Autonomic Management of Wireless Networks

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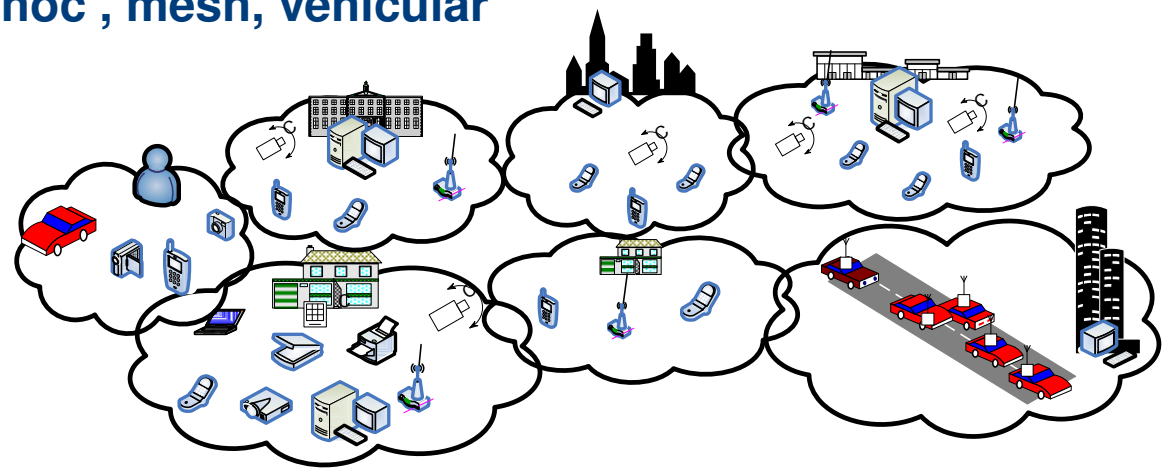
Outline

- Introduction
- Autonomic Management
- Wireless Networks PBM Framework
  (PBM: Policy-based Management)
- Policy Examples
- Conclusions

Introduction
Wireless Networks

- Wireless Networks are **everywhere**!
  - WMAN: e.g. Cellular 2G/3G/LTE
  - WMAN: e.g. WiMax / Mobile WiMax
  - WLAN: e.g. WiFi
  - WPAN: e.g. Bluetooth, IR
  - WBAN: e.g. Zigbee, RFID
- Multihop Wireless Networks
  → **ad hoc , mesh, vehicular**

? → 4G



Introduction

Wireless Networks' Issues

- Multiple technlologies → 4G
  - **Interoperability – Mobility – Scalability**
  - Multi-interface handsets
    - Today: 2G/3G, WLAN, Bluetooth, IR
    - Tomorrow: X, Y, Z, ?, ? , ?
  - New form factors
    - netbooks, MID, smatbooks, USB dongles etc …
  - Convergence of Fixed and Mobile Networks

→Increased scale

→Increased complexity →**Increased Cost**

→Increased heterogeneity

Introduction

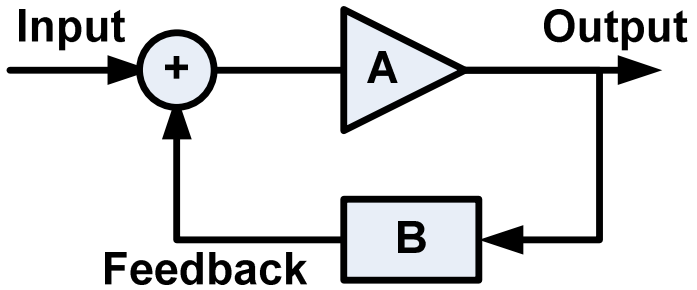
Wireless Networks' Issues

- Typical OPEX Breakdown for a Mobile Operator
  - ~20% on Network Operations (source: Motorola-Yankee Group)
- Typical budget for IT
  - ~70% on Labor (source: IDC study for IBM)
- Industrial initiatives to reduce costs

  → management automation → ***Self-* Capabilities***
- IBM: Self-Managing Autonomic Technology (2001)
- 3GPP/NGMN: SON for LTE (2008)
  - Self-Organizing Networks (SON) Long Term Evolution (LTE) standards attempt to change the operations and maintenance paradigm
    - NGMN: Next Generation Mobile Networks Alliance
    - 3GPP: 3rd Generation Partnership Project

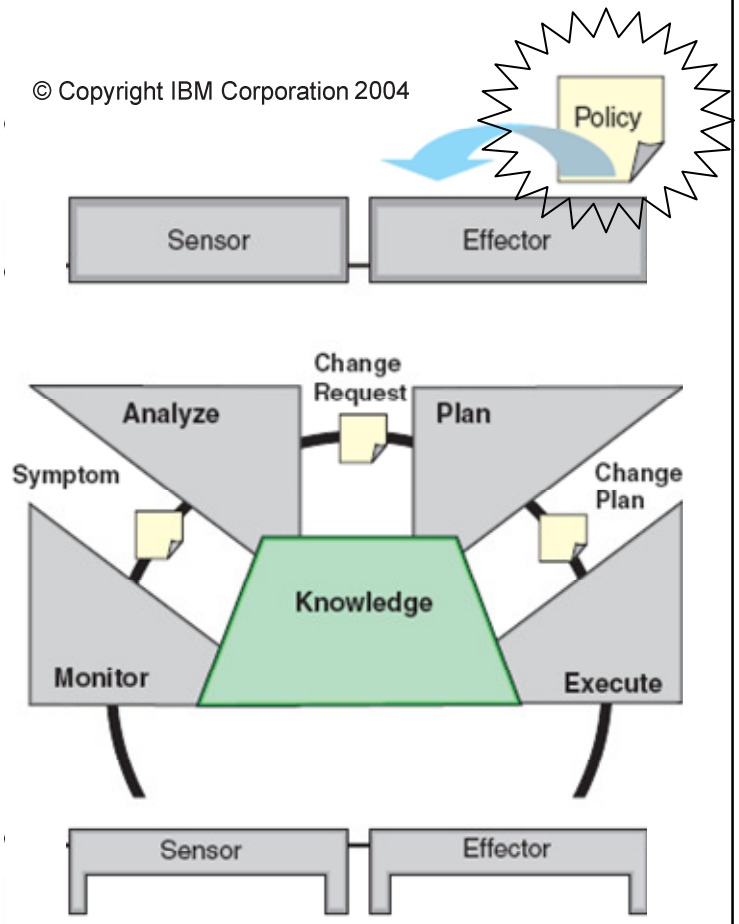
Autonomic Management
*Autonomic Computing and Self-**

- **Autonomic Computing**: a computing environment with the ability to manage itself and dynamically adapt to change in accordance with business policies and objectives [IBM2001]
  - "*Grand Challenge:* building and deploying computing systems that regulate themselves and remove complexity from the lives of administrators and users"
- **Self-management**: the ability of independently achieving seamless operation and maintenance by being aware of the surroundings
- **Self-***
  - Configuration
  - Healing
  - Optimisation
  - Protection)



Autonomic Management
Architecture and Principles

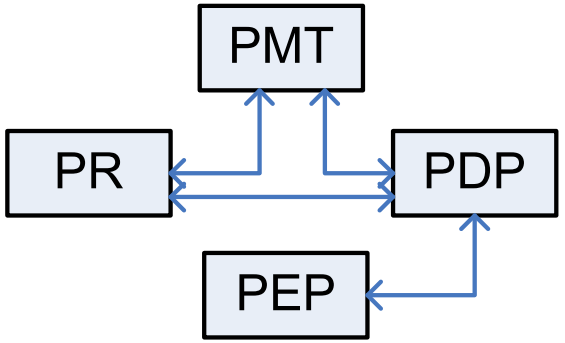
- **Autonomic Manager**
  - building block of autonomic systems
- K-MAPE architecture
  - **K**nowledge
  - **M**onitor
  - **A**nalyze
  - **P**lan
  - **E**xecute
- **Policy**: a set of rules to administer, manage and control access to network resources [IETF]



Autonomic Management
Policies and PBM

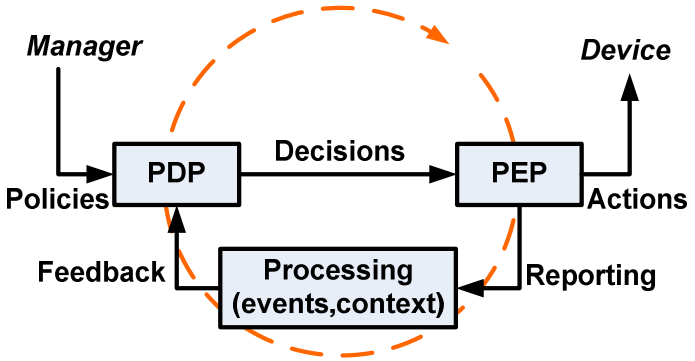
- **The policy-based management (PBM) paradigm**
  - Policies capture the high-level management objectives
  - The means to integrate self-management capabilities
  - PBM offers controlled programmability

- **IETF reference framework**
- Four functional elements
  - *PMT: Policy Management Tool*
  - *PDP: Policy Decision Point*
  - *PEP: Policy Enforcement Point*
  - *PR: Policy Repository*
- A generic specification of policy rules
  - ECA: on *Event* if *Condition* then *Action*

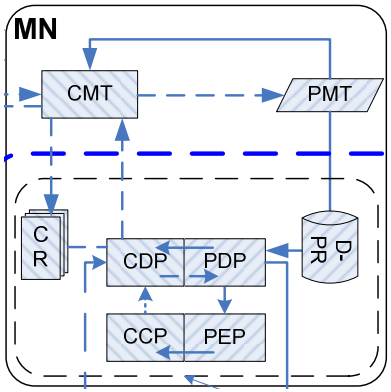


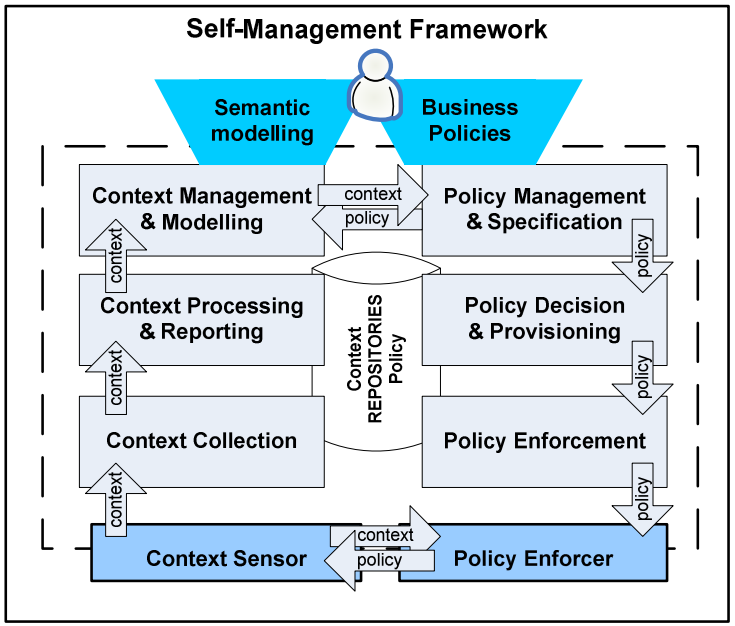
Wireless Networks PBM Framework
Architecture and Roles

- **Framework Architecture**
  - Closed-loop management
  - Context-aware counterparts to PBM
  - Hybrid role-based organizational model



- *Management Roles*
  - Cluster Node (CN)
  - Cluster Head (CH)
  - Manager Node (MN)



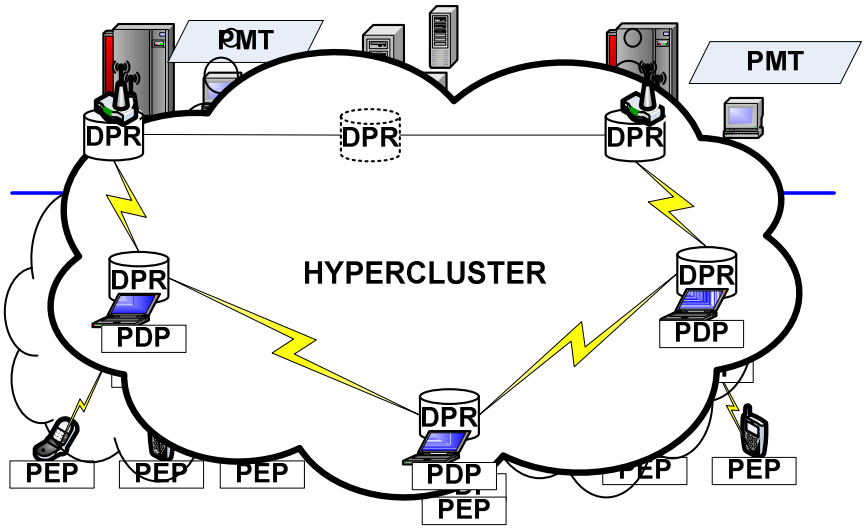


Wireless Networks PBM Framework

Hypercluster for Distributed Management

- *Hypercluster*: special set of nodes that are assigned the collaborative management of the wireless network
  - Consisted of devices having the MN or CH role
  - Flexible network organisation with CNs grouped in clusters
  - Management intelligence is distributed based on capabilities
  - Host and manage the Distributed Policy Repository (DPR)

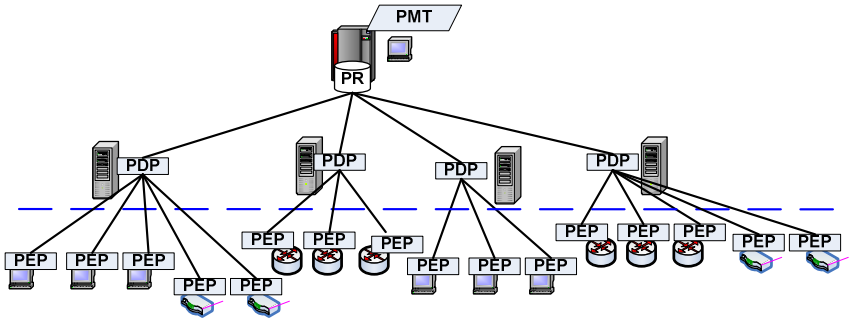
- Hypercluster formation
  - Static
  - Dynamic
  - Combined

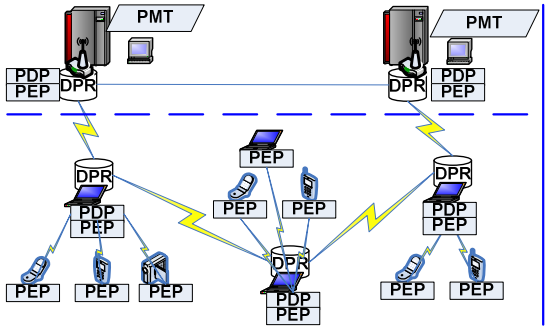


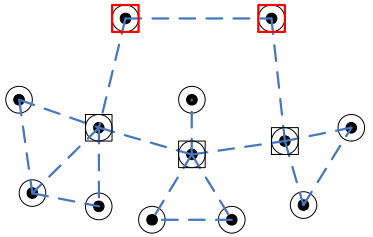
Wireless Networks PBM Framework

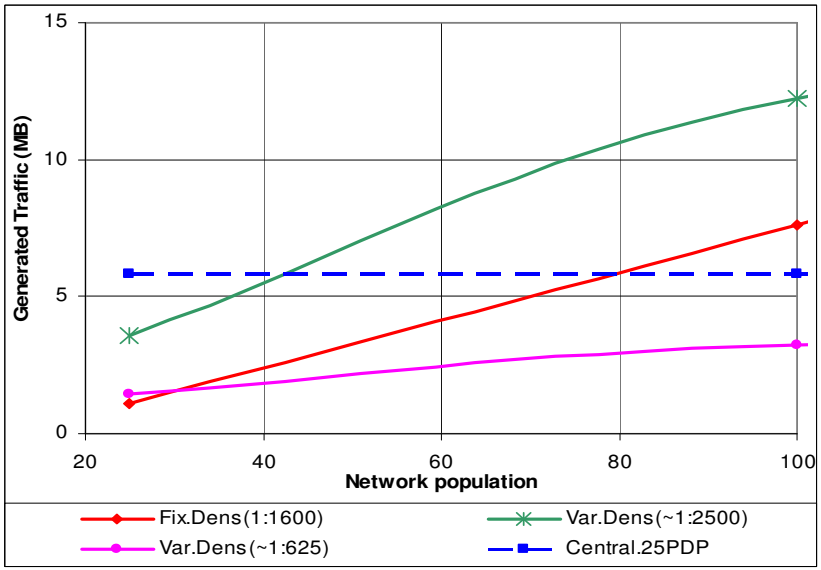
Scalability of Distributed-Hybrid Model

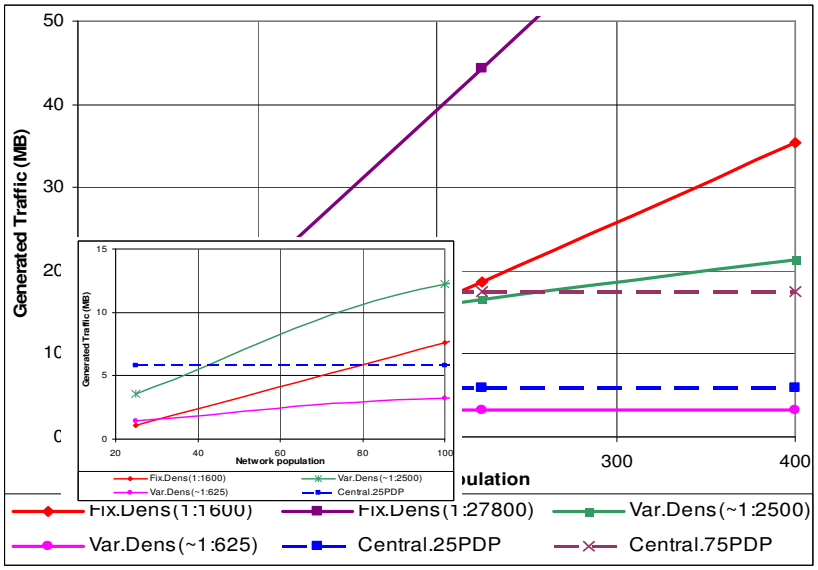
- Centralised-Hierarchical *Vs* Distributed-Hybrid Model











Wireless Networks PBM Framework

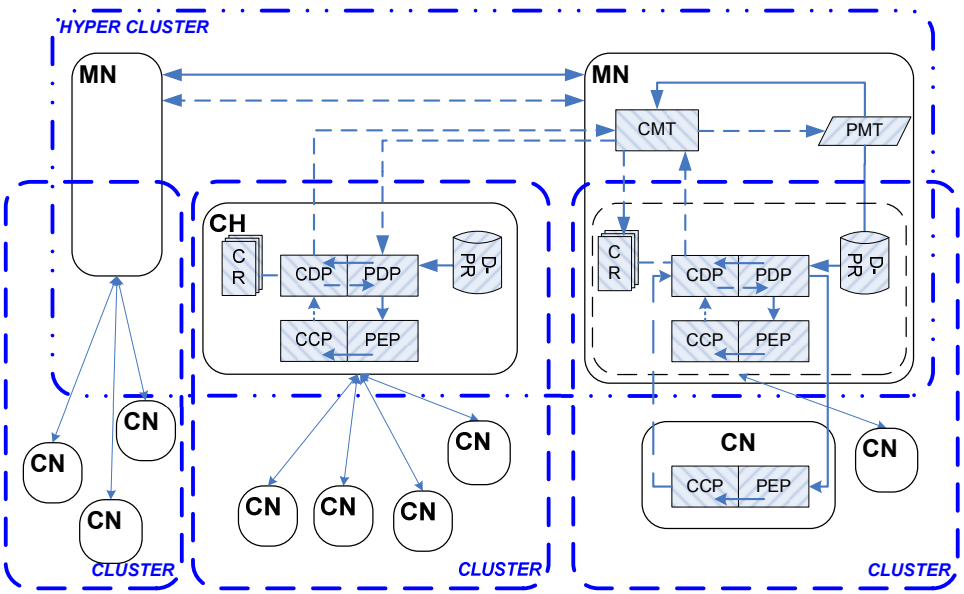
Organisational model and Policy Hierarchy

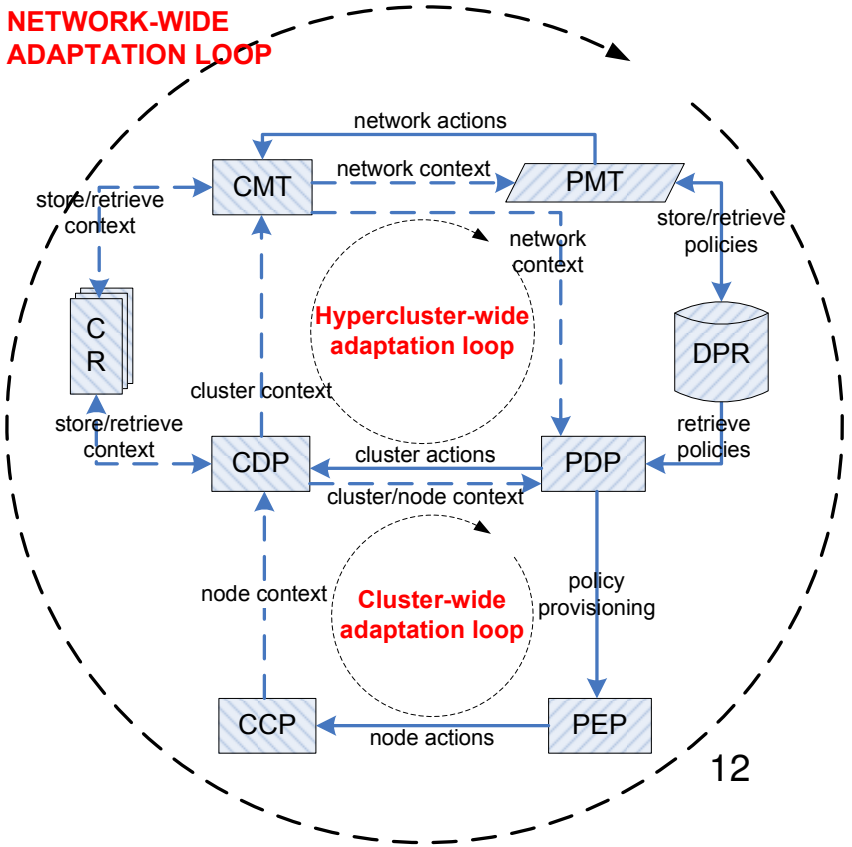
- Hybrid role-based organisation and policy hierarchy
  - **{Roles} [Event] if {Conditions} then {Actions}**
- Policy enforcement scope for closed-loop management

-Cluster-wide (energy conservation)

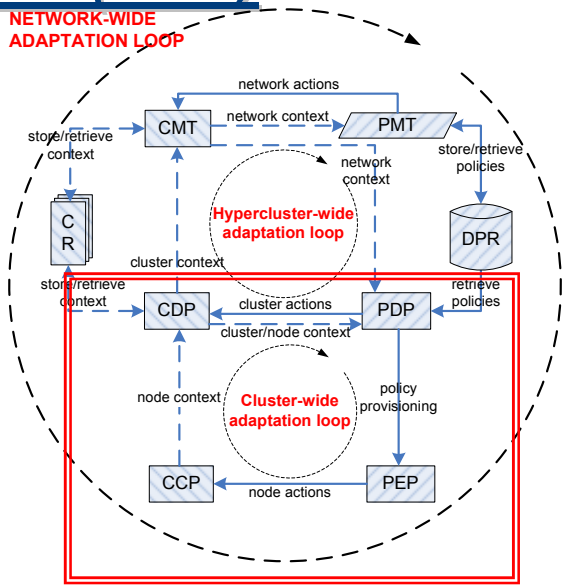
-Hypercluster-wide (repository repl.)

-Network-wide (routing adaptation)





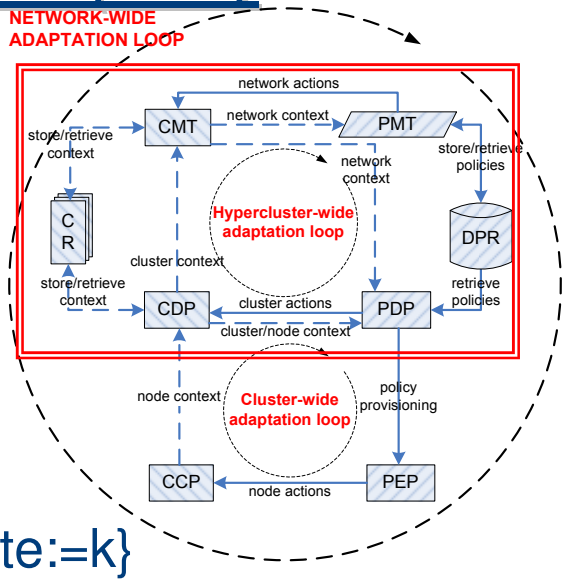
Policy Examples
for Autonomic Management (1/3)



- Cluster-wide Enforcement scope
  - triggered at: a Hyper-Cluster node
  - context from: Cluster nodes
  - actions enforced: Cluster-wide

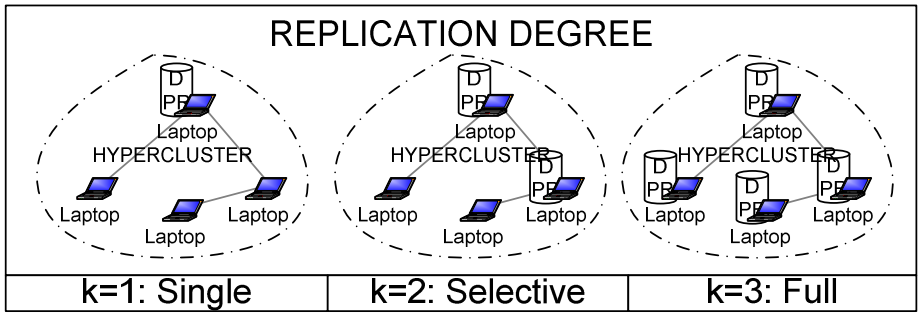
- Energy conservation example policy
  - {CN}[E] if {*BP*=(n..m)} then {*TransPow*:=k}
  - adaptively configures energy consumption according to node's current state , environment and the overall management objectives → BP context
  - reduce transmission power and conserve remaining battery power (k=1:Normal Power , k=2:Low Power)

Policy Examples
for Autonomic Management (2/3)



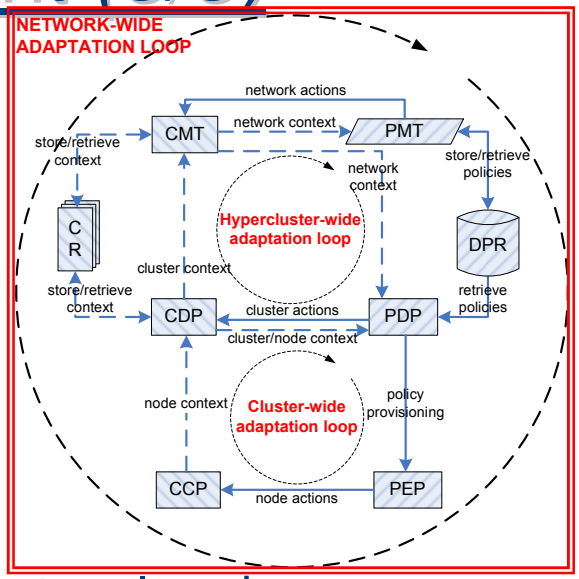
- Hypercluster-wide Enforcement scope
  - triggered at: Hypercluster nodes
  - context from: Hypercluster nodes
  - actions enforced: Hypercluster-wide

- Repository replication example policy
  - {MN,CH}[E] if {FM=(n..m)} then {ReplDegState:=k}
  - control the replication of the DPR (Distributed Policy Repository)
  - Fluidity metric (FM): a cluster-wide aggregated context
  - Three states reflect the need for PR replicas within the hypercluster nodes and adapt according to the volatility of the network



Policy Examples
for Autonomic Management (3/3)

- Network-wide Enforcement scope
  - triggered at: Manager Nodes
  - context from: all network nodes
  - actions enforced: network-wide

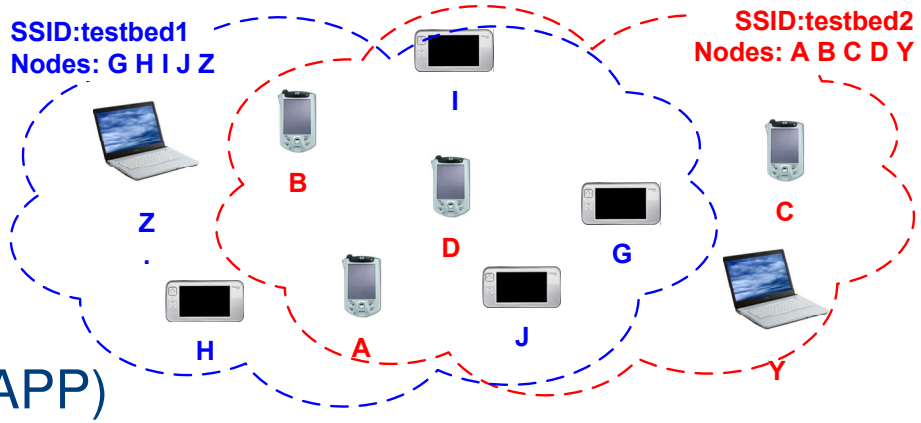


- Routing adaptation example policy
  - {MN}[E] if {RM=(n..m)} then {RoutProt:=k}
  - enables dynamic adaptation of the routing protocol and increases network performance according to the network's RM
  - Relative Mobility (RM) : aggregated context information extracted from the network-wide knowledge of node movements, GPS positioning data, etc.
  - when RM is low → use a proactive routing protocol (OLSR, k=1)
  - when RM is high→ use a reactive routing protocol (AODV, k=2)

Case Study Example

Implementation of Self- Capabilities*

- Testbed setup
  - 10 wireless nodes
  - 802.11b/g Wi-Fi
  - IBSS (ad hoc/p2p mode)
- Setup in two ad hoc clusters
  - Ad hoc file transfer within clusters
- Inter-layer communication (MAC-APP)
  - Cluster Head can monitor and assess wireless interface
  - Open source packet capturer (airodump-ng)
- Channel selection algorithm
  - Weighted Average WA(**x**)
  - Metric **x**: missed frames, avg.pps etc.
  - Weight **w**: depends on channel distance



	Operat.System (Kernel)	*Processor*	*Ram (MB)*	*Wifi support*
(2x)Sony Z1XMP	**Debian R4.0 (2.6.18)**	**1500 - Intel**	**512**	**802.11bg**
(4x)HP iPAQ H5550	**Familiar v0.8.4 (2.4.19)**	**400 - ARM**	**128**	**802.11b**
(4x)Nokia N800	**IT OS2007 (2.6.18)**	**330 - ARM**	**128**	**802.11bg**

Case Study Example
Implementation of Self- Capabilities*

- Self-Configuration for initial channel assignment
  - 20.4% increase of average goodput compared to default settings
  - Up to 33.3% increase for random channel assignment
  - Worst performance for consecutive channels
  - File download duration is accordingly improved

P#	*Event*	*if {Conditions} then {Actions}*
1	**Init_new_adhoc**	if **{ready}** then **{scanChannels()},{generateScanComplete(results)}**
2	**ScanComplete(results)**	if **{otherWLANdetected=true}^{FC:=freeChannels(results), FC=true}^{PC:=preffered(FC,*ch_list*),PC=true}** then **{optimizeChannel(PC,*algorithm*$_1$(*criteria*$_1$))}**
3	**ScanComplete(results)**	if **{otherWLANdetected=true}^{FC:=freeChannels(results), FC=true}^{PC:= preffered(FC,*ch_list*),PC=false}** then **{optimizeChannel(FC,*algorithm*$_2$(criteria$_2$))}**
4	**ScanComplete(results)**	if **{otherWLANdetected=true}^{FC:=freeChannels(results), FC=false}** then **{optimizeChannel(all, *algorithm*$_3$ (*criteria*$_3$))}**

Case Study Example

Implementation of Self- Capabilities*

- Self-Optimisation for dynamic channel switch
  - Peak increase of 33.5%
  - Average goodput increase by 20.3%
    - from 413.54 KB/s to 518.79KB/s
  - Download time reduced
    - from 116sec to 50sec for a 46MB file
  - Scenario in two phases

5	**NewWLANdetected**	*if* **{*dyn_adapt*=true}** *then* **{generateStartAdapt(newWLANinfo)}**
6	**LinkQualityCheck**	if **{LinkQuality<*thr_a*}^{*dyn_adapt*=true}** *then* **{generateStartAdapt(cachedWLANinfo)}**
7	**StartAdapt(WLANinfo)**	if **{channel_distance(WLANinfo,current) < *dist*}** **^{*app_specific_metric* < *thr_b*}** *then* **{scanChannels()},{generateAdaptChannel(results)}**
8	**AdaptChannel(results)**	*if* **{results_evaluation()=true}** *then* **{channel_switch(all,*$algorithm_4$*(*$criteria_4$*))},{verify()}**

Case Study Example

Implementation of Self- Capabilities*

- Self-Optimisation Scenario

Ph.1: file transfer Z→J

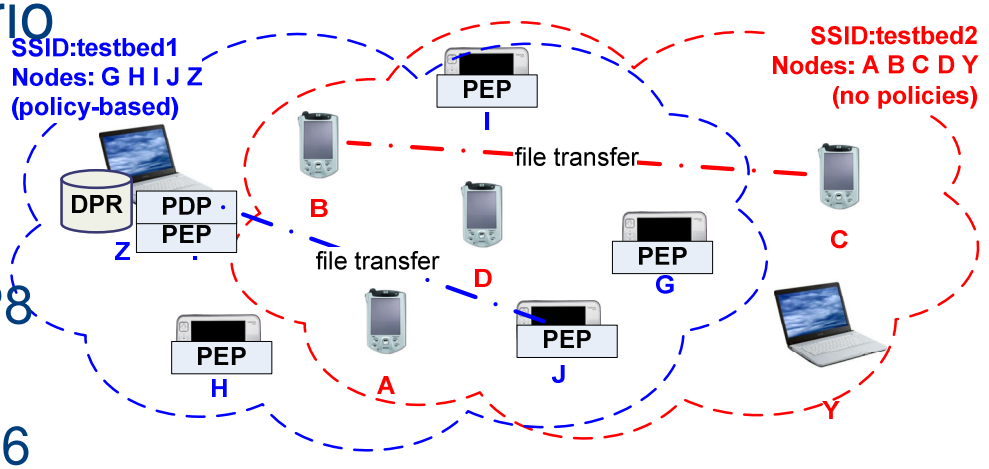
Ph.2: file transfer B→C

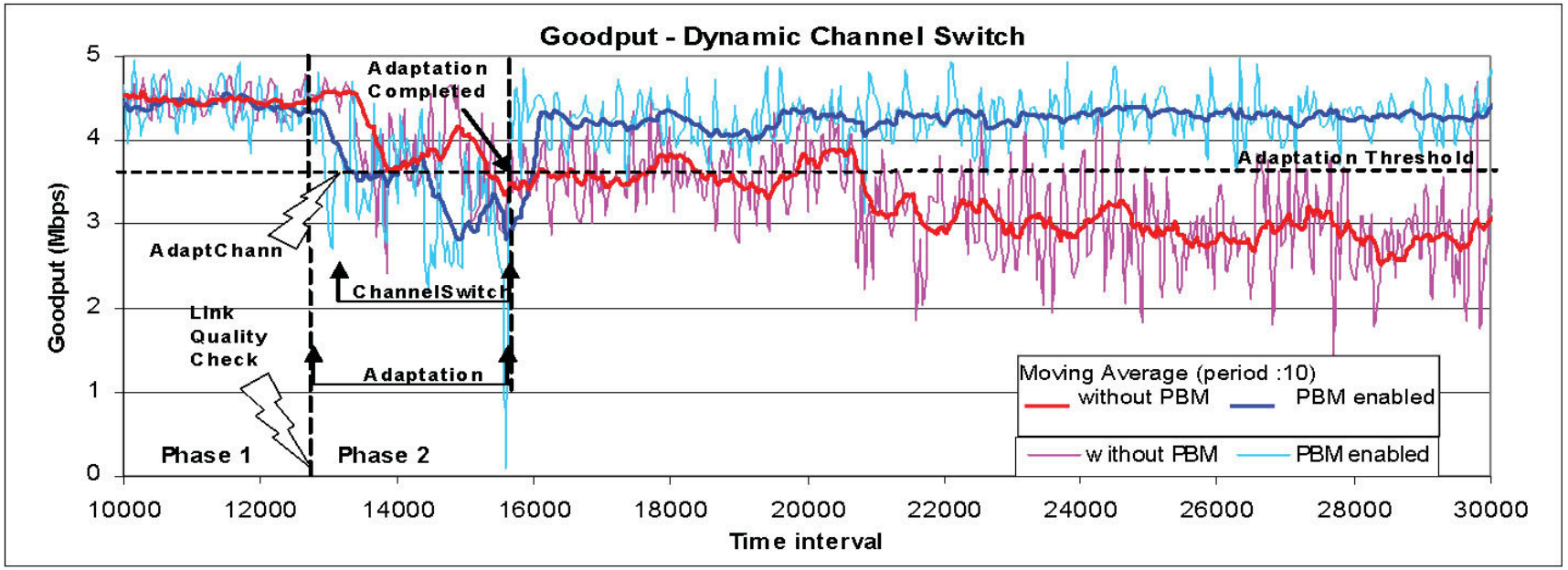
P6: LinkQuality: thr_a <50% ➔P7

P7: Goodput: thr_b <3.67MBps ➔P8

P8(AdaptChannel):algorithm

➔channelSwitch: from ch.1→ch.6





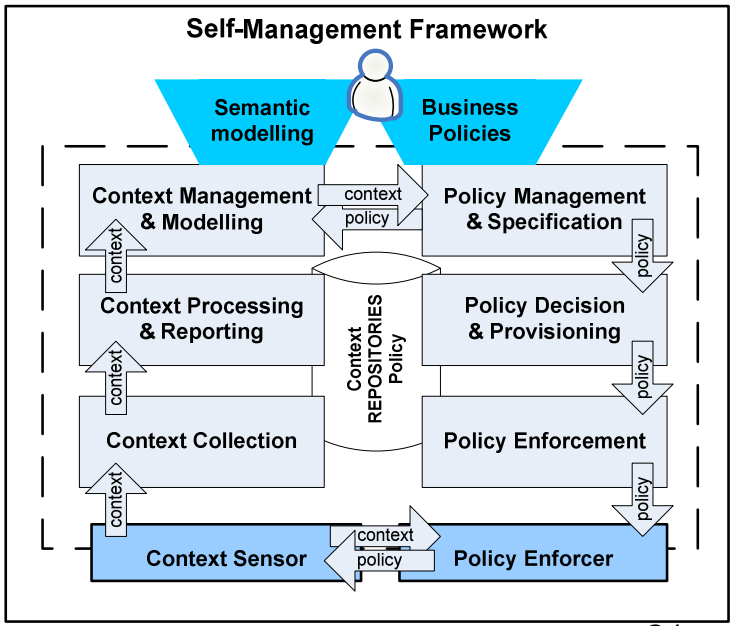
Conclusions
Industry quotes (2009)

- IBM on the growth versus cost dilemma
  - "IT complexity has to be simplified, or growth will begin to be hampered by the cost required to support it"
    - http://www.ibm.com/autonomic
- NGMN Use Cases related to Self-Organising Networks
  - "Reduction of cost and complexity is a key driver for RAN LTE. It is therefore of vital interest of operators to minimise operational effort & cost by introducing self-configuring and self-optimising mechanisms"
    - http://www.ngmn.org/uploads/media/NGMN_Use_Cases_related_to_Self_Organising_Network__Overall_Description.pdf
- Motorola on LTE OPEX cost reduction
  - "A distributed architecture is better positioned to deliver a successful SON solution, (…) based on a policy-based management scheme"
    - http://www.motorola.com/Business/US-EN/Business+Product+and+Services/LTE/SON_US-EN

Conclusions
Summary

- Autonomic Management promises solutions
  - Increase management automation and reduce human effort
- Wireless Networks can benefit significantly
  - Large-scale deployments
  - Unpredictable User behaviour
  - Limited Bandwidth and Resources
- Self-Management Framework
  - Wireless-oriented architecture
  - Layered policy-based hierarchy
  - Scalable hybrid organisation
  - Context-awareness for feedback

  → Work in progress!



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Thank You!
Questions & Discussion