Survivable Wireless Access

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Overview

- Wireless Access Network Architecture
- Network Survivability
- Research Objectives
- Survivability Design
- Survivability Analysis
- Visualization Demo

Mobile Network Architecture

Network Architecture
The Cell Site

Network Architecture
Adjacent Cells
Network Architecture

Handover

Frequency Spectrum

Network Architecture

Frequency Reuse

Given 175 system channels:

- 7 cell reuse: 25 channels/cell
- 4 cell reuse: 43 channels/cell

Network Survivability

The Survivability of a network refers to its ability to maintain performance guarantees in the wake of failures

Design & Analysis

- Survivable network design
  - Redundant resources
  - Restoration protocols
- Survivability analysis
  - Comparative analysis of competing survivable network designs

Research

- High-speed, fiber optic networks
  - Highly reliable links, high-impact failures
  - Cost-optimization problem
- Mobile “ad hoc” networks
  - Multihop unreliable links, lower bandwidth
  - Routing within changing topology
Network Survivability Research

- Little focus on cellular/PCS networks
  - One hop to fixed access points
  - Unreliable links
  - Low-impact failures
  - Degradation
- **Overriding constraint:** Frequency Spectrum!
  - Provisioning of backup channels is critical for fault tolerance
  - The number of wireless channels is determined by the network provider’s use of frequency spectrum, a heavily regulated, natural resource

Research Objective

**Strategies for Mobile Network Survivability**

*How can continuous wireless service be maintained during failure and overload conditions?*

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**Mobile Survivability Framework**

- **Access layer**
  - BSC
  - VLR
  - BSC
  - MSC
  - BS
  - EIR
  - SS7
  - HLR
  - AUC
  - VLR
  - MSC
  - Tipper, Ramaswamy

- **Intelligent layer**

- **Transport layer**

**Survivability Framework**

**Radio Level: Access Layer**

- **function:** radio communications
- **failures:** radio channel, tower
- **degraded mode:** interference, high demand
- **failure impact:** cell-site, signaling network
- **metrics:** new-call & handover blocking
- **protection:** physical redundancy
- **restoration:** load sharing

**Link Level: Access Layer**

- **function:** radio resource management
- **failures:** BS, BSC, T1 link
- **failure impact:** multiple cells
- **surv. metrics:** available user channels
- **protection:** physical diversity
- **restoration:** APS, multi-homing

**Survivability Framework**

**Transport Layer**

- **function:** switching, signaling, setup
- **failures:** MSC, SS7
- **failure impact:** multiple cells
- **metrics:** blocking, traffic volume, no. of users
- **protection:** physical diversity
- **restoration:** self-healing rings, SS7 controls
Survivability Framework

Intelligent Layer

- **function**: location management, service profiles
- **failures**: SS7, HLR, VLR, AUC
- **failure impact**: service mobility—multiple cells
- **metrics**: blocking, traffic volume
- **protection**: link diversity, database redundancy
- **restoration**: software techniques

Current Focus

Access Network Challenge

Designating “spare” wireless channels decreases system capacity

We propose cell-site architectures and adaptive channel allocation protocols to redistribute the use of wireless channels among cells in response to overload conditions.

Current Focus

Access Network Survivability

- **Survivable network design**
  - Dual-homing cellsite architectures
  - Adaptive resource management
- **Survivability analysis**
  - Modeling and simulation
  - Real-time metrics
  - Information visualization

Survivability Design

Dual-homing Cellsite

- Dynamic power control
- Reuse partitions
- Umbrella cells

Survivability Design

Adaptive Load Sharing

- Use knowledge of workload among channel groups for channel allocation decision
  - Adaptive load-based channel allocation (ALBCA)
  - ALBCA with channel rearrangement (ALBCA/CR)

Survivability Design

Voluntary Handover

- Allocate channels for new calls from lighter loaded channel groups
- Use voluntary handover to balance workload distribution
- Dynamically adjust handover activity rate

Jung
Survivability Design

Channel Rearrangement

- Allocate channels for new calls from lighter loaded channel groups
- Use channel rearrangement to redistribute workload on an as-needed basis
- Dynamically adjust rearrangement policy

Reference Protocol: ADRCA

- Allocate channels for new calls from "closest" BS
- Use guard band to protect ongoing calls (δ)
- Use FTR for adaptive admission control

Survivability Design

Adaptive Admission Control

- Use "guard channels" to manage the tradeoff between new call blocking and forced termination rate
- Dynamically adjust the number of guard channels in each cell

As traffic increases, new-calls limited to conserve channels for ongoing calls. Offload to surrounding cells.

Current Focus

Access Network Survivability

- Survivable network design
  - Dual-homing cellsite architectures
  - Adaptive resource management
- Survivability analysis
  - Modeling and simulation
  - Real-time metrics
  - Information visualization

Survivability Analysis

Modeling and Simulation

Integrates spatial maps with dynamical models

- Spatial maps
  - demographics
  - vehicle counts, flows
- Dynamical models
  - mobility model
  - radio model
  - teletraffic model

Subscriber Layer

Integrates spatial maps with dynamical models

- Spatial maps
  - demographics
  - vehicle counts, flows
- Dynamical models
  - mobility model
  - radio model
  - teletraffic model
<table>
<thead>
<tr>
<th>Survivability Analysis</th>
<th>Geographical Data Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>A custom data set represents system characteristics over a long timeframe (e.g. seasonal)</td>
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<tr>
<td>Each unit is a local database that describes the characteristics of a portion of the geographical region</td>
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</table>

<table>
<thead>
<tr>
<th>Survivability Analysis</th>
<th>Teletraffic Model</th>
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</thead>
<tbody>
<tr>
<td>Connection initiation distribution</td>
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<td>QoS guarantees</td>
<td></td>
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<tr>
<td>Connection holding distribution</td>
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<tr>
<td>Offered workload characteristics</td>
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<tr>
<td>Multi-service models under development: packetized voice, data, multimedia</td>
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<thead>
<tr>
<th>Survivability Analysis</th>
<th>Mobility Model</th>
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<tbody>
<tr>
<td>Initial connection location distribution</td>
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<tr>
<td>Multiple trip types</td>
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<tr>
<td>- stationary</td>
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<td>- to-from work</td>
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<tr>
<td>- Markov</td>
<td></td>
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<tr>
<td>- random</td>
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<tr>
<td>Dwell time by unit</td>
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<table>
<thead>
<tr>
<th>Survivability Analysis</th>
<th>Cellsite Architecture</th>
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<tr>
<td>Unit</td>
<td></td>
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<tr>
<td>Basestation</td>
<td></td>
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<tr>
<td>Long-haul coverage area</td>
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<tr>
<td>Short-haul coverage area</td>
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<thead>
<tr>
<th>Survivability Analysis</th>
<th>Resource Allocation Model</th>
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<tbody>
<tr>
<td>Admission control</td>
<td></td>
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<tr>
<td>Channel allocation</td>
<td></td>
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<tr>
<td>Multiple access/packet scheduling</td>
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<table>
<thead>
<tr>
<th>Survivability Analysis</th>
<th>Fault Model</th>
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<tbody>
<tr>
<td>BS failure, Hot Spot</td>
<td></td>
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<tr>
<td>An obstruction in unit 1 affects traffic in surrounding units</td>
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<tr>
<td>E.g. a 5 minute highway lane closure causes an increase in traffic for up to 30 minutes in units along the highway</td>
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Survivability Analysis
Hot Spot Calling Rates

![Graph showing CELL Density on Hot Spot on the highway over simulated time (second)]

Survivability Analysis
Simulation

- Object-oriented event-driven simulation
- Radio coverage of units is determined by the radio model and the network model
- Users move among units according to the location model and the mobility model.
- Connections arrive to users according to the call model, demanding resources, until call termination.

Survivability Analysis
Metrics

- Survivability objectives
  - Function of cost and performance metrics
  - Infrastructure costs and user costs
- Adaptive algorithm monitoring
  - Characterize critical states
- Transient analysis of adaptive algorithms
  
  Spatial and temporal analysis of real-time metrics needed

Failed Channel Group

Highway Traffic

Highway Obstruction
### Survivability Analysis

**Problem Space**

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Real-time Variables</th>
<th>System Variables</th>
<th>Network Conditions</th>
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<tbody>
<tr>
<td>Cell size</td>
<td>Measurement timing</td>
<td>Traffic flow</td>
<td>Normal</td>
</tr>
<tr>
<td>Distance to access point</td>
<td>Window size</td>
<td>Call length</td>
<td>Congested</td>
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<tr>
<td>Coverage-outage index</td>
<td>Threshold values</td>
<td>Other values</td>
<td>Transient failure</td>
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<tr>
<td></td>
<td>Rate</td>
<td>Duration</td>
<td>Steady-state failure</td>
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<tr>
<td>Adaptive Admission Control</td>
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<td>Recovery</td>
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<tr>
<td>New request blocking</td>
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<tr>
<td>rate</td>
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<tr>
<td>Favored blocking rate</td>
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<tr>
<td>Adaptive Channel Allocation</td>
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<tr>
<td>Handover activity rate</td>
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<td>Signaling rate</td>
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### Information Visualization

- 3-D animation of real-time metrics
- Illustrates spatial and temporal relationships
- Leverage user’s domain knowledge to reduce exploration space
- Demo

**Ongoing and Future**

- Multiple layer, multi-service model resource management
- Survivability objectives and functions
- Multi-variate visualization techniques
- Interactive steering of simulations
- Simulation characterization/Feature extraction

Subramanian