Autonomic Wireless Network Management

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Overview

- Problem Statement
- Autonomic Management System
  - Underlying principles
  - Functionality
  - Basic concepts
- Monitoring Capabilities
  - Relevance and implementation
- Implementation State
- Quantitative Evaluation
- Conclusion

Problem Statement

- Configuration and management of large wireless networks (= many base stations) is challenging
- Wireless network environments are especially demanding due to …
  - *high dynamics* – numbers, location and traffic patterns of mobile systems change constantly
  - *use of shared resource (unlicensed spectrum)* – problems can occur as a result of uncoordinated base station configuration/ deployment

⇨ Need for **autonomic management** (to adapt to changing environment/context)

State-of-the-Art

- Today's wireless networks systems are already self-configuring and self-managing to some extent (e.g., autonomic selection of frequencies)
- However, self-configuration and self-management is typically limited to …
  - **local information** that do not require explicit information exchange with neighbours
  - **few configuration options** due to lack of relevant feedback/context information

⇨ Need for **collaboration among autonomic systems** and more **feedback/context information**

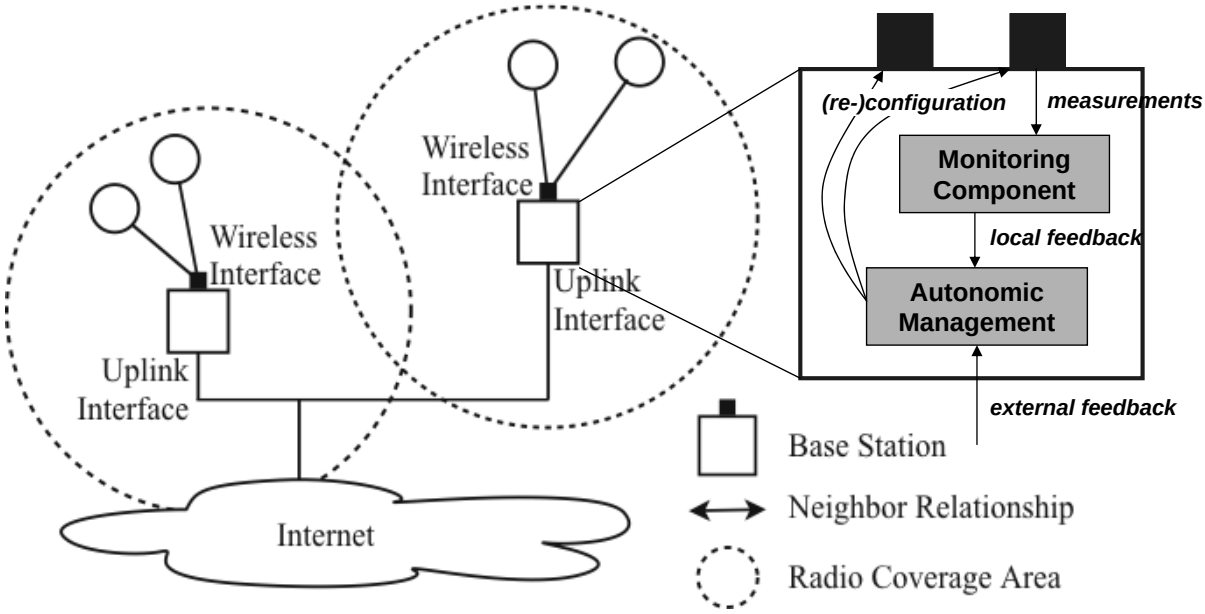
Tenets

- *Automatic operation:*
  - Autonomic systems must be able to bootstrap themselves in any environment (i.e., self-configuration of basic operation)
- *Aware operation*:
  - Autonomic systems must be *self-aware* (i.e., able to observe/monitor their operation and context)
- *Adaptive operation:*
  - Autonomic systems must continuously adapt themselves based on the changing context (e.g., fine-tune its operation)

Required Functionality

- Coordination of autonomous configurations
  - among **neighboring base stations** (e.g., frequency, transmission strength)
  - for **system-wide** management (e.g., load balancing, routing)
- Self-protection of system operation
  - identify and isolate potential attacks
- View of global system state
  - for validation/monitoring of system operation
  - for logging purposes

Autonomic Management System Architecture

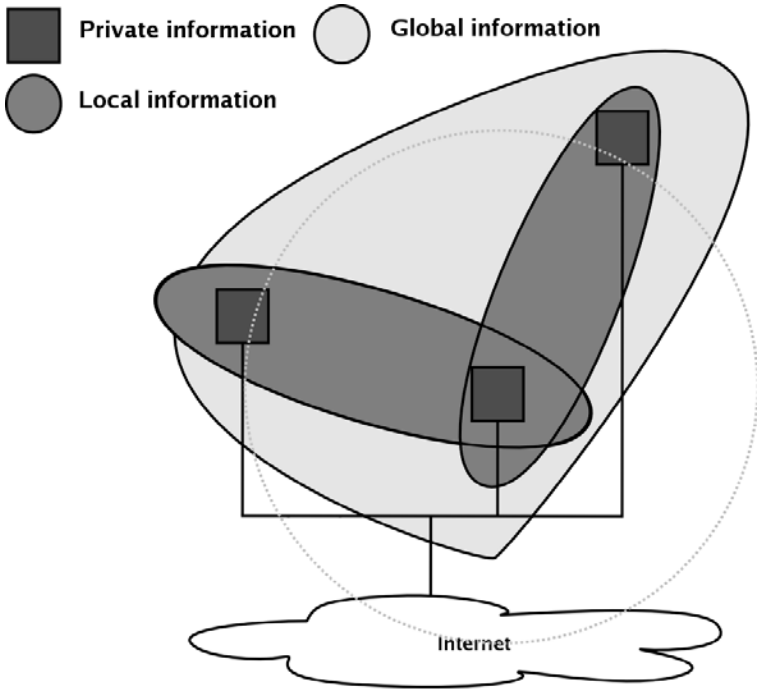


⇨ Individual autonomic systems have to **collaborate to optimize the overall system** (composite)

Autonomic Management

- Management functionality entirely distributed (across all base stations)
- Autonomic systems request/collect management and context information from neighbours
- Based on local and external information, every system makes autonomous decisions (self-X)
- Dissemination and synchronisation of information is achieved through epidemic communication paradigm
- Management information categorized into *global*, *local* and *private*

Information Categories



Wireless Monitoring for Self-Awareness

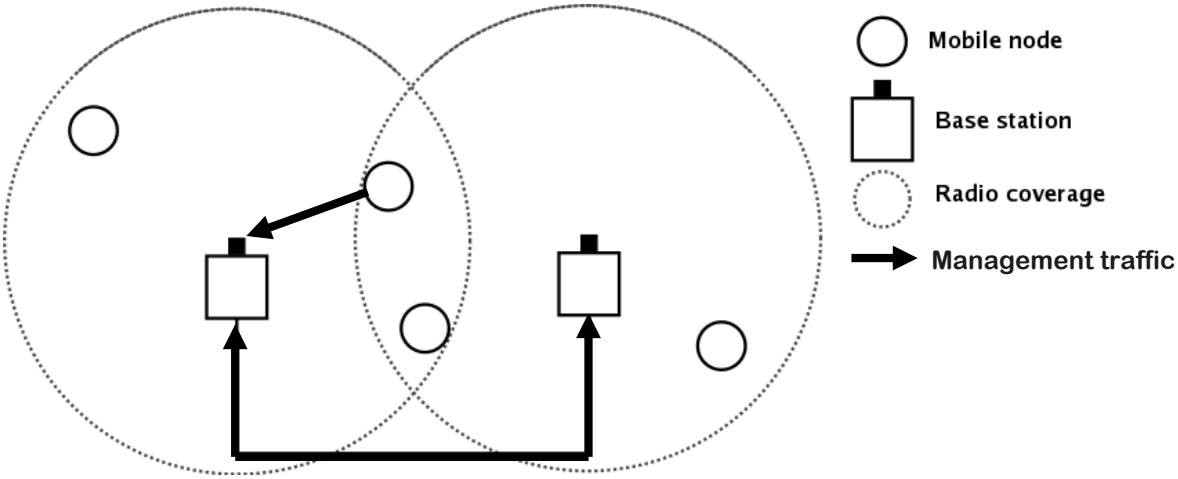
- **Self-awareness** (i.e. feedback on system operation/context) forms the **basis for autonomic behavior**

⇨ **Build-in monitoring capabilities are vital** for self-configuration and self-management

- Monitoring (incl. traffic measurements) also required to protect wireless networks

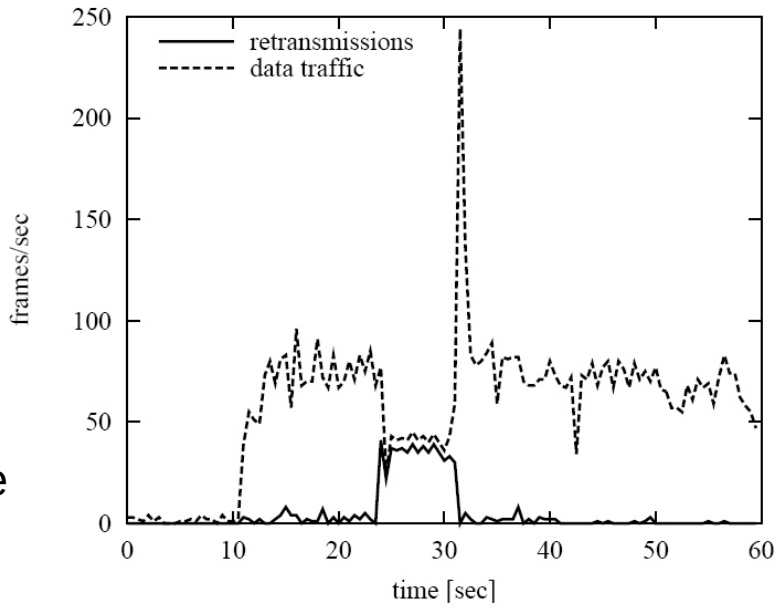
Use of Monitors in the System

- Built-in monitoring capabilities in most nodes
- Specialized monitoring/measurement nodes
- End systems (e.g. client nodes) should contribute as well – they can reveal important information!



Example: Connectivity Problem Detection

- Monitoring system can detect connectivity problems
- For example, observation of repeated transmissions of *retry* frames with identical sequence numbers can indicate wireless link problems



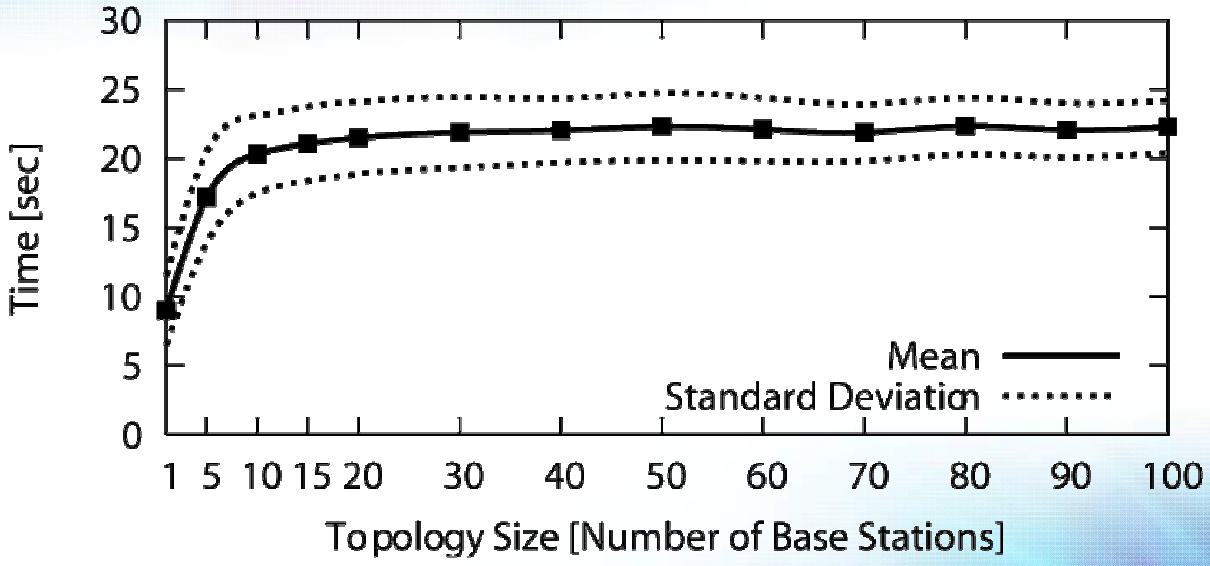
Implementation State

- Prototype implementation on 802.11a/b/g WLAN Router (running Linux)
- 1 uplink (backhaul) and 1-2 wireless interfaces
- C implementations for main components:
  - autonomic management (incl. epidemic communication modules)
  - wireless monitoring
- TCP for exchange of local and global information
- UDP for neighbour resolution/discovery (to bootstrap epidemic information exchange)

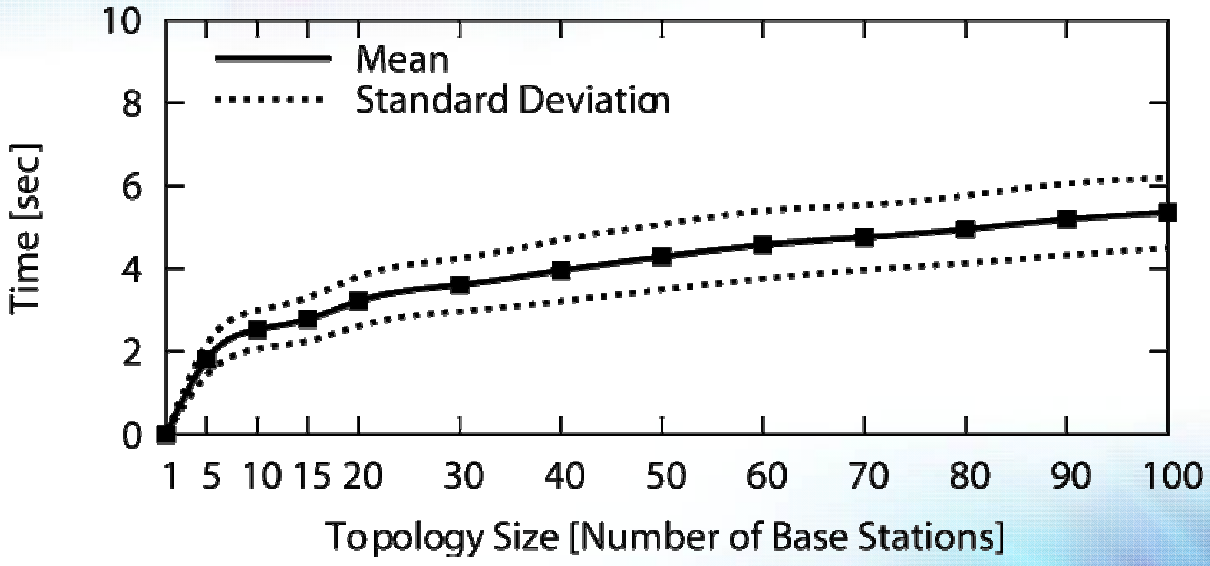
Quantitative Evaluation

- Performance evaluation of autonomic management system (for increasing numbers of base stations)
- Measurements include …
  - convergence time for initial self-configuration
  - dissemination time for new global information
  - number of messages for initial self-configuration
- Based on simulator (in Perl)
  - Allows for simulation of large numbers of base stations (on a single host)
  - Use of randomly generated topologies
- Results are shown as *mean values* with *standard deviations* over 500 simulation runs

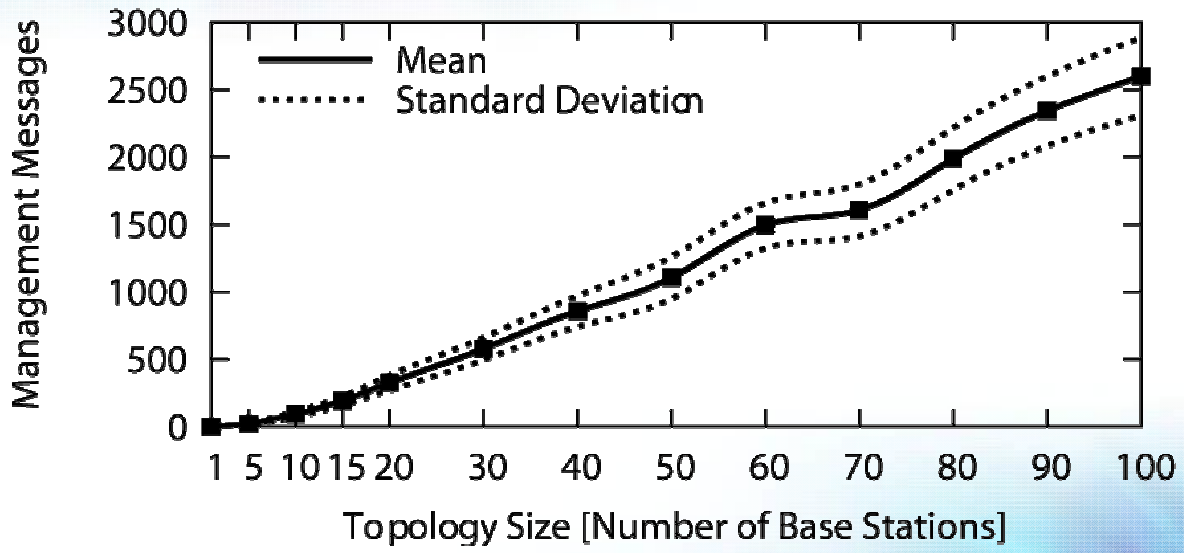
Convergence Time for Initial Self-Organization



Dissemination Time of new Global Information



Number of Messages for Initial Self-Organization



Conclusion

- Autonomic Wireless Management System
  - Fully decentralized approach
  - Inherent monitoring capabilities (feedback/context)
  - Self-configuration and self-management based on local and global information
- Current State
  - Prototype implementation available
  - Simulations show approach scales well
- Next Steps
  - Evaluation in real deployment scenarios
  - Development of further management and monitoring control applications
  - *Autonomic Systems Monitor* (a monitoring framework for autonomic systems)