groups Scenario Similarity with Speaker U_1

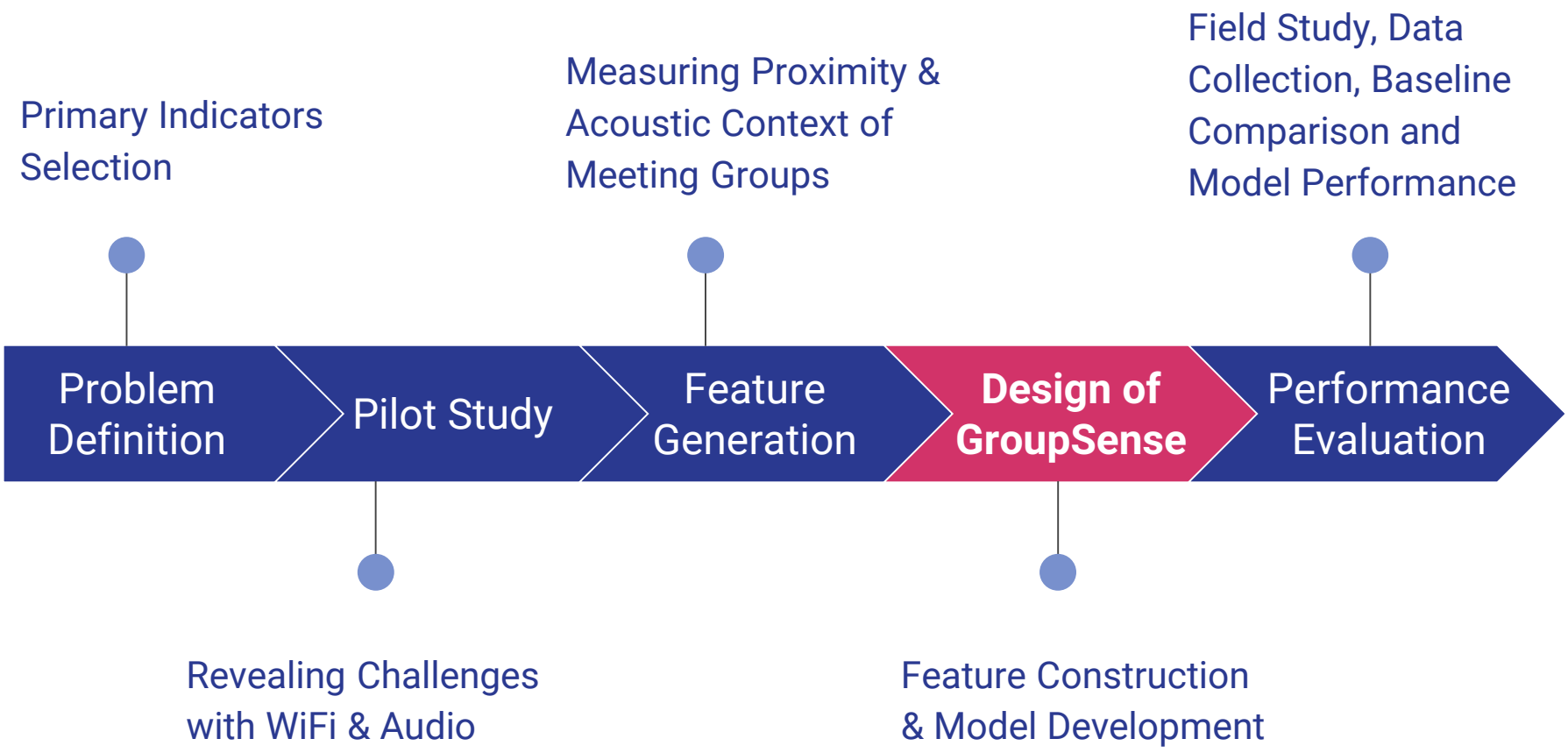
Measuring Acoustic Context

➢ Audio **Tone** Extraction





Multiple Speaker Multiple Groups Scenario Similarity among non-Speaker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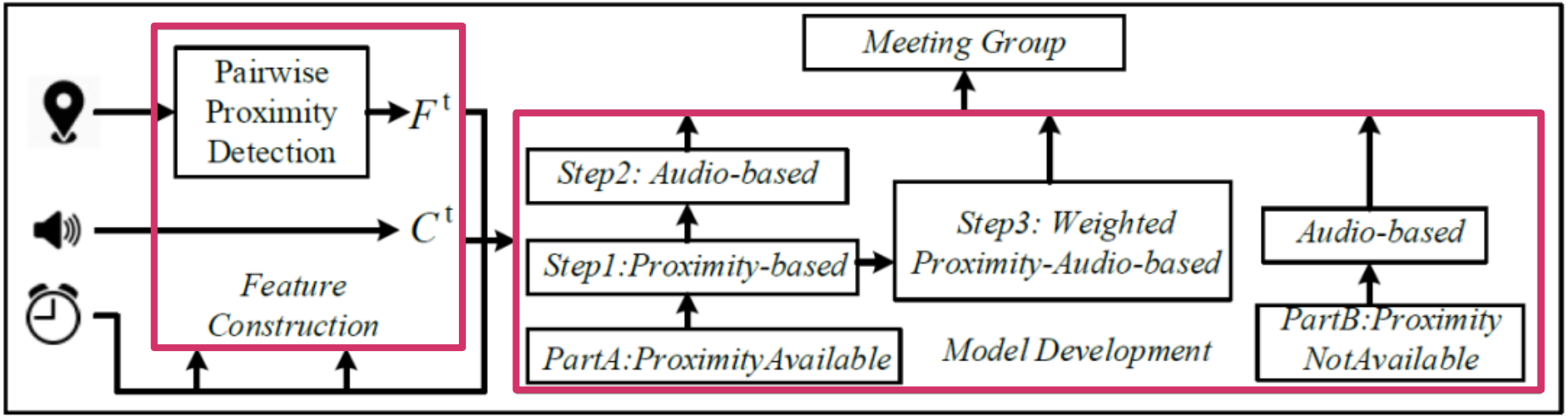
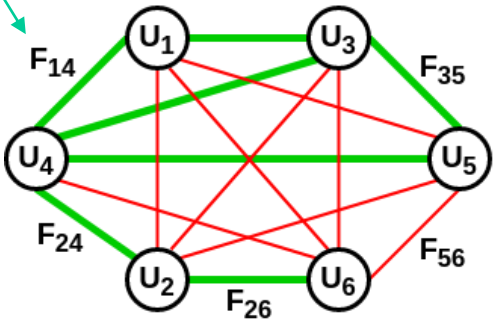
Design of GroupSense Model



$\mathcal{F}^t$: Proximity Feature, $\mathcal{C}^t$: Acoustic Context Feature

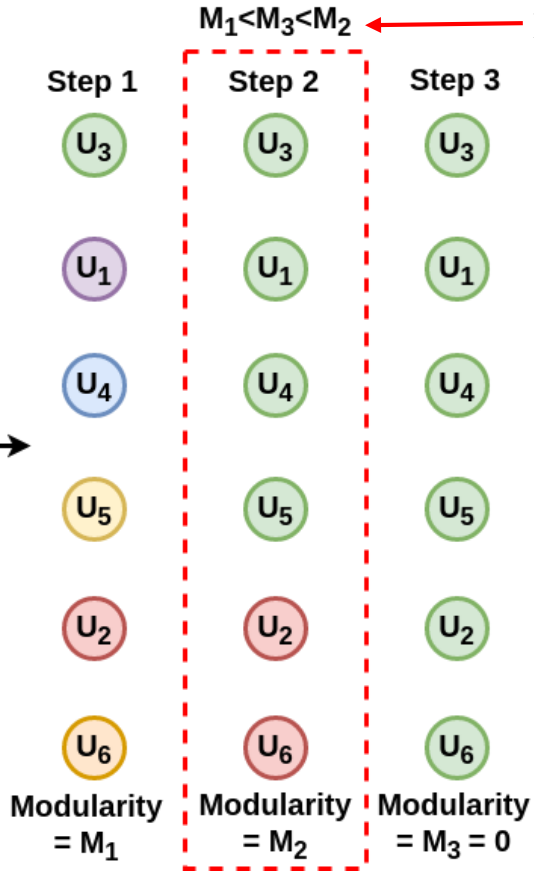
Community Detection

Proximity, acoustic context features



Community Detection

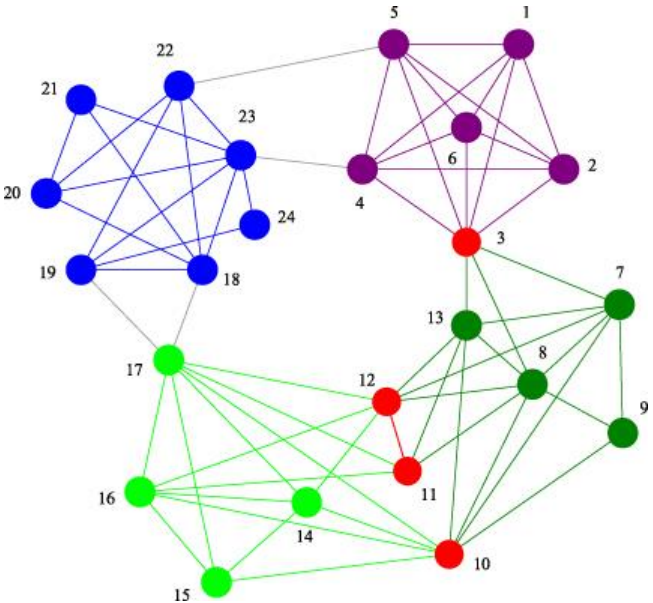
(WalkTrap)

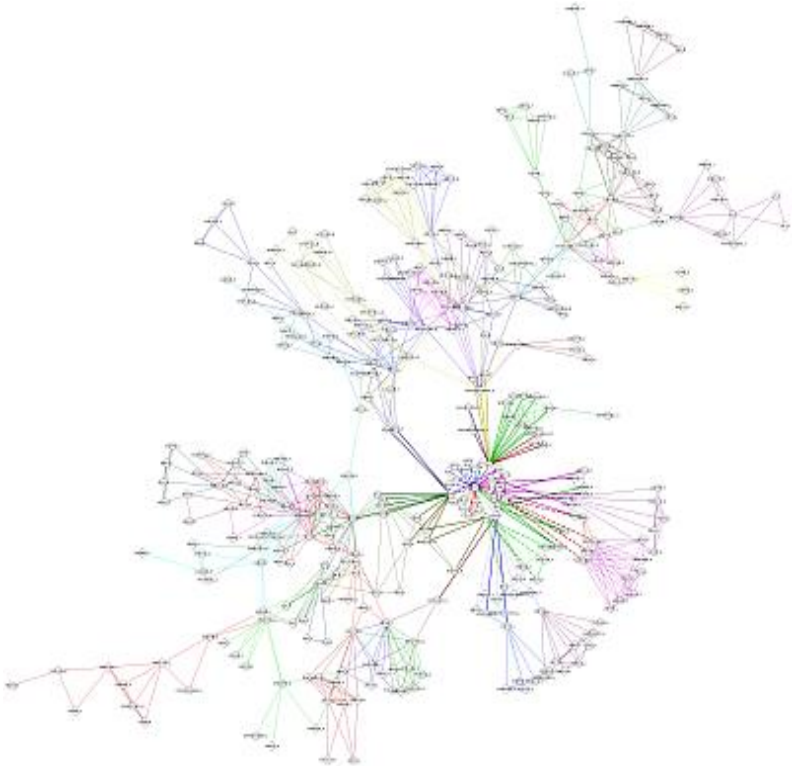


Modularity (Quality of communities)

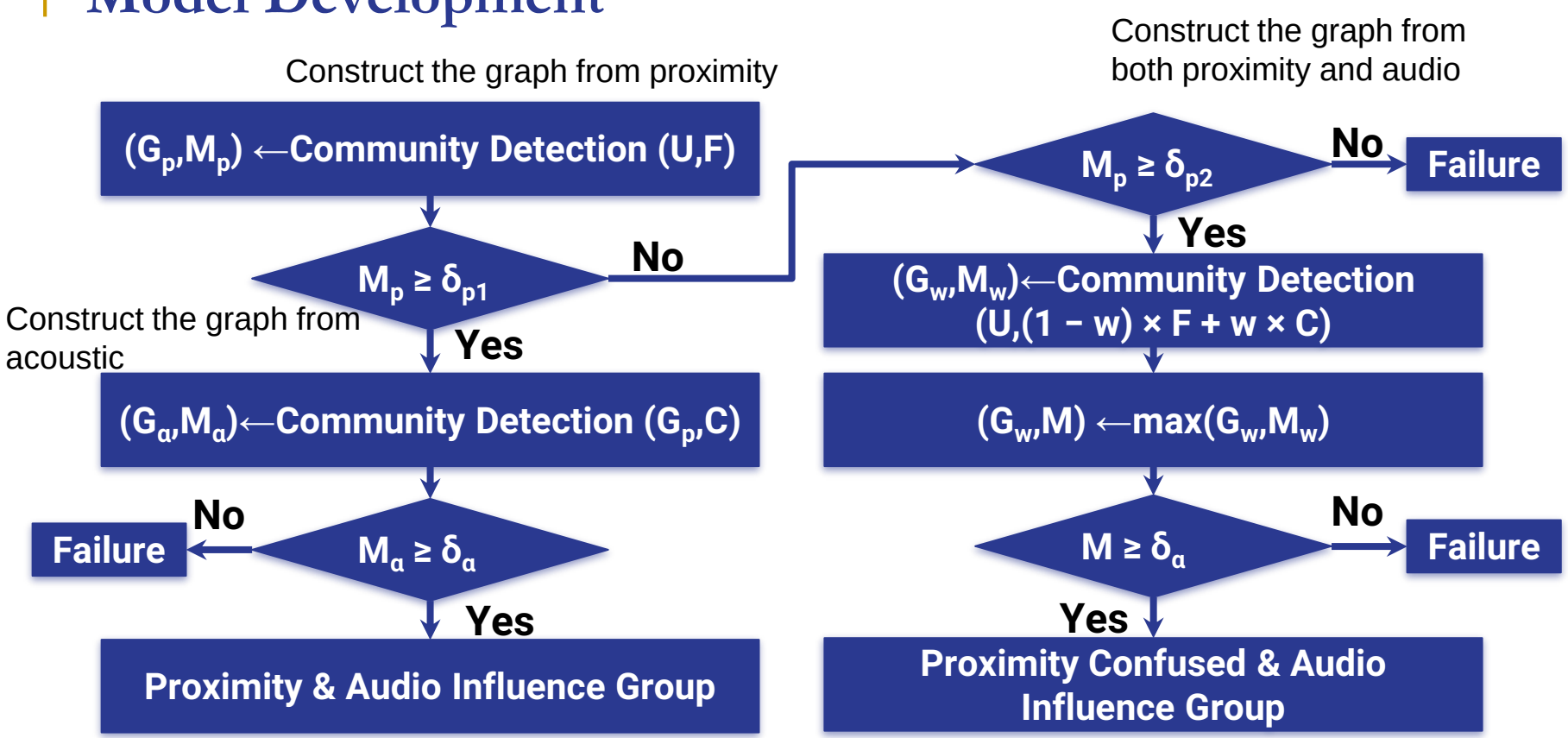
$$\mathcal{M} = \frac{1}{4\varphi}\sum_{ij}\left(w_{ij}^{e} - \frac{\rho_i \rho_j}{2\varphi}\right) f(\sigma_i, \sigma_j)$$

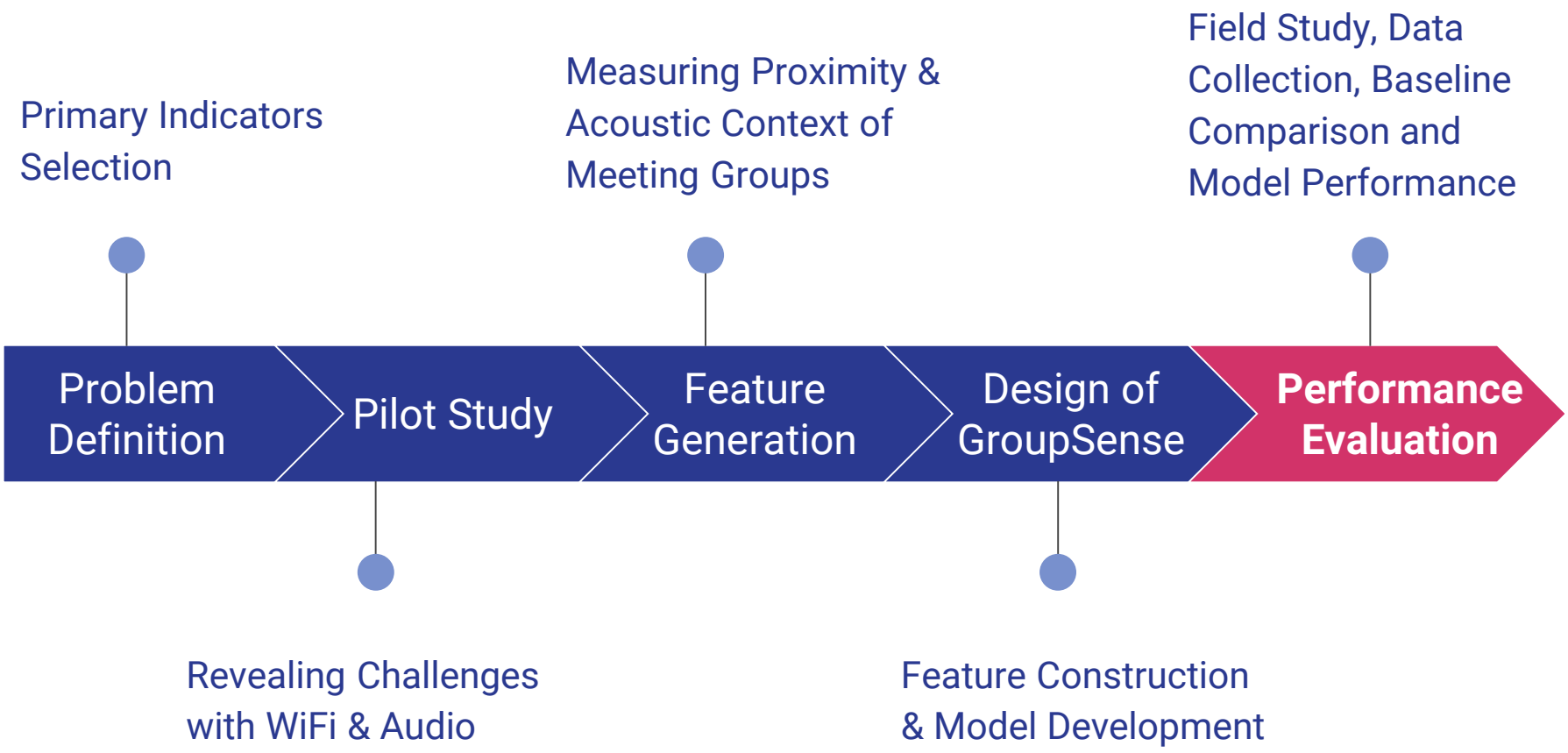
Community Detection





Model Development

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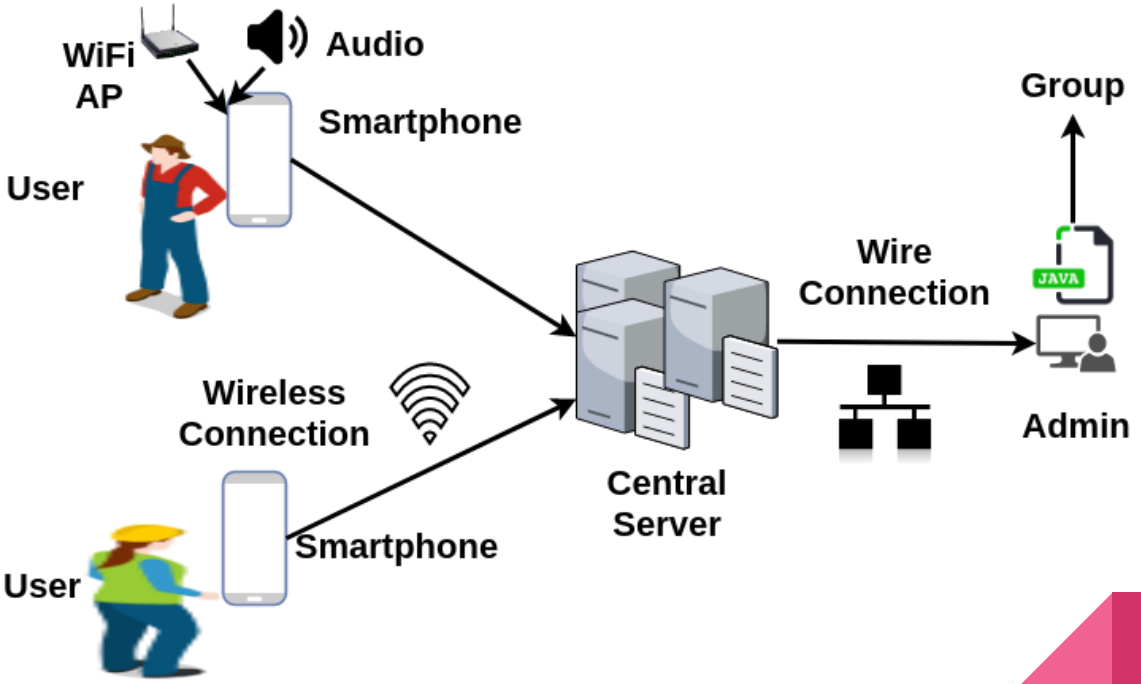
Data Collection Framework



Data Collection

Smartphone Android App

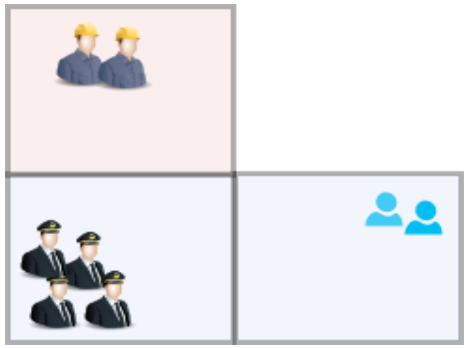
# of participants	40
Study duration	6 months
Sensor used	WiFi, Microphone, Accelerometer
Devices used	Samsung, OnePlus3, MotoX, MotoG, Hexiwear
Group Duration	> 10 minute

Ground Truth Data Collection App

Start time of a meeting
End time of a meeting
Meeting venue
Details of other participants of meeting

Performance Evaluation: Scenarios

S1 (Indoor: Two groups at neighboring rooms)



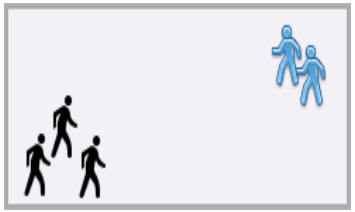
S2 (Indoor: Three groups at different rooms at the same department)

S3 (Outdoor: Cafeteria meetings)

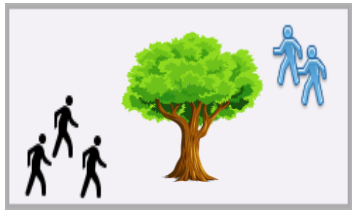
Performance Evaluation: Scenarios

S4 (Indoor: Large single group)

S5 (Indoor: Two different groups at a large lab)



S6 (Indoor: Two roaming groups)



S7 (Outdoor: Two roaming groups)

Baselines

- Next2Me[BE17]
  - **Sensor used:** WiFi, Microphone
  - **Features:** Manhattan distance of RSSI, audio frequency
  - **Method used:** Thresholding, Jaccard Similarity
- AudioMatch[CSC15]
  - **Sensor used:** GPS, Microphone
  - **Features:** location, STFT
  - **Method used:** DBScan, Hamming Distance

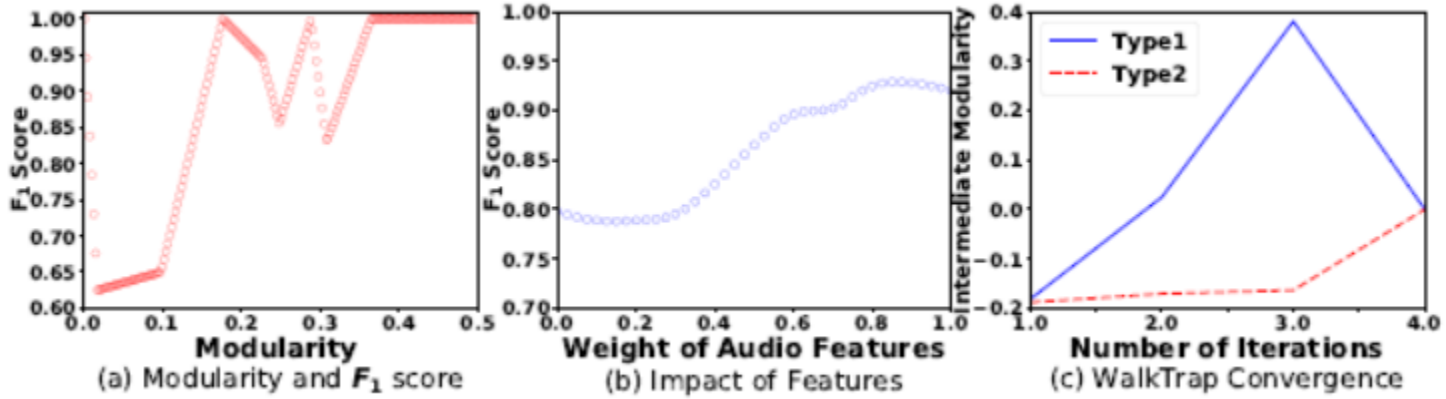
[BE17] Jon Baker and Christos Efstratiou. “Next2me: Capturing social interactions through smartphone devices using wifi and audio signals”. In EAI International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services (MobiQuitous), November 2017.
[CSC15] Paolo Casagranda, Maria Luisa Sapino, and K Selcuk Candan. “Audio assisted group detection using smartphones”. In Proceedings of IEEE Conference on Multimedia & Expo Workshops, pages 1–6, 2015.

System Performance

ID	Next2Me		GroupSense		AudioMatch	
	F_1Score	Modularity	F_1Score	Modularity	F_1Score	Modularity
S1	1.0000	0.1124	1.0000	0.2879	0.7273	0.0000
S2	0.9000	0.2030	1.0000	0.1760	0.6667	0.0000
S3	0.5333	0.1261	1.0000	0.3642	0.7273	0.0000
S4	0.8326	0.0772	1.0000	0.0000	1.0000	0.0000
S5	0.8571	0.0732	1.0000	0.3801	0.7273	0.0000
S6	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
S7	0.5833	0.1942	0.6500	0.0976	0.8333	0.0000
ALL	0.7971 (+0.1874)	0.0866	**0.9421 (+0.1323)**	**0.2114**	0.8212 (+0.1377)	0.0000

On an average **F_1-Score** is more than **90%** for GroupSense

System insights



F1-Score converges to 1.0 when the modularity is more than 0:35.

Hence a group is detected with high accuracy when the cohesiveness is also high.

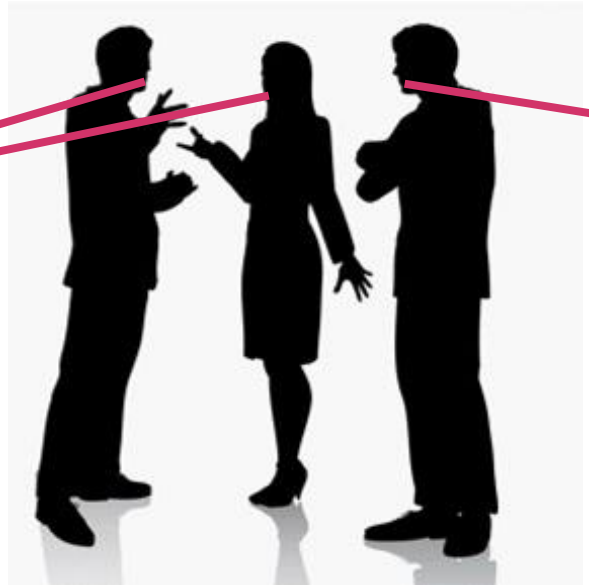
We plot F1-Score with respect to the weight (w) of the audio feature.

Indicating that both the features are important for correct detection of meeting groups

Summary

- Developed **GroupSense**, a smartphone based methodology to infer various **meeting groups**
- Developed a novel **unsupervised methodology** to process the context information for inferring the groups
- **Device independence** and **lightweight** computable system

What is Group Role?



Active Members

Passive Member

Motivation

- Members are **not equally participated** in group
- Group **participation information** important for **analysing the group** as well as **group members**
- **Individual members' role** infers the **importance** of the **group** formation


Thank You