Transaction-based Configuration Management for Mobile Networks

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Goal
- Automated assurance of network-wide configuration data consistency

Use cases: Network optimization and growth
- Example: cell adjacency management

Proposed solution:
  Transaction-oriented CM data management subsystem
- Integration into the element management architecture

Conclusions
General problem statement

Requirement for an element management system (EMS):

- The consistency of configuration data
  - Between NEs and EMS
  - Between NEs (dependencies)
  - needs to be assured at all times.

(Automated) rollbacks from inconsistent NE/network states must be possible → Transactions

<table>
<thead>
<tr>
<th>Error sources</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Non-ideal system components</td>
<td>O&amp;M network links: limited bandwidth, link interruptions</td>
</tr>
<tr>
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<td>NEs may fail</td>
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<tr>
<td>Concurrency</td>
<td>Multiple sources of configuration changes (planning, multiple operators, local changes)</td>
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<tr>
<td>Limited roll-out time</td>
<td>Service-affecting configuration changes can only be rolled out during defined time windows (night hours, weekends)</td>
</tr>
<tr>
<td>Logical errors</td>
<td>Misconfiguration (human factor)</td>
</tr>
</tbody>
</table>

Roll-out Align ment
Specific problem statement for RAN Configuration Management (3G / 3G evolution)

<table>
<thead>
<tr>
<th>Category</th>
<th>RAN CM property</th>
<th>Requirements to a full solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll-out phase</td>
<td>Few dependencies* comprising only small NE groups, but crucial and existent in numerous NE</td>
<td>Assurance of inter-NE consistency with adaptive commit strategy (not just 2PC**)</td>
</tr>
<tr>
<td></td>
<td>Current management protocols: inefficient for delta configuration</td>
<td>Transaction-oriented protocol</td>
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<td></td>
<td>NEs need to function autonomously (“NE is the master of its data”), but no atomic operation at NE</td>
<td>Transactions at NE (&amp; EMS) level</td>
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<td>Lack of speed</td>
<td>Parallelization of transactions</td>
</tr>
<tr>
<td>Alignment phase</td>
<td>Bulk alignment → reduced up-to-dateness</td>
<td>Delta alignment</td>
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<tr>
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<td>Low O&amp;M link bandwidth (Node B today: 128 kbit/s)</td>
<td>Bandwidth efficiency</td>
</tr>
<tr>
<td>Non-functional properties</td>
<td>O&amp;M link on microwave (Node B); planning / operator / local configuration changes</td>
<td>Robustness, “online” assurance of consistency</td>
</tr>
<tr>
<td></td>
<td>Numerous NE</td>
<td>Scalability</td>
</tr>
<tr>
<td></td>
<td>Manual work (NE configuration) in case of errors (→ downtime)</td>
<td>Efficiency through automation (network configuration)</td>
</tr>
</tbody>
</table>

* Dependencies: cell handover adjacencies, transport connections; future: security information

** 2PC: Two-phase commit: all NE of a group signal “ready to commit”; EMS triggers commit
Use cases in RAN Configuration Management (3G / 3G evolution)

Network optimization (Prio 1):
- Large radio network plan update
  - Example: regular plan exchange (monthly), e.g., to improve load balancing among RNCs (radio), minimize leased line expenditures (transport), accommodate changed user requirements due to an upcoming event
- Manual update of radio network covering multiple NE
  - Examples: correct radio configuration deficiency covering several RNCs, reconfiguration of a Node B cascade

Network growth (Prio 2):
- Addition / rehoming of Node Bs (attention of human operator required anyway, support useful)

Assumptions for the evolution of the use cases:
- Distribution: numerous NE involved in CM (3G LTE), increasing number of NE
- Dynamics: more frequent reconfiguration of NEs to satisfy changing user demands (enabler: remote electric antenna tilting) → >1 network plan per network, change of plan over time (of day, of year)
- Diversity: integrated heterogeneous access networks (3G/3G LTE/WiMax)
Example workflow for adjacency management: today

Low-level workflow:
- Verification
- Correlation of individual results
- Correction of cell #1 problem
  OR
- New script for “rollback"

Update HO params. cell #7: A
Update ADJC cell #2: A

Update HO params. cell #7: B
Update ADJC cell #1: B
Update ADJC cell #2: B

Update cell #7: success
Update cell #1: failure
Update cell #2: success

Roll-out Alignment / FM
Example workflow for adjacency management: future

Network planning

Operator

△ CLI script

Transaction group

Roll-out

Alignment

High-level workflow:

(Automated) operator decision between

- Temporary revocation of dependency & rescheduling of few transactions (this example)
  
  Update ADJC cell #1: B

- NE group-wide rollback to state A (e.g., for case Update cell #7: failure)

Transaction group

Scope of configuration change | Hierarchy level
-------------------------------|---------------------------
Network                       | Network Transaction
NE group                      | Transaction Group
Single NE                     | Transaction
Single operation on NE       | Command

Command

Rollback HO params. cell #7
Rollback ADJC cell #1
Rollback ADJC cell #2
Generic master-replica data management model

- Transactions (T) of one group (TG) register with the synchronization procedure
- T's are sent to the replicas
- Execution / tentative commit at replicas
- PT communicate changed replica state (or failure / timeout) to TM
- Dependent on the success / failure of the entire TG, changes are finally committed into master or replicas are rolled back

→ Replicas operate autonomously, master follows, but has final decision

<table>
<thead>
<tr>
<th>TG Synchronization Table</th>
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<tbody>
<tr>
<td>Transaction ID</td>
</tr>
<tr>
<td>UUID₁</td>
</tr>
<tr>
<td>UUID₁</td>
</tr>
<tr>
<td>UUID₂</td>
</tr>
</tbody>
</table>

- Local access
- Refresh
- Tentative commit
- Final commit

XML Tag: "Generic master-replica data management model"
Integration into the element management architecture

Network

Elements

Agent

"Replica"

Transaction Compiler / Manager

RV: recent view
PV: planned view

Configuration Preparation Tool

RV

PV

"Master"

Application

GET ("Committed read")

Element Manager

GET ("Dirty read")

Management protocol

Transaction-based protocol

Transaction

Compiler / Manager

Protocol adapter

Network Planning

Protocol adapter

CLI script

Δ

Δ

CLI

"Replica"

Transaction

Compiler / Manager

Protocol adapter

Network Planning
Policy Examples for Automated Rescheduling / Rollback

Policy properties:
- hierarchically organized (atomic and derived policies)
- tool-box supporting remote editing
- optimizing and learning process
- smooth migration and development possible
- high-level language necessary (subject for standardization?)
- monitoring, tracing, evaluation (appropriate GUI requested)
- complexity vs. automation
- transparency vs. control
- potential for OPEX reduction

→ policy environments for automated rescheduling and rollback are feasible already now, with IPDE as long-term goal

IPDE - Integrated Policy Developing Environment

High level language with loops, functions, ...

Boolean combinations for arbitrary policy scenarios

Timer controlled policies

Parameter controlled policies

Atomic policies

Automation / Less Control

Complexity / Less Transparency
### Proposed solution: master-replica data management subsystem

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<tr>
<th>Category</th>
<th>Requirements to a full solution</th>
<th>Solution properties</th>
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</thead>
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<tr>
<td>Roll-out phase</td>
<td>Assurance of inter-NE consistency</td>
<td>Transaction compiler: generates transactions from delta between recent and planned view (input: dependencies, execution plan)</td>
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<tr>
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<td>Transactions at EMS level</td>
<td>Transaction manager: rolls-out and monitors transactions</td>
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<tr>
<td></td>
<td>Parallelization</td>
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<td>Automation</td>
<td></td>
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<tr>
<td></td>
<td>Transaction-oriented protocol</td>
<td>Transaction-oriented protocol between master / replica (=NE), transactions at replica</td>
</tr>
<tr>
<td>Alignment phase</td>
<td>Delta alignment</td>
<td>Middleware (Transaction manager): controls access to master by replicas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protocol: delta updates as transactions</td>
</tr>
<tr>
<td>Non-functional properties</td>
<td>Bandwidth efficiency</td>
<td>Protocol: delta configuration changes</td>
</tr>
<tr>
<td></td>
<td>Robustness, “online” assurance of consistency</td>
<td>Middleware: concurrency awareness</td>
</tr>
<tr>
<td></td>
<td>Scalability</td>
<td>Protocol: reliable messaging, transactions</td>
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<tr>
<td></td>
<td>Efficiency through automation</td>
<td>Protocol / Middleware: several 100 replicas tested</td>
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<td>Middleware: network (not NE)-level interface</td>
</tr>
</tbody>
</table>
Summary

Policy-based rescheduling

Policy-based transaction generation (parallelization / execution plan)

OK

(recent view ≡ planned view)

escalate

reschedule
Conclusions

- Improvement of CM data consistency (NE/EMS & inter-NE), degree of automation
  - Manufacturer: reduced and simplified CM software development:
    - State-of-the-art data management technology can be applied
    - Applications do not need to consider low-level data consistency
  - Mobile Network Operator:
    - OPEX reduction (less (skilled) operational personnel needed)
    - Increasingly important with 3G RAN evolution
- Parallel operation to legacy CM protocols possible
- Partial introduction possible (transaction manager at EMS only)
- Info model upgrades can be nicely integrated into the roll-out process
- Proof-of-concept implementation has been done at Siemens Communications

- Future work: policy development process (encapsulating human operator's knowledge) based on operational experience