Transfer Learning Based Diagnosis for Configuration Troubleshooting in Self-Organizing Femtocell Networks

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Outline

1. Motivations
   - Backgrounds & Problem
   - Existing Work

2. Transfer Learning Based Diagnosis
   - Framework Overview
   - Cell-Aware Transfer Scheme

3. Evaluations
   - Simulation Setup
   - Simulation Results

4. Conclusions
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4 Conclusions
Many operators have launched femtocell service for ubiquitous indoor coverage.

- In late March 2010, AT&T announced nationwide roll-out of its 3G Femtocell (named as MicroCell).
- Both Sprint and Verizon upgraded to 3G CDMA femtocells during 2010.
Emerging Femtocell Technology

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Importance of cellular service

- High-reliability and high-quality cellular network services are expected.

However, unlike the operator-deployed macrocell networks, femtocells are...

- User-deployed, not well-planned
- Self-configuration
- Much more Access Points (FAP)

Misconfigurations!
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Existing Diagnostic Systems in Cellular

- Classification methods: Bayesian Network (BN)
  - BN based diagnosis cannot cope with data scarcity problem in femtocell

  **Data scarcity: Lack of user statistics**
  - 1 femto AP only support 1-4 active users

  **Data scarcity: Historical data easily outdated**
  - Re-deployment, turned on/off by users

  Accuracy of BN cannot be guaranteed without enough data
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Transfer Learning can transfer knowledge from other domains with

- Knowledge latent
- Common structure

**Question**

How to leverage Transfer Learning in femtocell diagnosis?
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How to leverage Transfer Learning in femtocell diagnosis?
## Transfer Learning in Femtocell

### Transfer Learning
- **Target task**
- **Target data**
- **Source tasks**
- **Source data**
- **Common structure**

### Femtocell Diagnosis
- **Target femtocell diagnosis**
- **Target femto user statistics & configurations**
- **Other femtocell diagnosis**
- **Other femto user statistics & configurations**
- **Same network type: femtocell networks**
## Transfer Learning in Femtocell

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Transfer Learning Based Diagnosis Framework

Traditional Approach

Data $D_1$ from target femtocell

Classifier $C_1$

Diagnosis model

Based on results

Weight the femtocell data

Transfer Learning Approach

Data $D_2$ from other femtocells

Classifier $C_2$

Use $C_2$ to predict $D_1$;
Use $C_2$ to predict $D_1$
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Diagnosis Model Training

- **TrAdaBoost algorithm**¹
  - Compute transfer weight based on error penalty.
  - Compute error based on misclassification rate using transferred data.

Is TraAdaBoost perfect for our case?

To design a scheme more suitable to femtocell diagnosis, we have three observations.

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Design Observation 1

**Misclassification cost**

Different misclassifications have different degrees of impact on the diagnosis model.

- Misclassification within interference problems (e.g. strong TX power and wrong channel)
  - ⇒ similar tuning method
- Misclassification between interference problem & coverage gap problem (e.g. strong TX power and weak TX power)
  - ⇒ completely wrong!
Design Observation 1

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  - $\Rightarrow$ completely wrong!
Assumption of classification-based diagnosis is that different faults correspond to different symptoms.

- Symptoms in femtocell: Distributions of user statistics/femto configurations
- Quantification of symptom differences: Differences between two distributions

Kullback-Leibler (K-L) divergence

\[
\text{Div}(P^F_1, P^F_2) = \sum_i P^F_1(i) \log \frac{P^F_1(i)}{P^F_2(i)} + \sum_i P^F_2(i) \log \frac{P^F_2(i)}{P^F_1(i)} \quad (1)
\]
Misclassification Cost

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Different importance of different kinds of data (e.g. RSS, power configuration)

Divergences of different data should be weighted.

**Information gain**

\[
Gain(A_i) = H(I) - H(I|A_i) \tag{2}
\]
Different importance of different kinds of data (e.g. RSS, power configuration)
- Divergences of different data should be weighted.

Information gain

\[ Gain(A_i) = H(I) - H(I|A_i) \] (2)
Misclassification Cost (cont.)

Sum up the weighted divergences of data in two classes.

\[
\text{Cost}_{F_1,F_2} = \sum_i \text{Gain}(A_i) \times \text{Div}(A_i^{F_1}, A_i^{F_2})
\]  

- Misclassification cost is used as penalty for misclassification in the training process.
Design Observation 2

Femtocell dissimilarity

- The characteristics of femtocells can be very different.
- Data from different femtocell should be distinguished.

- Some femtocells have similar indoor propagation properties and similar neighboring layouts.
- Some femtocells have very different wireless environments.

Transfer learning should be cell-aware!
Design Observation 2

**Femtocell dissimilarity**

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Femtocell Dissimilarity

Femtocell dissimilarity

Sum up the weighted divergences of data in two femtocells.

\[ D_{f_1,f_2} = \sum_i Gain(A_i) \times Div(A_{f_1}^i, A_{f_2}^i) \] (4)

- Dissimilarity is used to weight each femtocell.
Design Observation 3

For newly-deployed femtocell or reconfigured femtocell

- Misconfiguration instances in the target cell can be very rare.
- Computations of misclassification cost and femtocell dissimilarity may not be reliable.

- Use the information that lies in large number of measurement data in normal situations.
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Simulation Setup

- Femto APs are randomly distributed within 500 meters to the macro BS
- Propagation model: ITU and COST231 model
- Hard handover model
- Channel assignment: Greedily choose best SINR channel

Misconfigurations

- TX power too strong
- TX power too weak
- Wrong operating channel
- Handover Margin too large
- Handover Margin too small
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Motivations
Transfer Learning Based Diagnosis
Evaluations
Conclusions

Overall Accuracy

- **Basic SVM**
  - Support Vector Machine

- **TL-SVM**
  - directly apply TrAdaBoost

- **CAT**
  - Our Cell-Aware Transfer scheme

CDF of diagnosis accuracy for overall misconfigurations
Accuracies for Cases (cont.)

CDF of diagnosis accuracy for interference problems

CDF of diagnosis accuracy for coverage gap problems
Network Density Impacts

Diagnosis accuracy against femtocell density

![Graph showing diagnosis accuracy against femtocell density](image-url)
We propose a transfer learning framework for diagnosing femtocell configuration problems.

- Leverage transfer learning technology to address the data scarcity challenges

We design the Cell-Aware Transfer scheme.

- Misclassification cost
- Femtocell dissimilarity
- Leverage normal instances for newly-deployed femtocells