Towards Sustainable Networks
Energy Efficiency Policy from Business to Device Instance Levels

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Abstract: Policy-Based Systems have been proposed as a flexible and robust solution for policy enforcement in different sectors of ICT (Information and Communication Technology) infrastructure. Since networking systems present high degrees of electrical energy consumption, companies that provide ICT services or network connections need to work on energy-efficient networking processes to guarantee sustainable operations. This paper presents how an energy efficiency–related business policy can be refined to network policies that consider QoS constraints, how these policies manifest themselves in the equipments, and describes research's next steps, which involve making this refinement more automated.

1 INTRODUCTION

In 2007, Gartner found out that ICT (Information and Communication Technology) was responsible in average for 2% of energy expenses in some countries (GeSI, 2008). However, this contribution varies from country to country as discussed in (Bolla et al., 2011). In some countries, as Germany, France and Japan, ICT contribution can reach up to 10%. In the total of energy consumption, typically, the network communication systems are responsible for 70%, Data Centers for 20%, and other systems for 10%. In this scenario, when a company has as policy to be energy efficient, it has to work on energy efficient networking processes. But, at the same time, if this company provides ICT services, or more specifically network connections, as does an ISP (Internet Service Provider), the energy efficiency strategy cannot interfere in the provided QoS (Quality of Service), normally set in SLAs (Service Level Agreement).

Considering this, the present research project aims at developing an energy-efficient policy-based network management system architecture. A policy is considered as a set of rules[1]used to administer, manage and control the access to ICT resources and services (Strassner, 2003). A policy can be viewed as a set of hierarchical levels so-called *Policy-Continuum* as the *first* is the Business; the *second* is the System; the *third* is the Network; the *fourth* is the Device; and the *fifth* is the Instance level (Strassner, 2003).

An optimized energy-efficiency control requires a centralized network view, measuring the efficiency and the performance of each node in the network. One of the research questions inside this arena is how to translate an Energy Efficiency Policy defined at the business level to an Energy Efficiency Policy at network level. It is necessary to consider QoS constraints, since SLAs have to be specified in a machine-readable form (Klingert and Bunse, 2011). The mapping between SLAs requirements into machine-readable form is known as *"Policy Refinement Problem"* (Rubio-Loyola et al., 2006) and is clearly an open issue in the business and ICT alignment discussions.

In this way, one attempt is the work of (Rubio-Loyola et al., 2006) that uses a methodological approach to do this refinement, but not considering energy-efficiency aspects. Then, this paper aims at re-

[1]Policy rules have four main components: role - the context where the rule is applied; condition - informs under which state the rule should be applied; priority - in the case of rules conflict, it defines the priority among them; and action - describes the procedure to be performed if the condition rule is satisfied.

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fining an energy efficiency policy decided at business level down to the instance level to verify how such a policy can be considered in a network management system, using a methodological approach. As far as we know, this work is the first step towards an automated approach, which is an open issue (Uszok et al., 2008) and an important way to bind business and network policies. By now, the progress in this field is slow (Han and Lei, 2012).

For such discussion, in Section 2, the basic architecture for Policy-Based Systems and the policy levels of an ICT system are presented. Section 3 shows how policies are described. The mapping between energy efficiency policys levels of abstraction is shown in Section 4. At last, Section 5 summarizes this paper and presents the next steps.

2 POLICY-BASED MANAGEMENT

Policy-Based Management (PBM) uses system policies to control the overall system (Strassner, 2003). In the case of networks, it is called PBNM, Policy-Based Network Management. The architecture for such a system is described in Figure 1.

The operation model for this architecture consists of: policies creation, modification and storage, performed by the Policy Management System (PMS); search and retrieval of stored policies, by the Policy Decision Point (PDP); and policies enforcement in ICT processes or resources, by the Policy Enforcement Point (PEP).

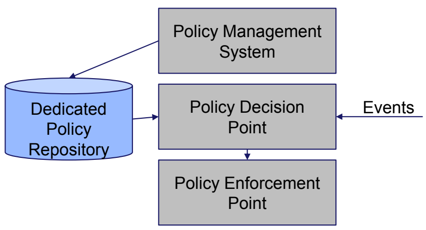

Figure 1: Policy-based network management.

According to the Internet Engineering Task Force (IETF), in ICT systems, policies can have different levels of abstraction with different scopes, such as illustrated in Figure 2 (Strassner, 2003). These scopes can be divided into "ICT Governance", responsible for the Policy Enforcement at Business and System levels, and "Network Management System", responsible for the Policy Enforcement at Network, Device and Instance levels.

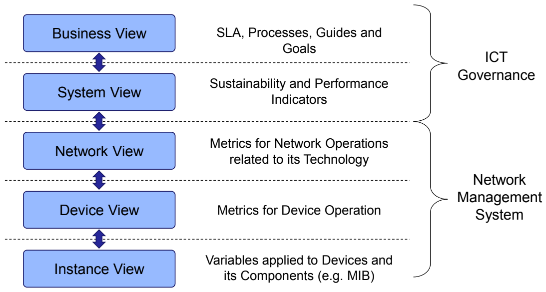

Figure 2: Policy levels.

A policy for network management can be specified at the business level, the first layer, through an SLA (Service Level Agreement). This policy has to be translated to the system level, the second layer, by using performance indicators. At the network level, the third layer, policies are described making use of structured languages, without the details about the network devices. As examples of structured languages deployed at the network policy level, Ponder (Lymberopoulos et al., 2003), SWRL (Horrocks et al., 2004), REWERSE (Bonatti et al., 2005) can be mentioned. The fourth layer, device level, shows how this information is used to reconfigure the equipments. The fifth layer, instance level, shows the specific configuration commands on a per-device and vendor basis. Typically, policies belonging to a policy continuum differ among themselves in syntax aspects, but they are related through semantics aspects. The translation between all these layers is not easy, and automated approaches are under development, such as KAoS (Uszok et al., 2008). This issue, known as "Policy Refinement Problem" (Rubio-Loyola et al., 2006) is one of this research's next steps.

3 POLICY SPECIFICATION

This section discusses how the policies described in Section 2 are specified.

3.1 Business and System Policies

The policies at the business and system levels are normally specified using natural language. Each policy defines its goals, conditions, associated indicators, actions, and scope. These policies have to be refined down to a machine-readable form (Klingert and Bunse, 2011). KAoS, for instance, uses constrained English sentences (Van der Meer et al., 2006) that are refined down to the network level, but, according to (Uszok et al., 2008), the automated approach is an open issue. (Han and Lei, 2012) say that the progress in this field is slow. It is important to develop this automated approach, once one consider that the companies' managers (business level) use a different language than the one used by the ICT/network managers (Strassner, 2003) and that, solely with the usual policy structure 'if, then, else', it could be difficult for them to define business policies.

3.2 Network Policy

Among the structured languages used to describe network policies, such as SWRL (Horrocks et al., 2004) and REWERSE (Bonatti et al., 2005), Ponder is a flexible and well accepted language (Rana and Foghlu, 2009). It is a specification language for management and security policies applied onto distributed systems. It was developed by a research group on Policies for Distributed Systems from London Imperial College. For policies specification, analysis and execution, a Ponder tool set can be composed by a compiler, an editor, and a management kit for supporting management of the model's modules from an administrative console.

3.3 Device and Instance Policy

The policy at device level is defined by a set of device commands. Thus, it is necessary to translate a policy described by a declarative language, as Ponder, to a policy described as a set of device commands. The challenge involves the translation from abstract policies to concrete policies. For correlating concepts from two different policy languages, it is necessary to define a semantic model that specifies the vocabulary's semantics and concepts' definitions adopted by the policy language. This purpose is achieved by information models such as CIM - Common Information Model; SID - Shared Information/Data Model; DEN - Directory Enabled Networks, and the next generation version, DEN-ng, which defines the mapping from abstract policies to concrete ones. This common semantics is used in the translation from the abstract policy to the concrete policy, making it understandable by devices. The concrete policy results in device-specific commands.

The difference between the *device* and the *instance* levels can be better understood by an example of a policy related to energy efficiency. On one hand, the *device* level should specify in an abstract way which functionalities and protocols are available for each device in order to expose how the policy rules will be represented in these devices. An example is the description of the supported power modes, such as the "sleep" or the "powered on" or even other modes and how it will be handled, such as using SNMP along with a specific MIB. On the other hand, the *instance* level may be composed by command line for the network administrator to apply actions into the devices. An example is a set of SNMP commands to set the device to "low-energy-consumption" mode, such as "state 7" that means the "sleep mode" in the EMAN-MONITORING-MIB (Chandramouli et al., 2011). A complete example of how a policy can be refined through all policy levels is described in the next section.

4 SUSTAINABILITY-ORIENTED POLICY AND ISSUES

This section shows how a sustainability policy defined at business level can impact and be mapped in different policies in all levels, down to the instance one. At the business level, it is specified a policy that can cover the whole company. The policy is related to "Sustainable Practices", as illustrated in Figure 3. As an example of "Sustainable Practice" it was selected "Rational Use of Resources".

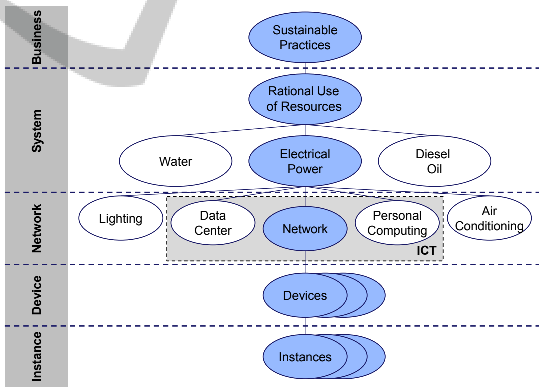

Figure 3: Policy mapping.

At the System Level, "Rational Use of Resources" involves rational use of water, diesel oil and electrical power, among other resources. As a matter of example, it was chosen "electrical power". At the Infrastructure Level, the rational use of electrical power includes mainly lighting, ICT (Information and Communication Technology) and air conditioning. As ICT infrastructure, it can be considered mainly Data Center, Network and Personal Computing. In this case, "Network", as an important energy consumer, was selected for further details. At the Device Level, one must consider that a network is composed by several devices (e.g., routers, switches, line regenerators) connected by communication links. If the goal is to have an energy efficient network, it will impact all of its devices. At last, at the Instance Level, any energy efficiency operation on some device will affect its components, as interfaces and ports. Such impact on device's components is analyzed at the Instance level.

At the first two layers, Business and System, policies are described using natural language. This high-level policy description is translated to the Network Policy level - in this example, using Ponder language. From this translated description, models that take into account the supported functionalities of each device are described. This generates the device level description. Some of these functionalities are described through subsets of MIB (Management Information Base) objects. These objects can include device's demand and performance, energy consumption, etc. At last, the device description is translated into instance description, a process which regards, for each specific devices, SNMP operations based on those MIB objects.

This policy mapping that takes place between different policy levels is presented and discussed in much more details in the next sections. There, it is presented a real example of an energy-efficiency business policy and, using a methodological approach, it is shown how to refine it down to the instance level. The goal is to verify that it is possible to do the policy refinement using existent tools to, in the near future, work in automated approaches, the main goal of this research.

4.1 Business and System Policies

As example of business policy, was taken the following policy: *"All the ICT (Information and Communication Technology) processes and procedures should be aligned with sustainable practices"*. This policy is associated to several business goals. In this case, it was considered the goal related to *"Resources Rational Use"*, which naturally includes energy efficiency. From this policy at the business level, one or more system-level policies are generated. Among different policies related to energy efficiency, one example is: *"deactivation of network equipments that are idle more than 70% of the time, if it is possible to redirect their traffic and keep the network QoS (Quality of Service) negotiated with the customer (established in SLA)"*. To reach the performance requirements, the following rule could be applied: "keep active network equipments with use rate greater than 30%".

4.2 Network Policy

The translation of the aforementioned System Policy, for instance, can result in the following Network Level policies (one policy at system level can be translated into one or more in network level):

- **Policy 1:** *"If some network equipment is idle more than 70% of the time and the network delay is less than 60 milliseconds, deactivate this equipment if its traffic load can be redirected to other equipment"*, i.e., if there is any redundant path. This policy consists on the identification of underutilization metrics and the subsequential optimization of the resources usage as long as there would be no degradation of the provided QoS (e.g., the network delay increase). The purpose is to get the best usage of the redundant paths that typically exists for QoS maintenance.
- **Policy 2:** *"If the network delay is greater than 80 milliseconds and there are redundant paths with deactivated equipments, then reactivate these equipments"*. This policy has as purpose activation of equipments that had been deactivated due to some other policy actions.

Figure 4 shows the description of Policy 1 using Ponder language. The Block 1 defines the limit operation value for the network parameter used in this example: the router minimum usage rate (30%). The Block 2 defines an authorization policy, i.e., an access control policy authorizing the service management agent (`/PolicyAgents/ServiceManagementAgent`) to set a router, belonging to the group `/Routers`, to the sleep mode if it is possible to transfer the traffic of this router to another one. This restriction is defined by the function `isPossibleToTransferTrafficLoad(r)` and avoids the network graph disruption. The Block 3 defines an obligation policy (`/Policies/LowUtilizationPolicy`), i.e., a policy that executes an action on an object when a specified event happens. This policy makes the agent (`/PolicyAgents/ServiceManagementAgent`) to set a router, belonging to the group `/Routers/`, to the sleep mode, when an event arrives informing the low utilization of such router.

4.3 Device Policy

Policies at the device level were represented by a model that describes the functionalities that each device has to provide in order to apply the Network Policy. This level is directly related to the device's type and vendor, since same types of devices from different

```
// Block 1:
minUtilization = 0.3;
// Block 2:
root at: "authorizationdomain" put:
    root/factory/domain create.
newauthorizationpolicy := root load:
    "AuthorisationPolicy".
root/factory at: "newauthorizationpolicy" put:
    newauthorizationpolicy.
root/authorizationdomain at:
"DisableRouterAuthPolicy" put:
    (newauthorizationpolicy subject:
    root/PolicyAgents/ServiceManagementAgent
    action: setSleepMode
    target: root/Routers
    when isPossibleToTransferTrafficLoad).
root/authorizationdomain/DisableRouterAuthPoli
cy
active: true.
// Block 3:
LowUtilizationPolicy :=
    root/factory/ecapolicy create.
LowUtilizationPolicy event:=
    root/event/UtilizationValue.
LowUtilizationPolicy condition:
    [:oldUtilization :newUtilization |
    (newUtilization < minUtilization)
    & (oldUtilization >= minUtilization)].
LowUtilizationPolicy action: [
    root/Routers setSleepMode: true; show ].
LowUtilizationPolicy active: true.
```

Figure 4: Example of network policy description in Ponder - Policy 1.

```
    //Example - policy 1
    Not dependant on Operating System
 functionalities;
    SNMP protocol support
    MIB support: RFC1213-MIB, TN3270E-RT-MIB,
 POWER-MONITOR-MIB
    Power states support: Sleep, Low e High
```

Figure 5: Example of device level policy.

vendors usually provide different functionalities. In this example, it is adopted the hypothetical equipment model described in Figure 5. The actions described will take place at the device level of this equipment.

The Figure 5 model represents a Device Policy and has the following information: mapping how the device implements the non-standardized functionalities. In this example, it is necessary to map the following power modes (Chandramouli et al., 2011):

1. SleepMode: the device's awakening functionality is available and the power consumption is near zero, corresponding to G1 and S3 levels in the Advanced Configuration and Power Interface (ACPI), an open industry specification that enables power management of mobile, desktop, and server platforms (Steele, 1998).
2. Low: indicates that essential functionalities are available and power consumption is reduced, corresponding to G0, S0 and P4 levels in the ACPI.
3. High: represents that all device functionalities are available and the power consumption is greater than the other modes, corresponding to G0, S0 and P0 levels in the ACPI.

```
  snmpget [options] [-Cf] [OID]
  Options: protocol version, device address,
MIB name
  -Cf : try to correct errors
  OID: variables to be read
  snmpset [options] [-Cf] [OID] [type] [value]
  Options: protocol version, device address,
MIB name
  -Cf : try to correct errors
  OID: variables to be set
  type: i (integer), t (time), a (ip address),
 s (string), D (floating point), ...
```

Figure 6: SNMP commands' syntax.

In this example, the device supports SNMP (Simple Network Management Protocol) and the following MIB (Management Information Base) object sets:

1. RFC1213-MIB: provides data for bandwidth utilization calculation, as the total number of ingoing (`ifInOctets`) and outgoing (`ifOutOctets`) bytes in the device and total transmission capacity (`ifSpeed`). The throughput (T) in Mbps, can be obtained as follows:

$$T = \frac{max(\Delta \texttt{ifInOctets}, \Delta \texttt{ifOutOctets}) \times 8 \times 100}{(\text{seconds in } \Delta)\texttt{ifSpeed}}$$

2. TN3270E-RT-MIB: provides data related to the network delay and average reply time since last measured time interval, etc.
3. POWER-MONITOR-MIB (Chandramouli et al., 2011): provides the device power state (PowerMonitorLevel), which varies from 1 to 12.

4.4 Instance Policy

Instance Level Policies describe how the functionalities at the device level are implemented via specific instance's language commands. In the case of this example, the *snmpget* and *snmpset* commands of the SNMP protocol are used to translate the instance level policy. The *snmpget* is used to retrieve information from network devices, providing one or more variables (object indentifiers, or OIDs) as parameters. The *snmpset* is used for information modification at a remote device and has similar syntax to

```
   // Example "Policy 1"
   //Collecting information for calcula
ting the band-width utilization:
   snmpget -v 2c -c public target_ip_address
 -m RFC1213-MIB ifInOctets.0
   snmpget -v 2c -c public target_ip_address
 -m RFC1213-MIB ifOutOctets.0
   snmpget -v 2c -c public target_ip_address
 -m RFC1213-MIB ifSpeed.0
   //Collecting information about
the network delay
   snmpget -v 2c -c public target_ip_address
-m TN3270E-RT-MIB
   tn3270eRtDataAvgRt.0
   // Configuring the CPU power state
   snmpset -v 2c -c public target_ip_address
-m POWER-MONITOR-MIB
   PowerMonitorLevel i 4
```

Figure 7: Example of Policy 1 translation to SNMP commands at the Instance level.

snmpget's syntax with an additional parameter related to the value to be set. Figure 6 describes these commands' syntaxes.

The Figure 7 presents the example of Policy 1 translation to SNMP commands at the Instance Policy level.

5 FINAL CONSIDERATIONS

Considering the increasing demand for ICT systems, especially for networking services, it is even more important to set energy efficiency policies for these services as basis for supporting Carbon free systems.

This paper presented how to refine an energy efficiency business policy down to the instance level, considering the Policy Continuum's five levels: Business, System, Network, Device and Instance. The first step was to use a methodological approach to prove that it is possible to consider an energy-efficient policy in a network management system. The next step is to develop an automated approach for the *"Policy Refinement Problem"*.

This automated approach is important since the business managers will be able to define business policies that will be directly applied to the network, devices and instances, making the business–IT alignment easier.

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