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Designing green network architectures using the ten commandments for a mature ecosystem

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ABSTRACT

The Climate Group notes that energy consumption by ICT activities represented 2% of global human activity in 2009 (Smart, 2012) [1]. ICT is therefore a sector contributing both to natural resource depletion and to greenhouse gas emission. Moreover, ICT generates considerable quantities of electronic waste, it emits radio waves (including GSM and WiFi) that can adversely affect human and animal health, and it can have an impact on the natural beauty of the landscape (e.g. antennas). A new challenge for ICT engineers is therefore to be able to design ICT more efficiently by considering environmental constraints. In the ecology domain, Benyus' book "Biomimicry" (Benyus, 2002) [2] proposed ten commandments for mature ecosystems. The objective of this paper is to apply these commandments to ICT, by focusing on green network architecture design. The main developments in this research are the proposed relationships between the ten commandments and the networking domain and metrics for assessing both the project-system and the system-of-interest when designing green network architectures.

1. Introduction

Included among future world challenges is the impact of technological development and new emerging technologies on the environment. It will require an enormous effort to address air, water, food, and energy challenges efficiently. The Smart 2020 report [1] written by the international Climate Group recommends the intensive deployment of Information and Communication Technologies (ICT) to enhance the monitoring of the environment and human activities (e.g. industry, building, and transport) and of distributed smart ICT systems that can address pollution, waste, food quality and supply, energy constraints, etc. Therefore, traditional methodologies for distributed system engineering have to be adapted and reviewed to minimize their ICT footprint on the environment in terms of carbon emission, radio wave propagation, waste, technological pollution, energy efficiency, resource reuse, etc. Networked system engineering has to be globally rethought, and [3] has analyzed the relevant literature for energy efficiency support by networks. The contributions of this paper are within the framework of a new ecology paradigm developed in Benyus' book "Biomimicry" [2]. In the final chapter of this book, "How will we conduct business", Benyus defines ten commandments for mature ecosystems. An ecosystem [4] is a complex of living organisms, their physical environment, and all their interrelationships within in a particular unit of space. The evolution of ecosystems generally occurs in two phases: the developing stage and the mature stage [5]. The developing stage involves few species and short food chains. This ecosystem is unstable but highly productive, in the sense that they build up organic matter faster than they break it down. The mature ecosystem is more complex, more diversified, and more stable. Currently, the business model used in our society is the developing stage, and the challenge is to move to the mature stage.

The general objective of this paper is to apply the ten commandments for conducting business to the context of network architecture design. The goal is to check if philosophical concepts from ecology make sense when considering a technical system as a network. To design a technical system, a systemic approach is recommended, which takes into account all requirements and constraints of the global system [6]. In this systemic approach, the design of the system (in this paper, the network architecture) must be evaluated according to two points of view, namely the project-system and the system-of-interest. This paper proposes metrics for both these views. The paper is organized as follows. Section 2 gives the relations between the ten commandments and networked systems, Section 3 defines the metrics for the

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project-system and in the system-of-interest, and Section 4 gives a simple example illustrating the application of these ideas.

2. Green network design

2.1. Introduction

The specification of guidelines for designing green network architectures is complex because they must cover different requirement specifications (network, ecology) and must integrate unrelated criteria, criteria that are mutually contradictory, and criteria that are mutually reinforcing. To achieve this issue, this paper proposes to apply system engineering for incorporating the criteria into one model and for analyzing them together during the design process.

System engineering [7,8] splits the assessment into two parts, namely the project-system and the system-of-interest parts. The purpose is to be able to use different metrics for evaluating these two parts (Fig. 1).

The objective of the project-system assessment is to define guidelines for designing green network architectures. All its procedures have to be verified to ensure that the methodology of the design has been met by the network designer. Here, the check-list principle is used.

The objective of the system-of-interest assessment is to develop metrics that enable evaluation of different network architecture solutions in terms of the ecology criteria. This is a quantitative evaluation, measured in terms of CO_2 emission or the percentage of product recycling, for example. In system engineering, these metrics are called the Measure of Effectiveness (MoE). In general, the MoE will reflect approximately the impact of a given action on the environment.

This paper will consider these two forms of assessment in the field of green networking and will provide to the network engineer both indicators for the project-system and MoEs for the system-of-interest.

But the crucial issue is to start by applying ecology concepts to the network domain. Many recent surveys on green networking have collected an impressive number of technical contributions [9–13], but these have not included the relationship with general ecology concepts developed in [2]. The problem is that, even if a new green network technical solution appears interesting as a local solution, it could have negative effects in terms of the global environmental system. Therefore, the objective is to translate the ten commandments for eco-mature systems into network technical terms, thereby filling the gap between ecology and network domains.

2.2. Ten commandments

In the book "Biomimicry" [2], Benyus says that "over billions of years, natural selection has come up with winning strategies adopted by all complex, mature ecosystems". These strategies are defined as the ten commandments for organisms in mature ecosystems, which

1. use waste as a resource,
2. diversify and cooperate to fully use the habitat,
3. gather and use energy efficiently,
4. optimize rather than maximize,
5. use materials sparingly,
6. don't foul their nests,
7. don't draw down resources,
8. remain in balance with the biosphere,
9. run on information, and
10. shop locally.

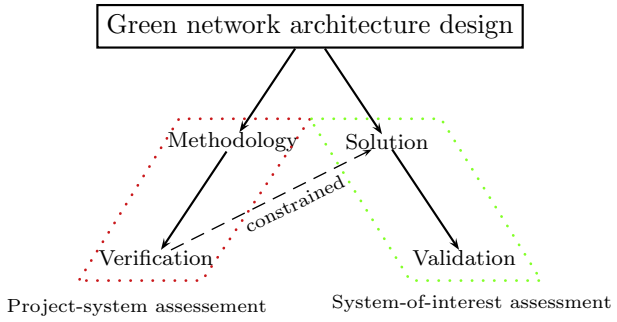

Fig. 1. Assessment in system engineering.

The idea is to apply these commandments (or lessons) to economic organization, substituting our current economy by an industrial ecology. In her book [2], Benyus provides examples of the ways the commandments are currently applied in companies or in an economy. The approach developed in this paper is similar, proposing relations between the ten commandments and professional activities in the network domain.

2.3. Ten commandments for designing network architectures

2.3.1. Use waste as a resource

"One of the key lessons from systems ecology is that, as a system puts on more biomass, it needs more recycling loops to keep it from collapsing" [2]. Recycling is a major issue for ICT. The rapid obsolescence of the hardware and software implemented in network devices, which continually offers new functionality with better performance, induces premature equipment renewal and produces electronic waste. During the step of network architecture design, the engineer has to select electronic equipment that can be recycled easily. This recycling has different aspects, including the reuse of old equipment in other applications and equipment dismantling. For example, reuse might involve replacing an old mobile phone with a new one and identifying a market for selling the old one to other customers with different needs. In the book "cradle to cradle" [14], the authors propose to design products with their raw materials separated into biological nutrients and technical nutrients. The interest is in avoiding the design of "monstrous hybrids" and in facilitating the recycling step by one part being dedicated to biological metabolisms and another part dedicated to technical metabolisms (enabling the recovery of rare materials, for example). The designer of a network architecture has to reject the electronic "monstrous hybrids", has to anticipate the architecture dismantlement issue, and has to take into account the rate of recycling of electronic components used in the network architecture. The recycling issue concerns not only materials but also energy. Electronic equipment consumes energy and dissipates heat. This heat can be reused as a resource for other applications. For example, the heat emitted by a data centre can provide heat for buildings [15].

2.3.2. Diversify and cooperate to fully use the habitat

"In mature ecosystems, cooperation seems to be just as important as competition. Using cooperative strategies, organisms spread out into noncompeting niches and basically clean up every crumb before it even falls off the table" [2]. The idea of this criterion is that the company (in our case an ICT company) has to be aware of the skills offered by other companies and to analyze their complementary and their diversity, thereby improving the competitiveness of all economic actors. Companies have to work "through trade associations, special alliances, and virtual firms to come up with common labelling and materials standards, which