Operational Fault Detection in Cellular Wireless Base-Stations

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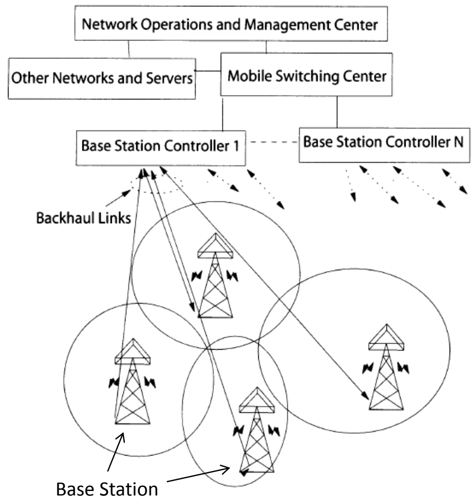
Motivation

- Improve reliability of cellular network
  - Build reliable systems
  - Detect and fix problems quickly
- Focus of paper: fault detection in base stations
- Base stations have fault management systems in place
  - Board Level Self Test
  - Software error handlers
  - Hardware alarms
  - Functional tests
- Universe of all possible faults is not known
  - Fault detector must be able to detect unknown faults

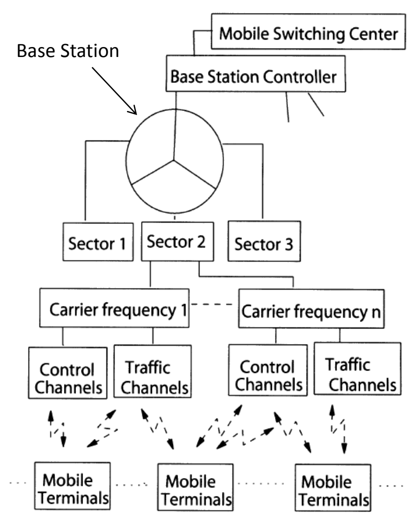
Background

- Base stations communicate with base station controller
- Base station controllers communicate with mobile switching center
- Two types of base stations
  - Macro-cell
  - Micro-cell



Background

- Base stations have 1-6 sectors
  - Most macro-cells have 3
- Each sector has one or more carrier frequency
- Each carrier frequency is composed of control channels and traffic channels



Methodology

- Faults defined as any hardware or software failure that would stop or significantly degrade call processing service of a part or entire base station
- Monitor call load activity
  - call = revenue
- Fault detector deployed at base stations
  - memory and computational constraints
- Cost of false alarms: unnecessary repairs
- Cost of missed faults: customer dissatisfaction
- Detect faults at three levels
  - Carrier level
  - Sector level
  - Base station level

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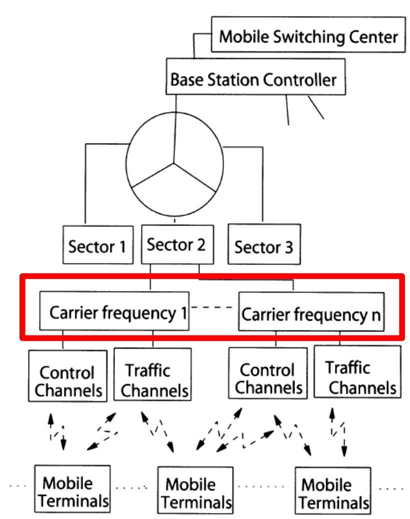
Carrier Level Detection

- Mobile accesses arrive randomly
  - Assignment of mobiles to carrier done using hash of user ID
- Divided into two cases
  - Uniform load
  - Non-uniform load



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Carrier Level Detection – Uniform Load

N = number of carriers in the sector
n_i = observed number of active users in the i^{th} carrier
$S = \sum_{i=1}^{N} n_i$ = total number of active users in the sector
$n_{lo} = \min\{n_i ; i=1,2,\ldots,N\}$

- Expected value of $n_i = S/N$ for all i
- Null hypothesis H_0: no fault
- Alternative hypothesis H_1: fault
- Perform chi-squared test

$$X^2 = \frac{(O-E)^2}{E} = \frac{(n_{lo}-S/N)^2}{S/N}$$

- Compute p-value from chi-squared statistics X^2

Carrier Level Detection – Non-Uniform Load

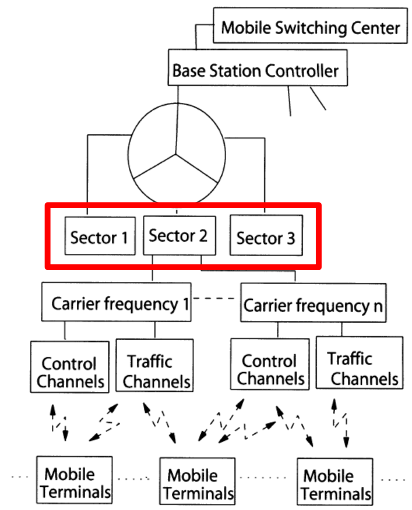
- Assumes expected distribution of n_i is known
  - $n_i^E = p_i \times S$

$$X^2 = \sum_{i=1}^{N} \frac{(O-E)^2}{E} = \sum_{i=1}^{N} \frac{(n_i-n_i^E)^2}{n_i^E}$$

- Only works when no more than one carrier is affected by the fault

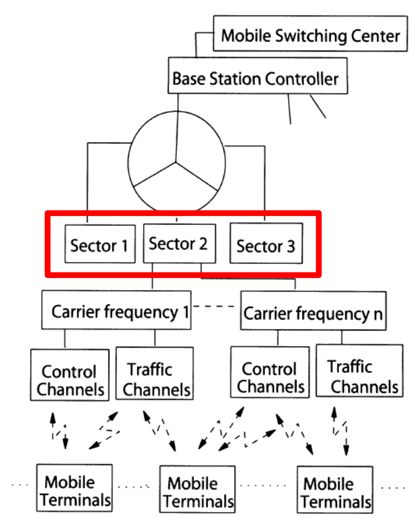
Sector Level Detection

- Applies to base stations with three or more sectors
- Since each sector faces different direction, their traffic load differs at different times of day
  - For a base station on highway, sectors facing the highway have different load profile from sectors facing away from the highway



Sector Level Detection

- Expected load distribution is not known a priori
  - Need to learn from data
- Need to keep memory and computational requirements very low



Sector Level Detection

M = number of sectors in the base station

p_i = proportion of active users in sector i

n_i = observed number of active users in the i^{th} sector

$S = \sum_i n_i$ = total number of active users in the base station

$n_{lo} = \min\{n_i\ ;\ i=1,2,\ldots,N\}$

- Learn $p_{i,min}$ during training phase of 2-3 weeks
- Null hypothesis H_0: $p_i \geq p_{i,min}$
- Alternative hypothesis H_1: $p_i < p_{i,min}$
- Compute the probability that the sector with lowest number of active users has $\leq n_{lo}$ users

$$p = \sum_{i=0}^{n_{lo}} \binom{S}{i} (p_{i,min})^i (1 - p_{i,min})^{S-i}$$

Sector Level Detection

- Load imbalance changes over time
- Suggested training time of 2-3 weeks capture daily and weekly variations
- Seasonal variations still not accounted for
  - Ski resorts are busier in winter
  - Beach resorts have higher activities in warmer seasons
- Solution: retrain $p_{i,min}$ on a routine basis

Base Station Level Detection

- Previous approaches involve comparing the system in question to its neighbors
- Can be adapted for base stations
  - requires communication and coordination across nodes
- Simpler approach: deem a base station faulty when it has zero active user for too long
  - only works for hard faults
- How long is too long?

Base Station Level Detection

- Approach 1: record the largest silence time during training period
  - dominated by non-busy hour (i.e., night time)
- Approach 2: do approach 1 separately for busy hour and non-busy hour
- Approach 3: divide the day into N periods and record the largest silence time separately for each period
  - increased data storage and processing requirements
- Seasonal variations not accounted for
  - Retrain on a routine basis