Survivable Wireless Access

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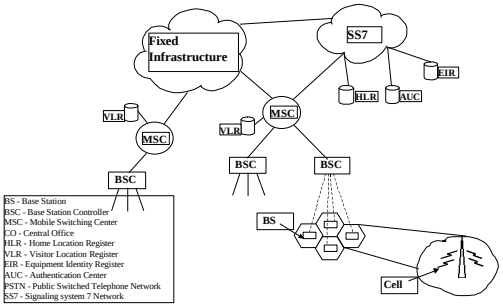
Supported in part by the National Science Foundation

EIA 0130799 September 2001-Nov. 2003
ANIR 0125263 August 2001-July 2004
ANIR 0101866 March 2001-Feb. 2002
ANIR 9980528 Oct. 2000-Sept. 2003
ANIR 9973672 Sept. 1999-May 2001
NCR-9633444 Sept. 1996-Feb. 1998

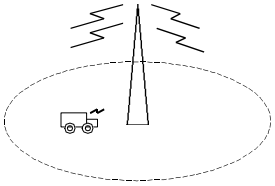
Overview

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

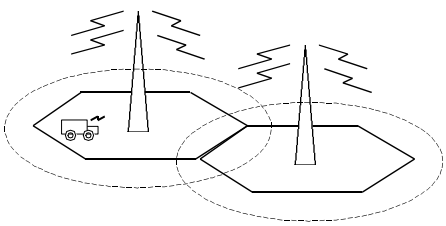
Mobile Network Architecture



Network Architecture
The Cell Site

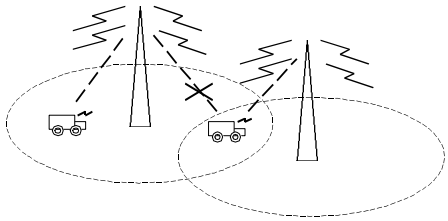


Network Architecture
Adjacent Cells



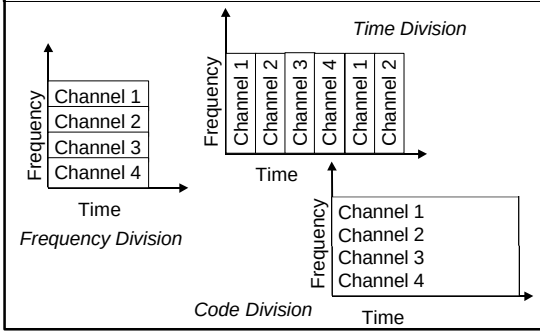
Network Architecture

Handover



Network Architecture

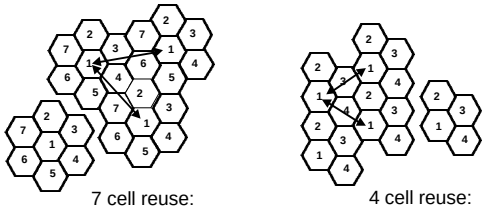
Frequency Spectrum



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

Network Survivability

Design & Analysis

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

Network Survivability

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

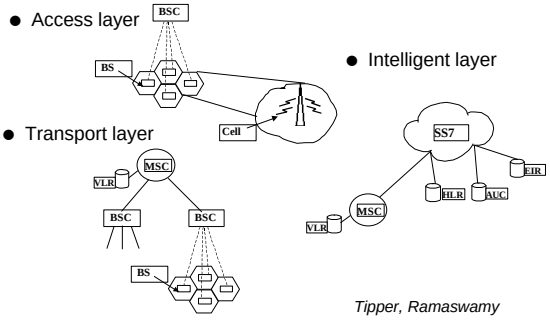
Research Objective

Strategies for
Mobile Network Survivability

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

Mobile Survivability Framework

- Access layer
- Intelligent layer
- Transport layer

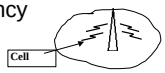


Tipper, Ramaswamy

Survivability Framework

Radio Level: Access Layer

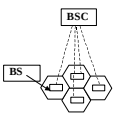
- *function*: radio communications
- *failures*: radio channel, tower
- *degraded mode*: interference, high demand
- *failure impact*: cell-site, signaling network
- *metrics*: new-call & handover blocking
- *protection*: physical redundancy
- *restoration*: load sharing



Survivability Framework

Link Level: Access Layer

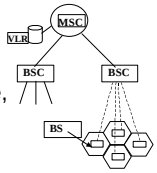
- *function*: radio resource management
- *failures*: BS, BSC, T1 link
- *failure impact*: multiple cells
- *surv. metrics*: available user channels
- *protection*: physical diversity
- *restoration:* APS, multi-homing



Survivability Framework

Transport Layer

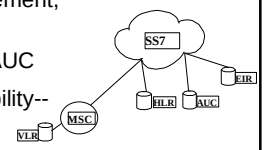
- *function*: switching, signaling, setup
- *failures*: MSC, SS7
- *failure impact*: multiple cells
- *metrics*: blocking, traffic volume, no. of users
- *protection*: physical diversity
- *restoration*: self-healing rings, SS7 controls



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

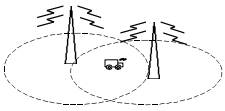
Access Network Survivability

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

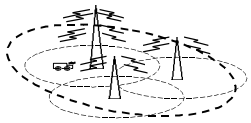
Survivability Design

Dual-homing Cellsite

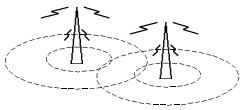
- Dynamic power control



- Umbrella cells



- Reuse partitions



Survivability Design

Adaptive Load Sharing

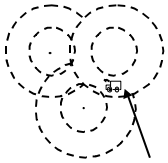
- Use knowledge of workload among channel groups for channel allocation decision
  - » Adaptive load-based channel allocation (ALBCA)
  - » ALBCA with channel rearrangement (ALBCA/CR)

Jung

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

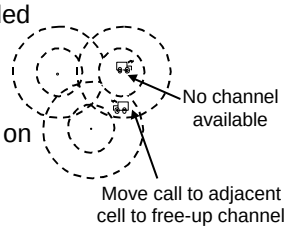


Hot cell offloads to adjacent cell

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



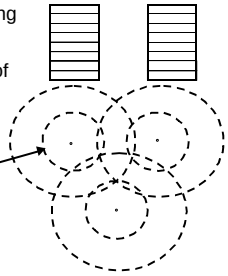
Reference Protocol: ADRCA

- 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



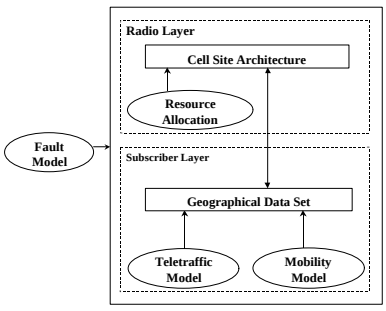
Current Focus

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



Jung

Survivability Analysis

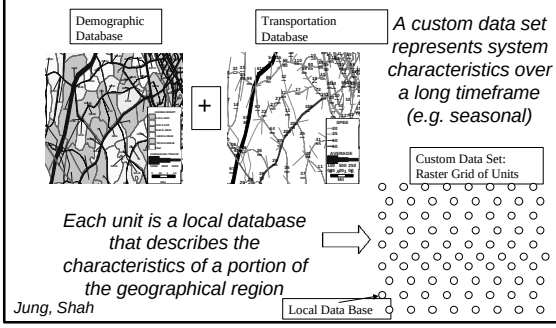
Subscriber Layer

Integrates spatial maps with dynamical models

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

Survivability Analysis

Geographical Data Set



A custom data set represents system characteristics over a long timeframe (e.g. seasonal)

Each unit is a local database that describes the characteristics of a portion of the geographical region

Jung, Shah

Survivability Analysis

Teletraffic Model

- Connection initiation distribution
- QoS guarantees
- Connection holding distribution
- Offered workload characteristics
- Multi-service models under development: packetized voice, data, multimedia

Suratkar

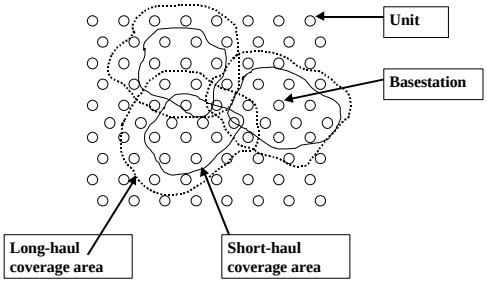
Survivability Analysis

Mobility Model

- Initial connection location distribution
- Multiple trip types
  - » stationary
  - » to-from work
  - » Markov
  - » random
- Dwell time by unit

Survivability Analysis

Cellsite Architecture



Survivability Analysis

Resource Allocation Model

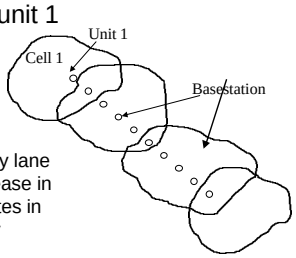
- Admission control
- Channel allocation
- Multiple access/packet scheduling

Jung, Pangamamula, Sood, Cao

Survivability Analysis

Fault Model

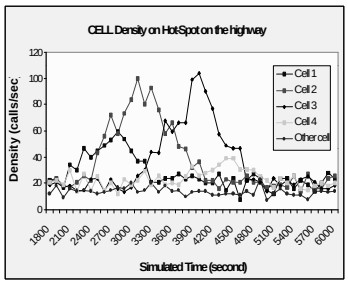
- BS failure, Hot Spot
- An obstruction in unit 1 affects traffic in surrounding units



E.g. a 5 minute highway lane closure causes an increase in traffic for up to 30 minutes in units along the highway

Survivability Analysis

Hot Spot Calling Rates



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

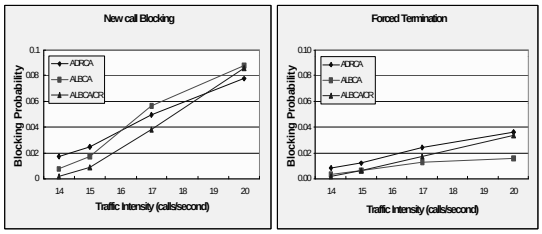
Metrics

- Survivability objectives
  - » Function of cost and performance metrics
  - » Infrastructure costs and user costs
- Adaptive algorithm monitoring
  - » Characterize critical states
- Transient analysis of adaptive algorithms

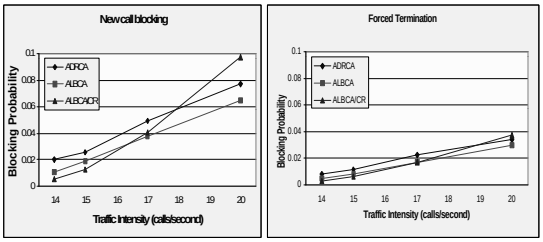
Spatial and temporal analysis of real-time metrics needed

Heybruck

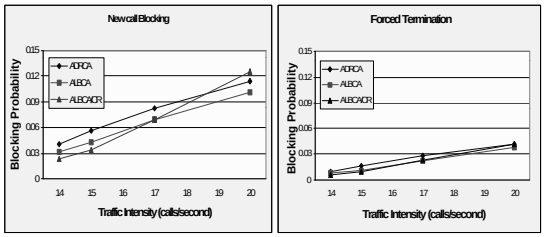
Failed Channel Group



Highway Traffic



Highway Obstruction



Survivability Analysis

Problem Space

Metrics	Real-time	System Variables	Network Conditions
Cellsite	Measurement	Traffic Model	
Distance to access point	Sampling rate	Offered load	
Coverage-outage index	Window size	Call length	Normal
	Threshold values		Congested
Adaptive Admission Control	Ratios		Transient failure
New request blocking rate	Other values	Mobility Model	Steady-state failure
Forced termination rate		Velocity	Recovery
	Interpretation	Trip type	
Adaptive Channel Allocation	Actual value		
Handover activity rate	Derivative	Failure Model	
Signaling rate	Integral	Type	
		Location	
		Duration	

Information Visualization

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

Subramanian

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