Self-Management in Cellular Networks
Drivers, Vision, Gains, Achievements & Challenges

Remco Litjens
Performance of Networks & Systems
Expertise Centre Technical Sciences
TNO

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INTRODUCTION

- Cellular networks are traditionally largely manually operated
  - Separation of network planning and optimization
    - (Non-)automated planning/simulation tools used to select sites, determine antenna tilt and optimise radio parameters
  - ‘Over-abstraction’ of applied technology models
  - Manual configuration of sites
  - Radio (resource management) parameters updated weekly/monthly
  - Delayed, manual and poor handling of cell/site failures
  - Future networks will exhibit a significant degree of self-management

- Broad attention
  - 3GPP, NGMN, FP7, CELTIC, …
  - Operators, equipment/tool vendors, academia/research institutes
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TRENDS & DRIVERS

- Complexity of future/contemporary wireless access networks
  - Multitude of tunable parameters with intricate dependencies
  - Multitude of radio resource management mechanisms on different time scales
  - Complexity is needed to maximize potential of wireless access networks
TRENDS & DRIVERS

› Heterogeneous access networks to be cooperatively managed
  › Multi-RAT: 2G/3G/LTE/LTE-A/WiFi
  › Multi-layer: Macro/micro/pico/femto
  › Multi-vendor

› Mode of operation
  › Network sharing, e.g. national roaming, hardware/spectrum sharing
  › Network ‘dynamicity’, incl. uncoordinated femtocell deployment
  › QoE/service-centric traffic management
TRENDS & DRIVERS

- Higher operational frequencies
  - Multitude of cells to be managed
- Service/traffic
  - Increasing demand for ubiquitous mobile broadband access
  - Growing suite of services with distinct characteristics & requirements
TRENDS & DRIVERS

› Market perspective
  › Need to reduce time-to-market of innovative services
  › Reduce operational hurdles of service introduction
  › Pressure to remain competitive
    › Reduce costs (OPEX/CAPEX)
    › Enhance resource efficiency

› ‘Society’
  › Mobile communications becomes more and more a critical infrastructure for economy and society as a whole: need for network robustness/resilience
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VISION

› Self-Management for Unified Heterogeneous Radio Access Networks
  › Service provider
  › Network operator
  ◀ Self-management system
  › Network resources
VISION

- Self-Management for Unified Heterogeneous Radio Access Networks
  - Policy transformation
  - SON coordination
  - SON functions
    - Multi-RAT/layer
    - Single-RAT/layer
  - Decision support system
VISION

› Self-Management for Unified Heterogeneous Radio Access Networks
› SON functions
  › Self-configuration
    › Incidental, intentional events
    › ‘Plug and play’ installation of new base stations and features
  › Self-healing
    › Incidental, non-intentional events
    › Cell outage detection
    › Cell outage compensation
VISION

› Self-Management for Unified Heterogeneous Radio Access Networks

› SON functions
  › Self-optimization
    › Measurements
    › Performance indicators
    › Network, traffic, mobility, propagation conditions
    › Optimize periodicity, accuracy
    › Automatic tuning
    › Smart algorithms process measurements into parameter adjustments, e.g. tilt, power, handover/scheduling parameters, …
VISION

› Self-Management for Unified Heterogeneous Radio Access Networks

› Policy transformation
  › Heading harmonization
  › Transform high-level operator objective to SON function specific objectives
    › Example - Optimization weights between call dropping, ping-pong handovers and radio link failure in handover optimization

› SON coordination
  › Tailing harmonization
  › Detect/resolve conflicts between SON functions
    › Conflicting actions, conflicting performance effects, …
VISION

- Self-Management for Unified Heterogeneous Radio Access Networks
  - Decision support system
    - Intelligent selection of required hardware upgrades
    - Advice on migration of sites to other technologies or frequency bands
    - Estimation of the resource cost of performance to assist the (re)negotiation of SLAs
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EXPECTED GAINS

› OPEX reductions …
  › Primary objective!
  › Less human involvement in
    › Network planning/optimization
    › Performance monitoring, drive testing
    › Troubleshooting
  › About 25% of OPEX is related to network operations
  › x00 million € savings potential per network
EXPECTED GAINS

- ... and/or CAPEX reductions ...
  - Via delayed capacity expansions
  - Smart eNodeBs may however be more expensive
- ... and/or performance enhancements
  - Enhanced service availability (robustness/resilience), service quality
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ACHIEVEMENTS

Existing solutions primarily target:
- Self-configuration
- Stand-alone self-optimization functions
  - Single-RAT, single-layer scenarios

Examples:
- Smooth automated integration of new sites
- Neighbor cell list optimization
- Handover parameter optimization
- Cell outage compensation
- Self-optimization of admission control thresholds
- Load balancing
- Interference coordination
- Automatic on/off-switching of sites
ACHIEVEMENTS

› Smooth automated integration of new sites
  › Minimize disruptive effects
  › Observation phase
    › Data collection
    › Off-line tilt/power optimization
  › Pre-computed trajectory
  › Integration phase
    › Gradual activation
      › Power 0 → P*
      › Tilt 90° → T*
  › Adoption in regular optimization cycles
ACHIEVEMENTS

Handover parameter optimization
ACHIEVEMENTS

› Cell outage compensation

Operator policy: Coverage, QoS

Coverage/QoS estimation

Measurements

Control parameters

Detection

Compensation
ACHIEVEMENTS

› Cell outage compensation
  › Mitigate local degradation of coverage; keep QoS at acceptable level
  › Determine set of compensating sites
  › Adjust control parameters
    › Antenna downtilt
    › UL/DL powers
    › …
ACHIEVEMENTS

- Cell outage compensation
ACHIEVEMENTS

› Cell outage compensation

Figure: (a) Outage situation with no compensation, and (b) snapshot of situation with largely converged compensation.
ACHIEVEMENTS

› Load balancing
  › Detect load asymmetry between neighboring cells
  › Adjust handover control parameters to balance loads
  › Example scenario: *moving hot spot*

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*non-regular network; hotspot is moving from cell 27 to 13*

*scenario 3*

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*reference*

*with load balancing*
CHALLENGES

› Development of SON functions

› Use cases
  › Self-optimisation of ‘multiflow’, CoMP and ICIC features
  › Automatic traffic steering in a multi-layer/RAT network
  › Dynamic spectrum management in a multi-layer/RAT network
  › Automated tuning of Active Antenna Systems

› Intrinsic challenges
  › Algorithm development
  › Multi-objective optimization
  › Data gathering: performance vs signalling cost
  › Timely detection for timely response
  › Dealing with delayed feedback
  › Effect of control actions vs natural variations
CHALLENGES

- Development of unified self-management system
- Policy transformation
- Dependencies
- SON coordination
- Guard function
- Autognostics
- Conflict handling
- Intricate parameter dependencies
- Prevent oscillations
CHALLENGES

- Development of unified self-management system
- Decision support systems
- Gradual introduction
  - Build confidence
  - On/off functions
  - Degree of freedom
  - Manual approvals
- Architectural embedding
  - Measurements
  - Protocols
  - Interfaces
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CONCLUDING REMARKS

- Self-management is the key approach to
  - ... reduce O/CAPEX
  - ... cost-effective provisioning of high-quality services
  - ... reduce time-to-market of new features, services

- Key aspects
  - Policy transformation
  - SON coordination
  - SON functions
  - Decision support system

- Key challenges
  - Effectiveness, reliability, stability
  - Measurements, interfaces, protocols, architectures
QUESTIONS?